SOUND TRANSIT
NORTH LINK LIGHT RAIL

LINK CONTRACT N125
TUNNELS, PORTAL, AND STATION EXCAVATIONS
CONTRACT SPECIFICATIONS

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PAINTING AND COATING  

PART 1 - GENERAL  

1.01 SUMMARY  
A. This Section includes specifications for surface preparation, painting, and finishing of hollow metal doors and frames. Surface preparation, priming, and finish coats specified in this Section are in addition to shop-priming and surface treatment specified under other Sections.  

1.02 REFERENCES  
A. This Section incorporates by reference the latest revisions of the following documents.  
1. Code of Federal Regulation  
   b. ASTM D16 Standard Terminology for Paint, Related Coatings, Materials, and Applications  
   d. ASTM D3359 Standard Test Methods for Measuring Adhesion by Tape Test  

1.03 DEFINITIONS  
A. Refer to ASTM D16 for interpretation of terms used in this Section.  

1.04 SUBMITTALS  
A. Procedures: Section 01 33 00, Submittal Procedures.  
B. Product Data: Provide data on all finishing products, including VOC content.  
   1. Manufacturer's technical information including label analysis and instructions for handling, storage, and application of each material proposed for use.
2. List each material and cross-reference the specific coating, finish system, and application. Identify each material by the manufacturer’s catalog number and general classification.

C. Samples: Submit four each color samples, 8 x 10 inch in size illustrating range of colors and textures available for each surface finishing product scheduled. Submit on representative substrate material.

D. Certifications:
   1. By manufacturer that all paints and coatings comply with VOC limits specified.
   2. By manufacturer that all paints and coatings do not contain any of the prohibited chemicals specified; GreenSeal GS-11 certification is not required but if provided shall constitute acceptable certification.

E. Manufacturer’s Instructions: Indicate special surface preparation procedures.

F. Maintenance Data: Submit data on cleaning, touch-up, and repair of painted and coated surfaces.

1.05 QUALITY ASSURANCE

A. Manufacturer Qualifications: Company specializing in manufacturing the Products specified in this Section with minimum ten years documented experience.

B. Applicator Qualifications: Company specializing in performing the work of this Section, employing experienced applicators who have completed painting system applications similar in material and extent to those indicated that have resulted in a construction record of successful in-service performance with minimum five years experience.

1.06 REGULATORY REQUIREMENTS

A. Conform to applicable code for flame and smoke rating requirements for all products and finishes.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Deliver products to site in sealed and labeled containers; inspect to verify acceptability.

B. Container Label: Include manufacturer’s name, type of paint, brand name, lot number, brand code, coverage, surface preparation, drying time, cleanup requirements, color designation, and instructions for mixing and reducing. Report any containers seen on site without Container Labels immediately to the Resident Engineer.

C. Paint Materials: Store at minimum ambient temperature of 45 degrees F and a maximum of 90 degrees F, in ventilated area, and as required by manufacturer’s instructions.

1.08 ENVIRONMENTAL REQUIREMENTS

A. Do not apply materials when surface and ambient temperatures are outside the temperature ranges required by the paint product manufacturer.

B. Do not apply coatings when relative humidity is outside the humidity ranges required by the paint product manufacturer.

1. Painting may continue when environmental conditions are outside of manufacturer’s ranges if surfaces and areas to be painted are enclosed and heated within temperature limits specified by the manufacturer during application and drying periods.
C. Application Temperatures for all Paints: 50 degrees F minimum, 90 degrees F maximum, unless required otherwise by manufacturer's instructions.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Paints not otherwise specified: "First Quality" commercial products from Manufacturers listed in the ASM, subject to Resident Engineer's approval.

4. Substitutions: See Section 01 25 00, Substitution Procedures.

B. Special Coating Systems for Metals:

2. Substitutions: See Section 01 25 00, Substitution Procedures.

2.02 PAINTS AND COATINGS - GENERAL

A. Material Compatibility: Provide primers, finish coat materials, and related materials that are compatible with one another and the substrates indicated under conditions of service and application, as demonstrated by the manufacturer based on testing and field experience.

B. Material Quality: Provide the manufacturer's best-quality trade sale paint material of the various coating types specified. Paint material containers not displaying manufacturer's product identification will not be acceptable.

1. Proprietary Names: Use of manufacturer's proprietary product names to designate colors or materials is not intended to imply that products named are required to be used to the exclusion of equivalent products of other manufacturers. Furnish the manufacturer's material data and certificates of performance for proposed substitutions.

C. Colors: Provide custom color of the finished paint systems to match the Architect's selection.

D. Paints and Coatings: Ready-mixed, except field-catalyzed coatings. Prepare pigments:

1. To a soft paste consistency, capable of being readily and uniformly dispersed to a homogeneous coating.
2. For good flow and brushing properties.
3. Capable of drying or curing free of streaks or sags.

E. Volatile Organic Compound (VOC) Content:

1. Provide coatings that comply with the most stringent requirements specified in the following:

2. Determination of VOC Content: Testing and calculation in accordance with 40 CFR 59, Subpart D (EPA Method 24), exclusive of colorants added to a tint base and water added at project site; or other method acceptable to authorities having jurisdiction.

F. Chemical Content: The following compounds are prohibited:

1. Aromatic Compounds: In excess of 1.0 percent by weight of total aromatic compounds (hydrocarbon compounds containing one or more benzene rings).

2. Acrolein, acrylonitrile, antimony, benzene, butyl benzyl phthalate, cadmium, di (2-ethylhexyl) phthalate, di-n-butyl phthalate, di-n-octyl phthalate, 1,2-dichlorobenzene, diethyl phthalate, dimethyl phthalate, ethylbenzene, formaldehyde, hexavalent chromium, isophorone, lead, mercury, methyl ethyl ketone, methyl isobutyl ketone, methylene chloride, naphthalene, toluene (methylbenzene), 1,1,1-trichloroethane, vinyl chloride.

2.03 PAINT SYSTEMS

A. Special Coating System for Ferrous Metals:

1. First Coat: Sherwin Williams Recoatable Epoxy Primer. 4.0 – 6.0 mils dft.

2. Finish Coats: Sherwin Williams Corothane II. 2.0 – 4.0 mils dft.

2.04 ACCESSORY MATERIALS

A. Accessory Materials: VOC-compliant linseed oil, shellac, turpentine, paint thinners and other materials not specifically indicated but required to achieve the finishes specified; commercial quality.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that surfaces are ready to receive Work as instructed by the product manufacturer.

B. Examine surfaces scheduled to be finished prior to commencement of work. Report any condition that may potentially affect proper application.

C. Test shop-applied primer for compatibility with subsequent cover materials. Surfaces receiving paint must be thoroughly dry before paint is applied.

1. Do not begin to apply paint until unsatisfactory conditions have been corrected.

2. Start of painting shall at the Applicator’s acceptance of surfaces and conditions within a particular area.

D. Coordination of Work: Review other Sections in which primers are provided to ensure compatibility of the total system for various substrates. On request, furnish information on characteristics of finish materials to ensure use of compatible primers.

1. Notify the Resident Engineer about anticipated problems using the materials specified over substrates primed by others.
3.02 PREPARATION

A. Surface Appurtenances: Remove or mask electrical plates, hardware, light fixture trim, escutcheons, and fittings prior to preparing surfaces or finishing. Remove items already installed that are not to be painted, or provide surface-applied protection prior to surface preparation and painting. Remove these items, if necessary, to completely paint the items and adjacent surfaces. Following completion of painting operations in each space or area, have items reinstalled by workers skilled in the trades involved.

B. Cleaning: Before applying paint or other surface treatments, clean the substrates of substances that could impair the bond of the various coatings. Remove oil and grease prior to cleaning. Schedule cleaning and painting so dust and other contaminants from the cleaning process will not fall on wet, newly painted surfaces.

C. Surfaces: Correct defects and clean surfaces which affect work of this Section, according to manufacturer's instructions. Remove or repair existing coatings that exhibit surface defects.

   1. Provide barrier coats over incompatible primers or remove and reprime. Notify Architect in writing about anticipated problems using the specified finish-coat material with substrates primed by others.

D. Marks: Seal with shellac those which may bleed through surface finishes.

E. Impervious Surfaces: Remove mildew by scrubbing with solution of tetra-sodium phosphate and bleach. Rinse with clean water and allow surface to dry.

F. Shop-Primed Steel Surfaces to be Finish Painted: Sand and scrape to remove loose primer and rust. Feather edges to make touch-up patches inconspicuous. Clean surfaces with solvent. Prime bare steel surfaces. Re-prime entire shop-primed item.

G. Metal Doors: Prime metal door top and bottom edge surfaces.

H. Materials Preparation: Carefully mix and prepare paint materials according to manufacturer’s directions.

   1. Maintain containers used in mixing and applying paint in a clean condition, free of foreign materials and residue.

   2. Stir material before application to produce a mixture of uniform density; stir as required during application. Do not stir surface film into material. Remove film and, if necessary, strain material before using.

   3. Use only thinners approved by the paint manufacturer and only within recommended limits.

3.03 APPLICATION

A. Paint all exposed door and frame surfaces whether or not colors are designated in schedules, except where a surface or material is specifically indicated not to be painted or is to remain natural. Where an item or surface is not specifically mentioned, paint the same as similar adjacent materials or surfaces. If color or finish is not designated, the Resident Engineer will select from specified colors or finishes for this project.

   1. Finished metal surfaces not to be painted include:

      a. Factory-finished aluminum.

      b. Anodized aluminum.
c. Stainless steel.
d. Chromium plate.
e. Copper.
f. Bronze.
g. Brass.

2. Do not paint moving parts of operating equipment.

3. Labels: Do not paint over Underwriters Laboratories, Factory Mutual or other code-required labels or equipment name, identification, performance rating, or nomenclature plates.

B. Apply products in accordance with manufacturer's instructions. Use applicators and techniques best suited for substrate and type of material being applied.

C. Do not apply finishes to surfaces that are not dry. Do not paint over dirt, rust, scale, grease, moisture, scuffed surfaces, or conditions detrimental to formation of a durable paint film. Allow applied coats to dry before next coat is applied.

D. Apply each coat to uniform appearance. Apply each coat of paint slightly darker than preceding coat unless otherwise approved.

1. Paint colors, surface treatments, and finishes are indicated in the schedules.

2. Provide finish coats that are compatible with primers used.

3. The number of coats and the film thickness required are the same regardless of the application method. Do not apply succeeding coats until the previous coat has cured as recommended by the manufacturer. Sand between each application entire surface to produce a smooth even surface according to the manufacturer's directions.

4. Apply additional coats if undercoats, stains, or other conditions show through final coat of paint until paint film is of uniform finish, color, and appearance. Give special attention to ensure that surfaces, including edges, corners, crevices, welds, and exposed fasteners, receive a dry film thickness equivalent to that of flat surfaces.

5. The term exposed surfaces includes areas visible when permanent or built-in fixtures, convector covers, covers for finned tube radiation, grilles, and similar components are in place. Extend coatings in these areas, as required, to maintain the system integrity and provide desired protection.

6. Finish doors on tops, bottoms, and side edges same as exterior faces.

E. Prime Coats: Before applying finish coats, apply a prime coat of material, as recommended by the manufacturer, to material that is required to be painted or finished.

F. Pigmented (Opaque) Finishes: Completely cover to provide a smooth, opaque surface of uniform finish, color, appearance, and coverage. Cloudiness, spotting, holidays, laps, brush marks, runs, sags, ropiness, or other surface imperfections will not be acceptable.

G. Completed Work: Match approved samples for color, texture, and coverage. Remove, refinish, or repaint work not complying with specified requirements.
H. Scheduling Painting: Apply first coat to surfaces that have been cleaned, pretreated, or otherwise prepared for painting as soon as practicable after preparation and before subsequent surface deterioration.

1. Allow sufficient time between successive coats to permit proper drying. Do not recoat until paint has dried to where it feels firm, does not deform or feel sticky under moderate thumb pressure, and where application of another coat of paint does not cause the undercoat to lift or lose adhesion.

I. Minimum Coating Thickness: Apply materials no thinner than the manufacturer’s recommended spreading rate. Provide the total dry film thickness of the entire system as scheduled.

J. Vacuum clean surfaces of loose particles. Use tack cloth to remove dust and particles just prior to applying next coat.

3.04 FIELD QUALITY CONTROL

A. See Section 01 45 00.20, Quality Assurance / Quality Control, for general requirements for field inspection.

B. Sound Transit may engage the services of an independent testing agency to sample the paint material being used. Samples of material delivered to the Project will be taken, identified, sealed, and certified in the presence of the Contractor.

1. If test results show material being used does not comply with specified requirements, the Contractor may be directed to stop painting, remove non-complying paint, pay for testing, repaint surfaces coated with rejected paint, and remove rejected paint from previously painted surfaces if, upon repainting with specified paint, the two coatings are incompatible.

C. Sound Transit may engage the services of an independent testing agency to test or inspect the applied coatings for adhesion and film thickness using, but not limited to, the following tests. Repair areas of coating that have been damaged due to testing or inspection.


3. ASTM D3359 Standard Test Methods for Measuring Adhesion by Tape Test

3.05 CLEANING

A. Collect waste material which may constitute a fire hazard, place in closed metal containers, and remove daily from site.

B. At the end of each work day, remove empty cans, rags, rubbish, and other discarded paint materials from the site.

C. Remove spattered paint by washing and scraping. Be careful not to scratch or damage adjacent finished surfaces.
B. Provide “Wet Paint” signs to protect newly painted finishes. Remove temporary protective wrappings provided by others to protect their work after completing painting operations.

C. At completion of construction activities of other trades, touch up and restore damaged or defaced painted surfaces.

3.07 SCHEDULE - COLORS

A. Hollow Metal Doors and Frames: Match Sound Transit standard “Charcoal Gray”

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 10 14 53
TRAFFIC SIGNAGE

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing, installing and relocating traffic signs and/or posts, and removing and salvaging existing signs and/or posts as indicated.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.

1. City of Seattle
   a. City of Seattle Standard Specifications for Road, Bridge, and Municipal Construction, including provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.
   c. Traffic Control Manual For In-Street Work

2. Washington State Department of Transportation (WSDOT)
   a. Standard Specifications for Road, Bridge, and Municipal Construction, including applicable provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.
   b. Standard Plans for Road, Bridge, and Municipal Construction

3. Federal Highway Administration (FHWA)
   a. Manual on Uniform Traffic Control Devices (MUTCD)

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Submit to the Resident Engineer for approval, the respective manufacturers’ product data for signage materials.

PART 2 - PRODUCTS

2.01 MATERIALS
A. For signage on Sound Transit owned streets, roadways, and parking lots, use materials, including posts, as indicated on the Contract Drawings and conform to the applicable provisions of WSDOT 9-28, unless specified otherwise.

B. For roadway signage on streets, roadways, and parking areas that will be owned or maintained by WSDOT, City of Seattle, or the University of Washington, use materials that conform to the standards and requirements of the respective owner.
PART 3 - EXECUTION

3.01 CONSTRUCTION

A. For traffic signs on streets, roadways and parking areas that will be owned or maintained by WSDOT, City of Seattle, or University of Washington, perform work described in this Section in accordance with the standard drawings and specifications of the respective owner. Use WSDOT standard drawings and specifications for University of Washington property.

B. Traffic sign, sign post, and post foundation removals and salvage will conform to requirements of City of Seattle's standards and specifications.

C. Removal of traffic signs shall be performed upon approval from the Resident Engineer. Removal of traffic signs shall not result in a degradation of, or have an adverse effect on, traffic operations; and shall not result in violation of MUTCD standards.

END OF SECTION
SECTION 10 14 55
TUNNEL SIGNAGE

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing permanent tunnel signage.

1. Tunnel Directional Exiting Signs
2. Cross Passage Identification Signs
3. Cross Passage Warning Signs
4. Milepost Markers

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents. In case of a conflict between the requirements of this Section and those of a listed document, the requirements of this Section shall prevail.

1. Washington State Department of Transportation (WSDOT)
   a. Standard Specifications for Road, Bridge, and Municipal Construction
      1) Section 8-21 Permanent Signing
      2) Section 9-28 Signing Materials and Fabrication

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Submit to the Resident Engineer for approval, the respective manufacturers’ product data for signage materials.

C. Sign Schedule: Submit Sign Schedule using same designations specified or indicated on Drawings or in a sign schedule.

D. Shop Drawings: Submit shop drawings for all sign types with copy. Submit one full size drawing of each sign type.

E. Samples for Verification: For each type of sign assembly showing all components and with the required finishes, in manufacturer's standard size unless otherwise indicated and as follows:

   1. Tunnel Signs: Not less than 12 inches (300 mm) square.

F. Qualifications Data: For Manufacturer.
1.04 QUALITY ASSURANCE
A. Manufacturer Qualifications: Company specializing in manufacturing the product specified in this Section with a minimum 3 years of documented experience.

1.05 DELIVERY, STORAGE, HANDLING AND CLEANING
A. Store and handle materials to avoid damage to products and injury to Installers.
B. At Substantial Completion, thoroughly wipe down and clean all installed signage.

PART 2 - PRODUCTS
2.01 MATERIALS
A. For tunnel signage, fasteners and hardware, use materials as indicated on the Contract Drawings and conform to the applicable provisions of WSDOT 9-28, unless specified otherwise.
1. All signs to be Type III or IV reflective sheet material on aluminum sheet, unless otherwise noted.
2. All bolts to be ASTM A 193, Grade B7 (high strength carbon steel anchor) and AISI 304 or AISI 316 stainless steel, meeting the requirements of ASTM F593 (condition CW). Bolts are to be 1/4-inch diameter by 1 1/4-inch expansion anchors with a minimum tensile strength of at least 120 ksi.

PART 3 - EXECUTION
3.01 EXAMINATION
A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of signage work.
B. Verify that sign-support surfaces are within tolerances to accommodate signs without gaps or irregularities between backs of signs and support surfaces unless otherwise indicated.
C. Verify that anchor inserts are correctly sized and located to accommodate signs.
D. Verify that electrical service is correctly sized and located to accommodate signs.
E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.02 INSTALLATION
A. General: Install signs using mounting methods indicated and according to manufacturer's written instructions.
1. Install signs level, plumb, true to line, and at locations and heights indicated, with sign surfaces free of distortion and other defects in appearance.
2. Install signs so they do not protrude or obstruct according to the accessibility standard.
3. Before installation, verify that sign surfaces are clean and free of materials or debris that would impair installation.

4. Corrosion Protection: Coat concealed surfaces of exterior aluminum in contact with grout, concrete, masonry, wood, or dissimilar metals, with a heavy coat of bituminous paint.

3.03 ADJUSTING AND CLEANING

A. Remove and replace damaged or deformed signs and signs that do not comply with specified requirements. Replace signs with damaged or deteriorated finishes or components that cannot be successfully repaired by finish touchup or similar minor repair procedures.

B. Remove temporary protective coverings and strippable films as signs are installed.

C. On completion of installation, clean exposed surfaces of signs according to manufacturer's written instructions, and touch up minor nicks and abrasions in finish. Maintain signs in a clean condition during construction and protect from damage until acceptance by Owner.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for piping materials, mechanical sleeve seals, sleeves, escutcheons, fire-stopping sealant, and common installation instructions for Division 21 piping systems.

B. This Section also includes fire extinguishers for each cross passage.

C. Related Sections: The work of the following Sections is related to the work of this Section.
   1. Section 01 78 23, Operation and Maintenance Data
   2. Section 03 62 00, Grout
   3. Section 05 50 00, Metal Fabrications
   4. Section 21 12 00, Fire Suppression Standpipes

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Mechanical Engineers
      a. ASME BPVC Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications
      b. ASME B31.1, Power Piping
      c. ASME B31.3, Process Piping
      d. ASME B1.20.1 Pipe Threads, General Purpose
      e. ASME B16.21 Nonmetallic Flat Gaskets for Pipe Flanges
      a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
      b. ASTM A312 and ASTM A358 Stainless Steel Grade TP304, welded seam without filler metal, joint efficiency 0.85, schedule 10S, weld-prep-beveled ends
   3. American Welding Society (AWS)
      a. AWS B2.1, Specification for Welding Procedure and Performance Qualification
      b. AWS D1.1 Structural Welding Code-Steel
4. City of Seattle
   a. Seattle Fire Code (International Fire Code with Seattle Amendments)

5. Factory Mutual Global
   a. Approval Guide (FM Approved)

6. Manufacturers Standardization Society for the Valve and Fittings Industry
   a. MSS SP-119 Factory-Made Wrought Belled End Pipe Fittings for Socket-Welding

7. National Fire Protection Association
   a. NFPA 3 Recommended Practice on Commissioning and Integrated Testing of Fire Protection and Life Safety Systems
   b. NFPA 13 Installation of Sprinkler Systems
   c. NFPA 14 Standard for the Installation of Standpipe and Hose Systems
   d. NFPA 51B Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.
   e. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail with Seattle Amendments
   f. NFPA 10 Standard for Portable Fire Extinguishers

8. Underwriters Laboratory Listings (UL Listed)

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: For each type of product indicated. Include rating and classification, material descriptions, dimensions of individual components and profiles, and finishes for mounting brackets. Provide product data for fire extinguishers.

C. Operation and Maintenance Manuals: Submit operation and maintenance instructions and data for equipment provided under this Division, in accordance with the requirements of Section 01 78 23, Operation and Maintenance Data.

D. Certified Fire Protection Installer Welding certificates.

E. Sound Transit approval of the fire protection plans are required before submitting plans to the Seattle Fire Department.

1.04 QUALITY ASSURANCE

A. Steel Support Welding: Qualify processes and operators according to AWS D1.1.

B. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
   2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.
C. NFPA Compliance: Fabricate and label fire extinguishers to comply with NFPA 10, "Portable Fire Extinguishers."

D. Fire Extinguishers: Listed and labeled for type, rating, and classification by an independent testing agency acceptable to authorities having jurisdiction.

E. All equipment and component assemblies furnished and installed on the fire suppression system shall be UL listed and FM approved for its specific use.

1.05 WARRANTY

A. Fire Extinguisher Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace fire extinguishers that fails in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:
   a. Failure of hydrostatic test according to NFPA 10.
   b. Faulty operation of valves or release levers.

2. Warranty Period: Six years from date of Final Acceptance.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe, Tube and Fittings

1. Joining Methods: See specific Division 21 piping Sections.

2. Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.

B. Joining Material

1. Pipe-Flange Gasket Materials: ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness unless thickness or specific material is indicated.


C. Mechanical Sleeve Seals: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.

1. Sealing Elements: Ethylene Propylene Diene Monomer (EPDM) interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.

2. Pressure Plates: Stainless steel, include two for each sealing element.

3. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements. Include one for each sealing element.

D. Sleeves

1. Steel Sheet-Metal: For pipe 6 inch nominal size and larger, 8 gauge galvanized sheet metal, round tube closed with welded longitudinal joint, constructed to inside diameter noted on drawings.
2. Stainless Steel Pipe: For pipe nominal 12 inch size and smaller, “As Welded” pipe, ASTM A 788, Type 304, plain ends.

E. Escutcheons: Manufactured wall and ceiling escutcheons and floor plates, with an inner diameter (ID) to closely fit around pipe or tube and an outer diameter (OD) that completely covers opening.

1. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with polished chrome-plated finish.

2. One-Piece, Cast-Brass Type: With set screw and polished chrome-plated finish.

3. Split-Casting, Cast-Brass Type: With concealed hinge and set screw and polished chrome-plated finish.

F. Grout: Refer to Section 03 62 00 for grout specification.

G. Fire-Stopping Sealant: Material shall be asbestos-free and capable of maintaining an effective barrier against flame and gases. Provide joint sealants with fire resistance ratings indicated, as determined in accordance with ASTM E 119, but not less than that equaling or exceeding the fire-resistance rating of the assembly in which firestop material is installed. The fire resistance rating for penetrations into the tunnel cross passages shall be 2 hours. Provide products with flame-spread values of less than 25 and smoke-developed values of less than 50, as determined in accordance with ASTM E 84.

1. Prepackaged, dry mixes consisting of a blend of inorganic binders, hydraulic cement, fillers, and lightweight aggregate formulated for mixing with water at Project site to form a non-shrinking, homogeneous mortar.

2. Silicone Sealants: Moisture-curing, single-component, silicone-based, neutral-curing elastomeric sealants of grade indicated below:

   a. Grade: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces and nonsag formulation for openings in vertical surfaces requiring a nonslumping, gunnable sealant, unless indicated firestop system limits use to nonsag grade for both opening conditions.

H. Steel Slotted Support Systems: Comply with MFMA-4, factory-fabricated component for field assembly.

1. Metallic Coatings: Hot-dip galvanized after fabrication and applied according to MFMA-4.

2. Channel Dimensions: Selected for load supported.

I. Attachments:

1. Concrete and Masonry Anchor Bolts and Studs: Attachments with pull-out and shear capacities appropriate for supported loads and building materials where used, as follows:

   a. Tunnel Anchor Bolts: Anchor bolts in the tunnel shall be stainless steel mechanical anchor type. Both types shall be rated for dynamic loading. Anchor bolt sizes and embedment lengths indicated on the drawings are for mechanical type anchors.

   b. Mechanical Anchor Bolts: Mechanical anchor bolts shall be stainless steel hex head finished bolt with a longitudinally tapered threaded end and a spring loaded multi-part conforming threaded expander nut. Anchor shall meet Fed. Spec. A-A 1923A for description of shield
expansion (lag, machine and externally threaded wedge bolt anchors), Type 4. Expansion anchor elements shall be AISI 304 or 316 stainless steel. Anchors shall be Hilti Kwik Bolt TZ Expansion Anchor or approved equal and compliant with the 2012 International Building Code.

c. Load ratings shall be equal or better than those listed for the specified Hilti anchor and the anchor size and minimum embedment shown on the drawings.

2.02 FIRE EXTINGUISHERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product by one of the following:

1. Amerex Corporation.
2. Ansul Incorporated; Tyco International Ltd.
5. Kidde Residential and Commercial Division; Subsidiary of Kidde plc.
6. Potter Roemer LLC.

B. Valves: Manufacturer's standard.

C. Handles and Levers: Manufacturer's standard.

D. Instruction Labels: Include pictorial marking system complying with NFPA 10, Appendix B.

E. Multipurpose Dry-Chemical Type in Steel Container UL-rated 4-A:60-B:C, 10-lb nominal capacity, with monoammonium phosphate-based dry chemical in enameled-steel container.

F. Mounting Bracket: Manufacturer's standard galvanized steel, designed to secure fire extinguisher to wall or structure, of sizes required for types and capacities of fire extinguishers indicated, with plated or red baked-enamel finish.

G. Identification: Lettering complying with authorities having jurisdiction for letter style, size, spacing, and location. Location shall be acceptable to Resident Engineer.

1. Identify bracket-mounted fire extinguishers with the words “FIRE EXTINGUISHER” in red letter decals applied to mounting surface.

PART 3 - EXECUTION

3.01 PREPARATION

A. Obtain permits under Seattle Fire Department and as required by Seattle Fire Code for use of flammable liquids, hazardous materials, compressed gases, cutting and welding equipment.

B. Examine fire extinguishers for proper charging and tagging.
1. Remove and replace damaged, defective, or undercharged fire extinguishers.

3.02 ERECTION

A. Metal Supports and Anchorages
   1. Refer to Section 05 50 00, Metal Fabrications, for structural steel.
   2. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor fire-suppression materials and equipment.
   3. Field Welding: Comply with AWS D1.1.

3.03 INSTALLATION

A. Piping Systems
   1. Install piping according to the following requirements.
   2. The Contract Drawings indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion and contraction, and other design considerations. Install piping as indicated unless deviations to layout are approved by the Resident Engineer.
   3. Install piping indicated to be exposed at right angles or parallel to structure walls unless otherwise indicated on the Contract Drawings. Diagonal runs are prohibited unless specifically indicated.
   4. Install piping to permit valve servicing, and at indicated slopes. Piping shall be free of sags and bends. Install fittings for changes in direction and branch connections. Install escutcheons for penetrations of walls and floors.
   5. Install sleeves, type as indicated on drawing, for pipes passing through concrete and masonry walls, and concrete floor slabs.
      a. All interior through-penetrations shall be sleeved and protected using fire-stopping sealant in accordance with manufacturer’s instructions and to provide a through-penetration flame rating of 3 hours in accordance with UL 1479.
   6. Verify final equipment locations for roughing-in.

B. Install fire extinguishers and mounting brackets in each cross passage as directed by the Resident Engineer and in compliance with requirements of authorities having jurisdiction.
   1. Mounting Brackets: 54 inches above finished floor to top of fire extinguisher.

3.04 GROUTING

1. Mix and install grout for fire-suppression equipment and piping support base bearing surfaces, and other equipment base plates, and anchors.
2. Clean surfaces that will come into contact with grout.
3. Provide forms as required for placement of grout.
4. Avoid air entrapment during placement of grout.
5. Grout Placement:
   a. Completely fill equipment bases
   b. On concrete bases to provide smooth bearing surface for equipment
   c. Around anchors

6. Cure placed grout.

3.05 CONSTRUCTION
   A. Piping Joints: According to the following requirements
      1. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
      2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
      3. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
         a. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
         b. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
      5. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Use isolating kits including; Type F – inner bolt circle insulating gaskets, insulating sleeves, insulating washers where required to provide cathodic insulation. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

3.06 COMMISSIONING
   A. Perform all testing in accordance with Contract Documents: Refer to Section 01 91 00 Commissioning.

3.07 FIELD QUALITY CONTROL
   A. Fire Extinguishers: Refer to Section 01 77 00 Closeout procedures.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing, and testing a partial standpipe system including, but not limited to standpipe piping, hangers and supports, fire hose valves (standpipes), automatic air vents, and sectionalizing valves.

B. The provisions of the Section do not cover the connection to the municipal water supply, backflow preventer, alarm valve, or the permanent fire department connections. This work will be provided by a separate contract.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 45 00.20, Quality Assurance/Quality Control
2. Section 01 50 00, Temporary Facilities and Controls
3. Section 01 57 24, Temporary Site Water Discharge
4. Section 01 78 23, Operation and Maintenance Data
5. Section 05 05 13, Shop Applied Coating For Metal
6. Section 05 50 00, Metal Fabrications
7. Section 21 05 00, Common Work Results for Fire Suppression
8. Section 22 05 50, Mechanical Identification

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American National Standards Institute (ANSI)
   a. B16.3 Malleable Iron Threaded Fittings
   b. B16.5 Pipe Flanges and Flanged Fittings
   c. B16.21 Nonmetallic Flat Gaskets for Pipe Flanges

2. American Society of Mechanical Engineers (ASME)
   a. Boiler and Pressure Vessel Code (BPVC), Section IX, Welding and Brazing Qualifications
   b. ASME B31.1 Power Piping
   c. ASME B31.3 Process Piping
3. American Society for Testing and Materials (ASTM)
   a. ASTM A105 Standard Specification for Carbon Steel Forgings for Piping Applications
   c. ASTM A183 Standard Specification for Carbon Steel Track Bolts and Nuts
   d. ASTM A307 Standard Specification for Carbon Steel Bolts and Studs, 60000 PSI Tensile Strength
   e. ASTM A536 Standard Specification for Ductile Iron Castings
   f. ASTM A312 and ASTM A358 Stainless Steel Grade TP304, welded seam without filler metal, joint efficiency 0.85, schedule 10S and schedule 40S, weld-prep-beveled ends
   g. ASTM A403, Stainless Steel, Grade F304, 150 lb. flat face flange, Schedule 10S

4. American Welding Society (AWS)
   a. AWS B2.1, Specification for Welding Procedure and Performance Qualification
   b. AWS D1.1 Structural Welding Code-Steel
   c. AWS D10.4-86, Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing

5. City of Seattle (COS)
   a. Seattle Fire Code (International Fire Code with Seattle Amendments)

6. Manufacturers Standardization Society for the Valve and Fittings Industry
   a. MSS SP-58 Pipe Hangers and Supports – Materials, Design and Manufacture
   b. MSS SP-69 Pipe Hangers and Supports – Selection and Applications
   c. MSS SP-89 Pipe Hangers and Supports – Fabrications and Installation Practices
   d. MSS SP-90 Guidelines on Terminology for Pipe Hangers and Supports
   e. MSS SP-119 Factory-Made Wrought Belled End Pipe Fittings for Socket-Welding

7. National Fire Protection Association (NFPA)
   a. NFPA 3 Recommended Practice on Commissioning and Integrated Testing of Fire Protection and Life Safety Systems
   b. NFPA 13 Standard for Installation of Sprinkler Systems
   c. NFPA 14 Installation of Standpipe and Hose Systems
d. NFPA 51B Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.

e. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail with Seattle Amendments

8. Underwriters Laboratory Listings (UL Listed)

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: For each type of valve, gasket kit, pipe hanger, anchorage device and channel support system component.

C. Shop Drawings, and Manufacturers’ product data including piping, fittings, valves, couplings, fire department connections, piping supports, maintenance data, and recommended spare parts. Show complete system in shop drawings, including construction phasing.

D. Pipeline layout drawings together with standard details.

1. Show on the line layout, hanger locations, each standard pipe joint and each special joint or fitting by number and each hanger or support.

2. Include detailed layout at crosspassages.

3. Provide temporary standpipe supply plans and details for review by the Seattle Fire Department.

E. Certified Test Reports on Contractor’s Material and Testing for underground piping in accordance with NFPA 13.

F. Operation and Maintenance Manuals: Section 01 78 23, Operation and Maintenance Data. In addition to these requirements include data for fire suppression valves and automatic air vents.

G. Welding Certificates.

H. Welding report interpreting weld radiographs to the Resident Engineer without recommendations.

I. Pipe support load calculations including: seismic braces, hanger assemblies, concrete anchors and all support details in accordance with NFPA 13.

J. Hydraulic fill time and residual pressure calculations in accordance with NFPA 14 and NFPA 130 as amended by the City of Seattle.

1.04 QUALITY ASSURANCE

A. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."

1. Comply with provisions in ASME B31.1 “Power Piping.”

2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

B. Employ shop and field welders and/or welding operators and welding procedures qualified in accordance with the requirements of Section IX of the ASME Boiler and
C. Employ a licensed fire protection installer to install standpipe system.
D. Verify materials are clearly marked with the manufacturer's name, nameplate data or stamp, rating, and ASTM conformance number, as applicable.
   1. Use only fire protection system components and equipment that is Underwriters Laboratories (UL) Listed and labeled and Factory Mutual (FM) approved for use in fire protection systems unless otherwise approved by the Seattle Fire Department. All piping materials shall as a minimum conform to the requirements of NFPA 13.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe and Fittings
   1. Conform to NFPA 14, NFPA 130 and amendments to these codes adopted by the Seattle Fire Department. Secure grooved end product from a manufacturer with ISO 9001 certification.
   3. Pipe 2-1/2 Inches and Larger: ASTM A106, plain-end or grooved end, schedule 40, galvanized. For grooved end, use only factory- or field-formed square cut or rolled-formed grooves per coupling manufacturers specifications. Pipe joints where cut grooves are required are identified on the drawings.
   4. Fittings 2 Inches and Smaller: Class 150 malleable iron threaded fittings conforming to ANSI B16.3. Conform to dimensions of ANSI B16.5.
   5. Fittings 2-1/2 Inches and Larger: Ductile iron grooved end fittings conforming to ASTM A536 and as manufactured by the grooved end coupling manufacturer.
   6. Belled-End Fittings: Comply with MSS SP-119
   7. Grooved Joint Piping System: Mechanical grooved couplings for Pipe 2-1/2 Inches and Larger with grooved ends shall be flexible Victaulic Style 77 or rigid Style 07 type, hot dip galvanized from the factory and with Grade E, Ethylene Propylene Diene Monomer (EPDM) (negative 30 degrees F to 230 degrees F) standard style gaskets. Furnish coupling housings of ductile iron conforming to ASTM A536. For couplings from 2-inch through 6-inch size use couplings rated for a working pressure of at least 700 pounds per square inch (psi) and FM rated for 500 psi. Coupling Bolts and nuts: heat treated, zinc electroplated to ASTM B633 track-head style conforming to physical properties of ASTM A183 minimum tensile strength of 110,000 psi. Furnish all couplings and fittings from the same manufacturer.
   9. Flanges for 2-1/2 pipe and larger: Class 150 forged steel, ASTM A105, weld neck, raised face or faced to match mating equipment or valves. Furnish gaskets
with ANSI B16.21, 1/16-inch thick synthetic finish with nitrate builder. Flange Bolts: ASTM A307 Grade B bolts with A563 Grade A heavy nuts.

10. Isolating Flange Kits: Flanges to be sealed using Type F – inner bolt circle isolating gaskets between the two flanges, Bolt penetrations to be sealed with full length sleeve and single washer set or one-piece sleeve and washer, From Manufacturer with ISO 9001 Facility.
   b. Isolating Sleeves: One piece sleeve, Resist pressures indicated in ASME B31.1, sleeve length not to exceed the flanges and gasket thickness when fully compressed, water penetrate.
   c. Sleeve with Isolating Washers: Washer and sleeve to be single component, Resist pressures indicated in ASME B31.1, Length not to exceed with of single flange and gasket,

B. Valves

1. General:
   a. Furnish and install valves shown on the Contract Drawings, specified or shown for the control and easy maintenance of piping and equipment. Provide valves having proper clearances; leak proof at the specified test pressure; maker's name or brand; the figure or list number; the guaranteed ANSI working pressure cast on the body and cast or stamped on the bonnet. Provide valves of a given type from one manufacturer except for special application.
   b. Provide gate valves suitable for repacking under pressure.
   c. Valves used for fire protection piping shall be listed for fire protection service.

2. Ball Valves: Provide ball valves for automatic drain service size as indicated. Where low point drains are not indicated, provide a minimum 1 inch size drain and ball valve.
   b. Ball valve: UL Listed and FM approved and rated for 600 psi water-oil-gas (WOG)

3. Butterfly Valves: Designed for fire protection service with grooved ends, ASTM A-536 grade 65-45-12 ductile iron body, end face and retainer. Disc shall be ductile iron conforming to ASTM A536 with electroless nickel coating conforming to ASTM B-733. Furnish with nitrile (Grade T). Use only valves UL Listed for minimum 365 psi service in fire protection systems. Furnish valve with gear operated actuator and handwheel. Actuator shall have bronze traveling nut on a steel lead screw contained in a ductile iron housing. Valve shall have a black alkyd enamel coating.
4. Fire Department Outlet Fire Hose Valves (FHV): Comply with NFPA 14 with the exception of where the Seattle Fire Department overrides the design requirements. 2-1/2 inch angle type cast brass; with a rough chrome plated finish, and valve rated to 300 psi. Furnish with red handwheel, female National Pipe Taper (NPT) inlet and the Seattle Fire Department compatible male hose thread outlet.
   a. Verify that valve is UL Listed and FM approved and furnish complete with brass cap with 1/8 inch hole for pressure relief and chain. Use fire hose valves of Elkhart Brass Model No. U-25-.25 or approved equal by Kidde Fire Fighting or the Waterous Company.

5. Deluge valve with solenoid operator will be added in 90%

6. Valves shall be factory set in accordance with the schedule on the drawings and be capable of flowing 300 gpm at inlet pressures greater than 175 psig and less than 400 psig, with outlet residual pressures between 170 psig and 130 psig at the 300 gpm delivered flow.

C. Combination Air & Vacuum Valves with Anti-Shock
   1. NSF 61, and AWWA C512 approved.
   2. Provided where combination air release and vacuum valves of 1/2-inch size as indicated.
   3. Furnish combination air and vacuum valves, Vent-O-Matic Series RBX or approved equal by APCO or Crispin. For Installation on vertical 1/2-inch threaded outlet connections off the top of the selected high points of the wet standpipe main.
   4. Combination air and vacuum valves used in fire protection piping shall be UL listed or FM approved for fire protection service and rated for 300 psi working pressure.
   5. Constructed under ISO 9001 certified operation

D. Escutcheons
   1. Split-hinged, locking type escutcheon held in place by either internal tension spring or a set-screw. Provide polished chromium-plated pressed steel material. Provide escutcheon to encompass the sleeve or opening.

E. Joint Pipe Couplings
   1. Grooved Joint Pipe Couplings: ASTM A-536 grade 65-45-12 All pipe couplings shall be flexible-type except where rigid-type are indicated on the Contract Drawings.

F. Hangers and Supports
   1. Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
      a. B-Line Systems, Inc.
      b. Grinnell Corp.
      c. GS Metals Corp.
d. National Pipe Hanger Corp.

e. PHD Manufacturing, Inc.

2. Pipe Hangers, Supports, and Components: MSS SP-58, factory-fabricated galvanized metallic coatings (hot dipped galvanized type) for support systems used in the tunnel.

3. Pipe Support Systems: Consist of factory-fabricated components for field assembly as follows:

   a. Pipe support shall be made from steel meeting the minimum mechanical properties of ASTM A1011 SS, Grade 33 and shall be hot-dip galvanized after fabrication in accordance with ASTM A123.

   b. All surface mounted struts in the tunnel shall be hot-dipped galvanized steel.

   c. Unless otherwise indicated on the Contract Drawings, surface mounted struts shall be 1-5/8- inch by 1-5/8- inch.

   d. Channel hole pattern shall accommodate attachment spacing and sized indicated.

4. All nuts, bolts, screws, clamps, brackets and miscellaneous fasteners in the tunnel shall be stainless steel.

5. Add pipe support type specific to stainless steel piping

G. Seismic Restraint Devices

   1. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an evaluation service member of ICC-ES an agency acceptable to authorities having jurisdiction.

      a. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.

   2. Pipe Support System: MFMA-3, shop- or field-fabricated support assembly made of hot-dipped galvanized slotted steel channels and accessories for attachment to braced component at one end and to building or tunnel structure at the other end and other matching components and with corrosion-resistant coating; and rated in tension, compression, and torsion forces.

H. Attachments

   1. Refer to 21 05 00, Common Work Results For Fire Suppression.

I. Structural Steel

   1. Refer to Section 05 50 00, Metal Fabrications, for structural steel.

PART 3 - EXECUTION

3.01 STANDPIPE COMPONENT INSTALLATION

   A. Install the standpipe systems as indicated, in accordance with requirements of NFPA 14.
B. Install standpipe piping so that it can be thoroughly drained and, where practicable, arranged to drain at the main drain valves.

C. Valve accessibility for operation and servicing is required. Install valves as indicated and with no stems located below the horizontal position.

D. Provide escutcheon plates at finished surfaces where exposed piping passes through floors, walls, and ceilings. Fasten escutcheons to pipe or pipe coverings.

E. Install seismic restraints on piping. Comply with requirements in NFPA 13 for seismic-restraint device materials and installation.

F. Install listed fittings to make changes in direction, branch takeoffs from mains, and reductions in pipe sizes.

G. Install listed fire-protection valves, trim and drain valves, specialty valves and trim, controls, and specialties according to NFPA 14 and the authorities having jurisdiction.

H. Install listed fire-protection shutoff valves supervised-open, located to control or isolate sources of water supply as shown on the Contract Drawings. Install permanent identification signs indicating extent of system controlled by each valve.

I. Standpipe pipe, fittings, valves, and drains, shall not interfere with the pedestrian envelope or the train clearance envelope within the tunnel.

3.02 APPLICATIONS

A. Grooved Joint Pipe Couplings: All pipe couplings shall be flexible-type except where rigid-type are indicated on the drawings.

3.03 HANGER AND SUPPORT INSTALLATION:

A. Pipe hanger and support installation shall conform to the following:

1. Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure or the tunnel structure.

2. Space supports as indicated in the drawings. Install additional supports at concentrated loads, including valves, flanges, guides, strainers, and expansion joints, and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms.

3. Install expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

4. Install hangers and supports complete with necessary inserts, bolts, rods, nuts, washers, and other accessories.

5. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of flexible couplings, expansion loops, expansion bends, and similar units.

6. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.
7. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and so maximum pipe deflections allowed by ASME B31.3, "Process Piping," are not exceeded.

8. Standpipe hangers and supports, shall not interfere with the pedestrian envelope or the train clearance envelope within the tunnel.

3.04 CONSTRUCTION
   A. Welding
      1. Shop fabricate all major piping assemblies.
      2. Field welding, in general, is not permitted. In specific cases and only with the approval of the Resident Engineer may the Contractor be allowed to field weld. Submit request to field weld with sufficient proof that no other method is feasible.
      3. Where field welding is required and approved, welder must be a certified fire system installer.
      4. All welds shall have 100 percent penetration and smooth lines of fusion on the exterior and interior. Do not exceed 1/16-inch weld reinforcement.
      5. Examine welds in accordance with the requirements of ANSI/ASW D1.1, Section 6, Parts A and B, and ASTM E94 and ASTM E1032, as applicable. In addition, examine by radiography 100 percent of the welds that are embedded in concrete or buried and examine fully by random radiography a minimum of 10 percent of all remaining circumferential butt welds.
      6. Additional welding requirements for welded stainless steel to be added at 90%

   B. Repair of Galvanized Surfaces:
      1. Clean welds, bolted connections, field cut grooved pipe, and abraded areas such as rolled grooves on galvanized pipe and apply galvanizing-repair paint in accordance with Section 05 05 13, Shop Applied Coating For Metal.

3.05 IDENTIFICATION
   A. Comply with the requirements of Section 22 05 50, Mechanical Identification.

3.06 COMMISSIONING
   A. Perform all testing in accordance with Contract Documents: Refer to Section 01 91 00 Commissioning.

3.07 FIELD QUALITY CONTROL
   A. Testing
      1. Perform 100 percent visual inspection of all field welds.
      2. Upon completion of system installation test installed systems and products hydrostatically, using testing instruments calibrated by an Independent Testing Laboratory in accordance with Section 01 45 00.20, Quality Assurance/Quality Control, and flush after removal of testing equipment in accordance with applicable requirements of NFPA 14. Repair leaks and retest repaired parts of the system. Repair damages resulting from the system’s failure during the test at no additional cost to Sound Transit.
a. Hydrostatic test shall include all standpipe and shall last for two hours. The test pressure at all locations within the tunnel shall not drop below 350 psi.

b. Contractor shall provide and dispose of the quantity of water necessary for testing. Refer to Section 01 57 24, Temporary Site Water Discharge, for testing water disposal requirements.

1) The contract may request permission from the Resident Engineer to allow water provided for hydrostatic testing to remain if performed subsequent to all required pipe flushing.

3. Conduct standpipe system flow test in accordance with NFPA 14 including but not limited to the following:

a. System demand testing shall conducted by flowing water at a rate of 300 gallons per minute at fire hose outlets required by the Seattle Fire Department.

4. Furnish items used in testing

a. Calibrate pressure gages.

b. Use testing instruments calibrated by a qualified laboratory in accordance with Section 01 45 00.20, Quality Assurance/Quality Control.

5. Perform tests in the presence of the Resident Engineer and Seattle Fire Department. Notify the Engineer, Seattle Fire Department, and Seattle Public Utilities 14 days in advance of the test. The Resident Engineer will review certificates and test reports, and will inspect the standpipe system to verify conformance with NFPA 3 and NFPA 14.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for materials and installation common to piping systems specified in Division 22 including dielectric fittings, mechanical sleeve seals, sleeves, escutcheons, grouting, equipment, fire stopping sealant, supports and anchorages.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 78 23, Operation and Maintenance
2. Section 03 30 00, Cast-in-Place Concrete
3. Section 05 05 13, Shop Applied Coatings For Metal
4. Section 05 50 00, Metal Fabrications
5. Section 22 14 01, Drainage Systems for Structures
6. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Society for Testing and Materials (ASTM)
   a. ASTM A53 Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   b. ASTM A312 and ASTM A358 Stainless Steel Grade TP304, welded seam without filler metal, joint efficiency 0.85, schedule 40S, weld-prep-beveled ends
   c. ASTM A392 Zinc-Coated Steel Chain-Link Fence Fabric
   d. ASTM B32 Solder Metal
   e. ASTM B813 Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube
   f. ASTM B828 Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings
   g. ASTM D1785 Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 80, and 120
h. ASTM D2235 Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings

i. ASTM D2564 Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems

j. ASTM D2661 Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings

k. ASTM D2672 Joints for IPS PVC Pipe Using Solvent Cement

l. ASTM D2846 Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems

m. ASTM D2855 Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings

n. ASTM D3035 Polyethylene (PE) Plastic Pipe Based on Controlled Outside Diameter.

o. ASTM D3138 Solvent Cements for Transition Joints Between Acrylonitrile-Butadiene-Styrene (ABS) and Poly(Vinyl Chloride) (PVC) Non-Pressure Piping Components

p. ASTM D3139 Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals

q. ASTM D3212 Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals

r. ASTM F402 Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings

s. ASTM F493 Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings

t. ASTM F656 Primers for Use in Solvent Cement Joints of Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings

2. American Society of Mechanical Engineers (ASME)

a. ASME B1.20.1 Pipe Threads, General Purpose, Inch

b. ASME B16.21 Nonmetallic Flat Gaskets for Pipe Flanges

3. American Welding Society (AWS)

a. AWS A5.8 Filler Metals for Brazing and Braze Welding

b. AWS B2.1, Specification for Welding Procedure and Performance Qualification

c. AWS D10.12 Guide for Welding Mild Steel Pipe

d. AWS D10.4-86, Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing

e. AWS D1.1 Structural Welding Code

f. AWS BRH Brazing Handbook
4. National Fire Protection Association (NFPA)
   a. NFPA 3 Recommended Practice on Commissioning and Integrated Testing of Fire Protection and Life Safety Systems

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. (A1) Product Data: For each type of product indicated. Include rating and classification, material descriptions, dimensions of individual components and profiles, and finishes for fire extinguisher and mounting brackets.
C. Welding Certification.
D. Operation and Maintenance Manuals: Submit operation and maintenance instructions and data for equipment provided under Division 22, in accordance with the requirements of Section 01 78 23, Operation and Maintenance Data.

1.04 QUALITY ASSURANCE
A. Steel Support Welding: Qualify processes and operators according to AWS D1.1.
B. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
   1. Comply with provisions in ASME B31.1, "Code for Pressure Piping."
   2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

PART 2 - PRODUCTS
2.01 MATERIALS
A. Pipe, Tube and Fittings
   1. Joining Methods: Refer to Section 22 14 01, Drainage Systems For Structures and Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances
   2. Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.
B. Joining Materials
   1. Special Joining Materials if Not Listed Below: Refer to Section 22 14 01, Drainage Systems For Structures and Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances
   2. Pipe-Flange Gasket Materials: ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness unless thickness or specific material is indicated.
C. Dielectric Fittings: Combination fitting of copper alloy and ferrous materials with threaded, solder-joint, plain, or weld-neck end connections that match piping system materials.
   1. Insulating Material: Suitable for system fluid, pressure, and temperature.
   2. Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 150- or 300-psig minimum working pressure as required to suit system pressures.
3. **Dielectric Couplings:** Galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 degrees F.

4. **Dielectric Nipples:** Electroplated steel nipple with inert and noncorrosive, thermoplastic lining; plain, threaded, or grooved ends; and 300-psig minimum working pressure at 225 degrees F.

**D. Mechanical Sleeve Seals:** Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.

1. **Sealing Elements:** ethylene propylene diene monomer (EPDM) interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.

2. **Pressure Plates:** Carbon steel. Include two for each sealing element.

3. **Connecting Bolts and Nuts:** Carbon steel with corrosion-resistant coating of length required to secure pressure plates to sealing elements. Include one for each sealing element.

**E. Sleeves**

1. **Above Grade:** Unless otherwise indicated on the drawings, provide steel pipe, ASTM A53, Type E, Grade B, Schedule 40, hot-dipped galvanized, plain ends.

2. **Below Grade (or one side in contact with dirt):** As detailed on Contract Drawings.

**F. Grout:** Refer to section 03 62 00 for grout specification.

**G. Fire-Stopping Sealant:** Material shall be asbestos-free and capable of maintaining an effective barrier against flame and gases. Provide joint sealants with fire resistance rating of minimum 2 hours, as determined per ASTM E 119, but not less than that equaling or exceeding the fire-resistance rating of the assembly in which firestop material is installed. Provide products with flame-spread values of less than 25 and smoke-developed values of less than 50, as determined per ASTM E 84.

1. **Prepackaged, dry mixes consisting of a blend of inorganic binders, hydraulic cement, fillers, and lightweight aggregate formulated for mixing with water at Project site to form a non-shrinking, homogeneous mortar.**

2. **Silicone Sealants:** Moisture-curing, single-component, silicone-based, neutral-curing elastomeric sealants of grade indicated below:

   a. **Grade:** Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces and nonsag formulation for openings in vertical and other surfaces requiring a nonslumping, gunnable sealant, unless indicated firestop system limits use to nonsag for both opening conditions.

   b. **Grade for Horizontal Surfaces:** Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces.

   c. **Grade for Vertical Surfaces:** Nonsag formulation for openings in vertical and other surfaces.
H. Attachments:

1. Concrete and Masonry Anchor Bolts and Studs: Insert-type attachments with pull-out and shear capacities appropriate for supported loads and building materials where used, as follows:

   a. Tunnel Anchor Bolts: Anchor bolts in the tunnel shall be stainless steel mechanical anchor type or epoxy anchor bolts. Both types shall be rated for dynamic loading.

   b. Mechanical Anchor Bolts: Mechanical anchor bolts shall be stainless steel hex head finished bolt with a longitudinally tapered threaded end and a spring loaded multi-part conforming threaded expander nut. Anchor shall meet Fed. Spec. A-A 1923A for description of shield expansion (lag, machine and externally threaded wedge bolt anchors), Type 4. Expansion anchor elements shall be AISI 304 or 316 stainless steel. Anchors shall be Hilti HDA Undercut Anchor or approved equal.

PART 3 - EXECUTION

3.01 PREPARATION

A. Obtain permits under Seattle Fire Department and as required by Seattle Fire Code for use of flammable liquids, hazardous materials, compressed gases, cutting and welding equipment.

3.02 ERECTION

A. Metal Supports and Anchorages

1. Refer to Section 05 50 00, Metal Fabrications, for structural steel.

2. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor plumbing materials and equipment.

3. Field Welding: Comply with AWS D1.1.

3.03 INSTALLATION

A. Piping Systems

1. Install piping according to the following requirements and Section 22 14 01, Drainage Systems For Structures and Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances

2. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved by the Resident Engineer.

3. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and cross passages.

4. Install piping indicated to be exposed at right angles or parallel to structure walls. Diagonal runs are prohibited unless specifically indicated otherwise.
5. Install piping to permit valve servicing.
6. Install piping at indicated slopes.
7. Install piping free of sags and bends.
8. Install fittings for changes in direction and branch connections.
9. Install piping to allow application of insulation where indicated.
10. Select system components with pressure rating equal to or greater than system operating pressure.
11. Install sleeves for pipes passing through concrete and masonry.
   a. Above ground, Exterior-Wall Pipe Penetrations: Seal penetrations as indicated on the drawings
   b. Above ground, Interior-Floor Pump Discharge Penetrations: Seal pipe penetration with silicone fire stopping sealant.
   c. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials.
12. Verify final equipment locations for roughing-in.
13. Refer to equipment specifications in other Contract Specification Sections for roughing-in requirements.

B. Equipment
1. Install equipment to allow maximum possible headroom unless specific mounting heights are not indicated.
2. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.
3. Install plumbing equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.
4. Install equipment to allow right of way for piping installed at required slope.

3.04 APPLICATION
A. Grouting
1. Mix and install grout for plumbing equipment base bearing surfaces, pump and other equipment base plates, and anchors.
2. Clean surfaces that will come into contact with grout.
3. Provide forms as required for placement of grout.
4. Avoid air entrapment during placement of grout.
5. Grout Placement:
   a. Completely filling equipment bases.
b. Concrete bases: provide smooth bearing surface for equipment.

c. Around anchors.

6. Cure placed grout.

3.05 CONSTRUCTION

A. Piping Joints: according to the following requirements and Section 22 14 01, Drainage Systems For Structures and Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances

1. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

3. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

   a. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.

   b. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.


5. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

B. Piping connections

1. Make connections according to the following, unless otherwise indicated:

   a. Install nipples, in piping nominal pipe size (NPS) 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.

   b. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment.

   c. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.

C. Commissioning

1. During, design, construction, and upon completion of the construction commissioning practices shall occur according to NFPA 3.

D. Repair of Galvanizing:

1. Refer to Section 05 05 13, Shop Applied Coatings For Metal, for galvanizing repair paint product specification, and the following:
a. Touching Up: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

b. Clean welds, bolted connections, field formed cut or rolled grooved pipe, and abraded areas and apply galvanizing-repair paint to comply with ASTM A780

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the means of identification of plumbing and fire protection equipment, piping, controls, and valves.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 78 23, Operation and Maintenance Data
2. Section 21 12 00, Fire Suppression Piping
3. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents:

1. American National Standards Institute (ANSI):
   a. ANSI A13.1 Scheme for the Identification of Piping Systems

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit manufacturer's product data of pipe markers, valve markers or tags, equipment nameplates, and control nameplates.

C. Schedules: Submit valve schedule for each piping system, typewritten and reproduced on 8 1/2 by 11-inch bond paper for mounting. Tabulate valve number, piping system, system abbreviation (as shown on tag), location of valve (room, space, cross passage number, or tunnel station), and variations for identification (if any). Mark valves that are intended for emergency shut-off and similar special uses with "flags" in the margin of the schedule. In addition to mounted copies, furnish extra copies as required for maintenance manuals as specified in Section 01 78 23, Operation and Maintenance Data.

D. Samples: Submit samples of each color, lettering style, and other graphic representation required for each identification material or system.

PART 2 - PRODUCTS

A. MATERIALS

1. Pipe:
a. Provide pipe markers of semi-rigid plastic that are accessible for maintenance operations (except piping in finished spaces). Include direction-of-flow arrows.

b. Color code marker background with a clearly printed legend to identify the contents of the pipe. Colors and legend shall conform to ANSI A13.1.

c. Provide pipe markers for the pump station discharge piping.

d. The 5-inch standpipe piping will not be marked.

2. Valve Identification:

a. Valve Markers: Satin finished aluminum faced black plastic backed, 1-1/2 inches in diameter. Letters shall be 1/4 inch high and numbers shall be 1/2 inch high; both shall be engraved. Marker fasteners shall be meter seals, four-ply 18 gage stainless steel wire, stainless steel "S" hooks, or meter seals. Markers shall bear identifications as indicated.

b. Control Valves: Supervised butterfly valve markers, and fire hose valve (FHV) markers shall be satin finished aluminum faced black plastic backed, 2 by 4-inch, letters, and numbers shall be 1/4 inch high, engraved, identifying function as indicated.

c. Valve List Frame: Crafted wood with clear glass front.

d. Valve List: Provide on heavy white bond paper, either typed or printed.

e. Valve List Closure: Crafted of transparent plastic. Front and back plastic sheets, which form closure, shall not be thinner than 15 mils. Two holes shall be punched at top of plastic closure to allow a nickel-plated bead chain to be affixed thereto.

3. Equipment Nameplates Including the Standpipe System Drain Valves and Air Vent Valves: Aluminum or stainless steel, where indicated, 2 inches by 4 inches, with a black enamel background and either etched or engraved lettering. Lettering shall be as indicated. Nameplates shall bear notations corresponding to the same notations on the framed wiring diagrams and operating instructions.

4. Control Nameplates: Laminated colored plastic with white lettering. Each switch shall have its switch positions clearly indicated and identified. Nameplates shall be worded to identify the respective item and function.

PART 3 - EXECUTION

A. INSTALLATION

1. Pipe Markers: Install adjacent to each valve and fitting, except on plumbing fixtures and equipment at each branch and riser take-off; at each pipe passage through wall, floor, and ceiling construction; at each pipe passage to underground; and on 25-foot centers on horizontal pipe runs.

2. Valve Markers: Fasten to valve body so as to be easily read.

3. Valve List Frame: Mount on a wall where indicated by the Resident Engineer. One valve list shall be mounted in the frame.

5. Control Nameplates: Mount with corrosion-resistant fasteners.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing, and testing the tunnel track drainage system along the length of the tunnel structure, including embedded piping and drainage inlets. This Section also includes embedded seepage piping and cross passage drainage piping, including cross passage drains.

B. Related Sections: The work of the following Sections is related to the work of this Section:

1. Section 01 57 24, Temporary Site Water Discharge.
2. Section 01 78 23, Operation and Maintenance Data.
3. Section 05 13 00, Shop Applied Coatings for Metal.
4. Section 22 05 00 Common Work Results for Plumbing.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents:

1. American Society for Testing and Materials (ASTM)
   b. ASTM A74 Standard Specification for Cast Iron Soil Pipe and Fittings
   c. ASTM D1785  Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
2. Uniform Plumbing Code and local amendments
3. National Fire Protection Association (NFPA)
   a. NFPA 3 Recommended Practice on Commissioning and Integrated Testing of Fire Protection and Life Safety Systems

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Shop drawings showing piping layouts, sizes, types, valves, drains, and cleanouts.
C. Manufacturers’ Product data for specified materials and equipment.
D. Equipment Manufacturer's printed operating and maintenance instructions in accordance with Section 01 78 23, Operation and Maintenance Data, including detailed parts list, recommended spare parts list, and complete operation and maintenance procedures.

E. Certified test results and certificates of compliance as necessary to verify conformance with specified requirements.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe and Fittings

1. General: Provide pipe and fittings of sizes and configurations indicated.

2. Tunnel Embedded Track Drainage Piping: Use Polyvinyl chloride (PVC), ASTM D1785, Schedule 80, Type I, Grade 1.
   a. Fittings: Same material and schedule as pipe.

3. Seepage Drain Piping From Tunnel Walkway to Invert and Drain Piping Between Cross Passage Drains and Invert: High Density Polyethylene (HDPE), ASTM D3035 or ASTM 2447.
   a. Pipe Working Pressure Rating: 160 psi water at 73 degrees F
   b. Pipe Thickness: Standard dimension ratio (SDR) of 11.

B. Trackway Drainage Inlets

1. General: Drainage inlets include a sheet metal pan, grate and frame as detailed on the Contract Drawings.

2. Sheet Metal Pan: Sheet metal, thickness as shown, galvanized to 0.45 oz/sq. ft. per side and in accordance with Section 05 13 00 – Shop Applied Coatings for Metal.

3. Typical Track Drain Grate and Frame: Galvanized cast iron body, heavy-duty, 24.5-inch x 24.5-inch grate size, 2-inch deep, minimum 1.7 square feet open area, Neenah R-4760 with angle frame and anchor studs, or equal.

C. Cross Passage Drains (DR-1 and DR-2)

1. General: Commercial deck drain, double wall PVC base, removable slotted aluminum top and snap-in connection to base, Stegmeier Corp., or equal.

2. Maximum Size: 2-inch wide by 4-inch deep.

3. Accessories:
   a. Side adaptor with 1-1/2-inch drain connection and removable slotted aluminum top for cleanout.
   b. Fernco coupling, or equal, with stainless steel clamps.
PART 3 - EXECUTION

3.01 PREPARATION

A. Prior to installing or placing drainage products, clean excavations of water and extraneous material.

B. Clean interior of pipe, pipe fittings, drains, and cleanouts before installation.

C. Install sleeves through walls, floors, roofs, and other structures before installing drainage lines.

3.02 INSTALLATION

A. Install track drainage piping as indicated.

1. Prior to invert concrete pour, verify the slope of the piping conforms to the tunnel gradient or as otherwise indicated

2. Install drainage piping prior to invert concrete pour on supports maximum 8 ft on centers such as channel iron or blocks and making sure to prevent point loading of the piping.

B. Install cross passage drain in accordance with manufacturer’s installation instructions, and as indicated. Provide necessary formwork and adjust drain sections so top of drain is flush with top of finished concrete floor.

3.03 FIELD QUALITY CONTROL

A. Testing

1. Do not cover products to be embedded in concrete until products have been inspections, tested, and accepted.

2. Test installed drainage lines and equipment as follows:

   a. Piping may be tested in sections. Temporarily seal ends.

   b. Cut pipe for drainage inlets after testing is successfully completed.

   c. Fill gravity drains with water and allow to stand for not less than 30 minutes without leaking

   d. Repair leaks and retest systems until the system exhibits no leaks. Test with a water head of 30 feet for testing integrity of pipe.

   e. Provide and dispose of water required for testing. Refer to Section 01 57 24, Temporary Site Water Discharge, for testing water disposal requirements.

3.04 COMMISSIONING

A. During, design, construction, and upon completion of the construction commissioning practices shall occur according to NFPA 3.
3.05 CLEANING

A. Removing foreign material from the surfaces of products when cleaning. Leave the manufacturer's labels intact. Flush all sections of the piping system and dispose of the flushing water from the tunnel using temporary pumps where necessary.

END OF SECTION
SECTION 22 14 10
TUNNEL TRACK DRAINAGE PUMPING STATION PIPING AND APPURTENANCES

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and testing the tunnel track drainage pumping station piping and appurtenances indicated for Cross Passage No. 31.

B. This Section includes specifications for furnishing the sump pump controller for installation in the motor controller panel specified in Section 26 29 13, Enclosed Motor and Lighting Controllers.

1. Provide design, programming, graphic creation, material and labor for a complete and operable system. Coordinate electrical interface requirements with electrical subcontractor.

C. This Section includes specifications for furnishing liquid level sensors and level switches.

D. Refer to Section 01 50 00, Temporary Facilities and Controls, for requirement for temporary pumps at Cross Passage No. 31.

E. The final or permanent sump pumps will be provided in a future contract.

F. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 50 00, Temporary Facilities and Controls
2. Section 03 30 00, Cast-In-Place Concrete
3. Section 22 05 00, Common Work Results for Plumbing
4. Section 22 05 50, Mechanical Identification
5. Section 22 14 20, Well Casing and Force Main
6. Section 26 29 13, Enclosed Motor and Lighting Controllers
7. Section 33 01 00, Operations and Maintenance of Utilities

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Society for Testing and Materials (ASTM)
   a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dip, Zinc-Coated, Welded and Seamless
   b. ASTM A123 Standard Specification for Zinc (Hot-Dip Galvanized) Coating in Iron and Steel Products

d. ASTM A153 Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

e. ASTM A536 Standard Specification for Ductile Iron Castings

f. ASTM B127 Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip

g. ASTM D2000 Standard Classification System for Rubber Products in Automotive Applications

2. American National Standards Institute (ANSI)

a. ANSI B18.10 Track Bolt and Nuts

b. ANSI B18.5 Round Head Bolts (Inch Series)

c. ANSI B18.22 Plain Washers

d. ANSI B16.1 Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800

e. ANSI B31.1 Power Piping

f. ANSI B40.1 Pressure Gauges and Gauge Attachments

g. ANSI A13.1 Scheme for the Identification of Piping Systems

3. American Water Works Association (AWWA)

a. ANSI/AWWA C104/A21.4 American National Standard for Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water

b. ANSI/AWWA C110/A21.10 American National Standard for Ductile-Iron and Gray-Iron Fittings, 3-inch through 48-inch, for Water and Other Liquids


e. ANSI/AWWA C150/A21.50 American National Standard for the Thickness Design of Ductile-Iron Pipe

f. ANSI/AWWA C151/A21.51 American National Standard for Ductile-Iron Pipe, Centrifugally Cast, for Water

g. ANSI/AWWA C153/A21.53 American National Standard for Ductile-Iron Compact Fittings, 3-inch through 24-inch and 54-inch through 64-inch, for Water Service

h. AWWA C210 Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines

i. ANSI/AWWA C606 AWWA Standard for Grooved and Shouldered Joints
4. Federal Specifications
   a. WW-H-171E Hangars and Supports, Pipe
   b. WW-P-421 Pipe, Cast, Gray and Ductile Iron, Pressure (For Water and Other Liquids)

5. National Fire Protection Association
   a. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
   b. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit the following a minimum of 4 weeks prior to starting construction of the initial lining for the concrete wet well at Cross Passage number 31:

1. Calculations for pipe support and/or manufacturers load capacity data.

2. Manufacturer's standard drawings and catalog cuts and certificates of conformance for the following items:
   a. Pipe and fittings
   b. Joints and couplings (including gaskets)
   c. Valves
   d. Gauges
   e. Wall sleeves
   f. Pipe to wall penetration closure
   g. Sump pump floor access hatches (including hardware)
   h. Programmable logic controller
   i. Level sensors, transmitters and float switches.
   j. Manufacturer's installation instructions.

3. Provide technical details of the level sensor/transmitter for installation inside the motor controller enclosure.

4. Shop Drawings. Show complete and accurate information of:
   a. Dimensioned piping layout, complete with locations of all supports, presented in tabular format with a description of each support type, at a minimum scale of 3/8 inch equal to 1 foot.
   b. Sump pump floor access hatches and cover dimensions.
   c. Fire- and smoke-damper installations, including sleeves.
   d. Coordinate dimension of piping and systems with the requirements of Section 31 71 23 Tunnel Excavation by Sequential Excavation Method.
1.04 OPERATION AND MAINTENANCE MANUALS:

A. In accordance with Section 22 05 00, Common Work Results For Plumbing and Section 01 78 23, Operation and Maintenance Data. In addition to these requirements, include data for valves, sump pit appurtenances, PLC, level controls, propeller supply fan and combination fire smoke/damper.

1.05 COORDINATION

A. Coordinate programming of PLC with installation of temporary pumps. Program sequence of operation.

1.06 QUALITY ASSURANCE

A. Determine specific locations and sizes for access doors needed to gain access to and remove sump pumps using the lifting rail.


C. PLC Programming and Level Sensor Installation: All work associated with the products, programming and testing specified herein must be accomplished by trained mechanics and electricians in the continuous employment of a firm whose normal business is the installation and maintenance of automation control systems instrumentation.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Promptly remove damaged products from the job site. Replace damaged products with undamaged products.

B. Load and unload all pipe, fittings, valves, and appurtenances by hoists or skidding. Do not drop products. Do not skid or roll products on or against other products. Use pad slings, hooks, and pipe tongs in such a manner to prevent damage to products.

C. Keep stored products safe from damage or deterioration. Keep the interior of pipe, fittings, valves, and appurtenances free from dirt or foreign matter. Drain and store valves in a manner that protects valves from damage by freezing. Store gaskets, plastic pipe and fittings, and other products, which deteriorate with sunlight in a cool location, out of direct sunlight. Do not allow gaskets to come in contact with petroleum products.

D. Store valves and appurtenances in accordance with manufacturer's recommendations.

E. Stack ductile iron, plastic, and steel pipe according to the requirements of the pipe manufacturer. Do not stack fittings, valves, or valve stands.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Furnish all pipe, fittings, and appurtenances as indicated and specified in this Section. For all pipe, fittings, valves, and appurtenances use only new products.

2.02 NON-BURIED PIPE AND FITTINGS

A. Non-Buried (Exposed) Pipe:

1. Located within the pump station, inside the wet well and the cross passage.

2. Grade C ductile iron: AWWA C151, as modified by Fed. Spec. WW-P-421.
3. Minimum metal wall thickness of Class 53 for flanged or grooved wall pipe.
4. Coated in accordance with "Pipe Coating" article within these specifications.
5. Flanged pipe:
   a. AWWA C115.
6. Cement mortar lining: AWWA C210 Type V cement.

B. Non-Buried Joints:
1. Mechanical grooved type joints or flange joints with screwed on ductile iron flanges where required for connection to flanged valves.
   c. Field made-up flanges: not allowed.

C. Non Buried Fittings:
1. Designed and manufactured for a minimum pressure rating of 250 pounds per square inch (psi).
2. Mechanical grooved ends.
3. Flange joints conforming to ANSI/ AWWA C110.
4. Grooved type joints: ANSI/AWWA C110, for center to end dimensions and AWWA C153 or ANSI 21.10/WWA C-110 for wall thickness.
5. Lining cement mortar: AWWA C210 Type V cement.
6. Factory furnished exterior coating equal to that of the connecting pipe.

2.03 PIPE COATING:
A. Applied to the exterior surfaces of wet well and cross passage ductile iron pipe and fittings in accordance with AWWA C210:
1. Factory applied primer coat equal to MC- Ferro Clad.
   a. Prime Coating Thickness: Minimum 3 mils to 5 mils DFT (dry file thickness).
2. Factory applied intermediate coat equal to MC Ferrox B 200.
   a. Intermediate Coating Thickness: Minimum 3 mils to 5 mils DFT.
3. Factory applied final coat equal to MC Ferrox A 200.
   a. Final Coating Thickness: Minimum 2 mils to 4 mils DFT.
4. The prime, intermediate and final coats will be compatible with each other.

2.04 NON-BURIED GROOVE-TYPE MECHANICAL COUPLINGS:
A. Coupled with grooved ends by engaging and holding these ends to form a watertight joint by means of a bolted, segmental clamp housing enclosing a sealing gasket.
B. Provide a rigid joint comparable to a flanged system.

C. Clamp housing:
   1. Two or more parts made of ductile iron conforming to ASTM A536.
   2. Minimum 400 psi working pressure for 8-inch diameter pipe and smaller.
   3. Bolts and nuts for connecting clamp housing connections:
      a. Track bolts and nuts conforming to ANSI B18.10
      b. Roundhead, square neck type conforming to ANSI B18.5
      c. Hex nuts conforming to ANSI B18.22
      d. Zinc plated to ASTM B633
   4. Bolt holes: of a shape to hold fast the necks of the bolts used

D. Gaskets:
   1. Halogenated Butyl rubber, flush seal type, conforming to ASTM D2000
   2. Supplied by the coupling vendor.
   3. Shaped to effectively seal joint against leakage, when compressed.

E. Grooved ends of piping: In accordance with the published recommendations of the manufacturer of the coupling, as approved by the Resident Engineer.

F. Strength of coupling: Not less than that of the pipe.

G. Housing covered with factory applied, enamel coating.

2.05 GROOVE-TYPE MECHANICAL FLANGE ADAPTERS:

A. Join pipe and fittings with grooved ends to flanged valves and other equipment.

B. Engage groove in pipe or fitting and hold this end to the adjoining flange to form a rigid, watertight joint.

C. Clamp housing: Two or more parts made of malleable iron conforming to ASTM A536

D. Bolts and nuts: Heavy hex cadmium plated steel.

E. Gasket: Halogenated Butyl and supplied by the flange adapter manufacturer.

F. Flange washer: Between the flange adapter gasket and the flange or flange gasket if so stipulated by the adapter manufacturer.

G. Flange: Conform to ANSI B16.1: Class 125 drilling.

H. Coating of the flange adapters: Equal to the approved coating for the grooved couplings

2.06 FLANGE JOINT ACCESSORIES:

A. Gaskets for flange joints: See Section 22 05 00, Common Work Results For Plumbing.

B. Nuts and bolts: zinc plated steel, heavy hex nuts.
2.07 BURIED PIPE AND FITTINGS:
A. Pump station force main pipe installed in well casing at Cross Passage No. 31 and buried pipe to the grade level sewer manhole in East Roanoke Street, is specified in section 22 14 00, Well Casing and Force Main.

2.08 DISCHARGE DRAIN PIPING:
A. Pump station drain piping from each pump discharge riser to the sump.
B. Hard Copper Tube: ASTM B 88, Type K, water tube, drawn temper.
C. Copper Pressure Fittings: ASME B16.18, cast-copper-alloy or ASME B16.22, wrought-copper, solder-joint fittings. Furnish wrought-copper fittings if indicated.
D. Copper Unions: MSS SP-123, cast-copper-alloy, hexagonal-stock body, with ball-and-socket, metal-to-metal seating surfaces, and solder-joint or threaded ends.

2.09 VALVES
A. Furnish all isolation, check and drain valves, shown on the discharge side of the sump pumps, as indicated and specified herein.
B. Plug Valves:
   1. Eccentric plug type unless otherwise indicated or specified herein
   2. Valves:
      a. Non-lubricated eccentric type with Neoprene resilient faced plugs
      b. Furnished with flanged end connections.
      c. Flanges: Faced and drilled to the ANSI 125/150 standard.
      d. Valve bodies:
         1) Rectangular ported design and made of ASTM A126 Class B cast iron and with bolted bonnets.
         2) Furnished with welded overlay seats of not less than 90 percent pure nickel.
         3) Seat area: raised with surface completely covered with weld to ensure that the plug face contacts only nickel.
   3. Plug:
      a. ASTM A126 Class B cast iron.
      b. Cylindrical seating surface eccentrically offset from the plug shaft.
      c. Interference between the plug face and the body seat externally adjustable in the field with the valve in the line under pressure.
   5. Stem seals:
      a. Multi-V ring adjustable packing type
b. Replaceable in-line without valve disassembly.

6. Port area: Not be less than 80 percent of the mating pipe area.

7. Gear operated requiring not more than 50 pounds force (lbf) at the rim of the hand wheel under all operating conditions.

8. Furnished with travel stops for the full open and closed positions and provided with intermediate position indication in 15-degree increments.

9. Rated for minimum 175 psi working pressure.

C. Swing Check Valves:

1. ASTM A126 Class B cast iron, with steel reinforced, Buna-N rubber lined flapper with bubble-tight seating.

2. Unrestricted flow area

3. 125-pound class rating and a 175-psi working pressure.

4. Inside of the valve: Rubber lined such that internally the valve has no exposed metal surfaces.

5. Positive non-slip backflow device, for the purpose of backflushing the pumps.

6. Phenolic primer red oxide exterior coating.

7. Swing check valve: APCO Series 100R or approved equal.

D. Ball Valves:

1. 2 inches and smaller for drain service:
   a. ASTM A126, Class B Cast iron body
   b. Threaded end connections.

2. ASTM A126 Class B Cast iron or ASTM A536 ductile iron ball.

3. Seats: Cast Monel, ASTM B127 or BUNA-N rubber

4. Packing: TFE V-flex

5. Tested to the design working pressure (150 psi) with the ball in the closed position to determine tightness of the ball and seats.

E. Actuated Drain Valve:

1. 2-way solenoid valve, pilot-operated, 3/4-inch NTP connection, 3/4-inch orifice size, brass body, PTFE seals and disc, stainless steel wetted parts, 300 PSI operating pressure, watertight enclosure, UL listed for general purpose valve, ASCO 8210 Series, G

   a. Power: 120 VAC, 48 VA holding, 240 VA inrush unless otherwise indicated on the electrical Contract Drawings.

2.10 HANGERS AND SUPPORTS

B. Stainless steel materials in the sump areas and stainless steel or hot-dip galvanized pipe hangers and supports in the cross passages.

2.11 PIPING APPURTEANCES

A. Gauges: ANSI B40.1, single style pressure gauge for water with 4.5-inch dial, brass or aluminum case, bronze tube, gauge cock and pressure snubber. Provide scale range suitable for the intended service.

B. Sleeves in masonry and concrete walls, floors, and grade beams: Refer to Section 22 05 00, Common Work Results for Plumbing, for product specification.

C. Pipe to Exterior Wall and Pipe to Exterior Floor Mechanical Sleeve Seals: Refer to Section 22 05 00, Common Work Results for Plumbing, for product specification.

D. Miscellaneous Steel:
   1. Pipe supports, hangers, anchors, sleeves, and associated steelwork:
      a. Hot-dip galvanized in accordance with ASTM A153, 2 ounces per square foot minimum.
      b. Configured as indicated.

E. Attachments: Refer to Section 22 05 00 Common Work Results For Plumbing.

2.12 PIPING IDENTIFICATION:

A. Refer to Section 22 05 50, Mechanical Identification, for pipe marker material specification.

B. Indicate flow direction with arrows adjacent to labels.

C. Spacing no greater than 10 feet.

2.13 SUMP PIT APPURTEANCES

A. Aluminum Angle Frame Sump Access Hatch:
   1. Performance Requirements: Provide triple leaf access door and frame assemblies manufactured as integral units ready for installation.
      a. Opening Size: The nominal hatch size and clear inside opening is indicated on the Contract Drawings.
      b. The hatch shall be designed to provide fall through protection per OSHA standard 1910.23 and controlled confine space entry per OSHA standard 1910.146.
   2. Fabricate to support 600 pounds per square foot minimum live load.
   3. Cover: Reinforced 1/4-inch type 5086 aluminum diamond plate with steel hold open arm that automatically locks cover in a 90-degree open position. A removable exterior turn/lift handle with spring loaded ball detent shall be provided to open the cover.
   4. Design of access hatch shall incorporate a triple leaf configuration, allowing each leaf to operate independently. Frame shall be a one piece unit.
5. Frame: Extruded aluminum, with a continuous 1-1/2-inch anchor flange. Include additional supports at mid-points as determined by hatch manufacturer for hatch configuration indicated on drawings.

6. Hinges: Stainless steel with a 3/8-inch grade 316 stainless steel pin. Hinges shall be bolted to the angle frame and diamond plate, with grade 316 stainless steel bolts and ny-lock nuts.

7. Hardware: 316 stainless steel recessed Slamlock, with keyway protected by a threaded stainless steel plug. Plug shall be flush with the top of the 1/4 inch diamond plate. Slamlock shall be fastened with grade 316 stainless steel bolts and washers. Provide a separate recessed padlock clip with hinged access cover. Provide recessed lift handle flush with top of cover.

8. Safety Grate: The grating shall be designed to withstand pedestrian (300 PSF) loading. The sump access hatch design shall assure the safety grate is in place before the cover can be closed. Each grate shall be hinging system and shall lock in the 90-degree position once opened. Grate shall be coated with OSHA type safety orange color two part epoxy paint.

B. Steel Angle Frame Catch Basin Access Cover:

1. Curb Frame Material: 1/4 inch steel angle with strap anchors welded to exterior.

2. Cover Material: Steel diamond plate with steel flush lifting handle that does not protrude above the cover.


C. Access Ladder:

1. Ladder Material: 6061-T6 Aluminum

2. Ladder Design: Shop fabricated ladder shall comply with OSHA Standard 1910.27. Include supports for connection to concrete wall as indicated on the Contract Drawings.


4. Attachments: Anchor bolts as indicated on Contract Drawings. See Section 21 05 00, Common Work Results for Fire Suppression, for anchor bolt specification.

2.14 PROPELLER SUPPLY FAN

A. Propeller fans shall have wheels constructed of either steel or aluminum blades with hubs, mounting rings and plates that are cast or die formed and with smooth curves where the air enters the wheels.

B. Propeller fans shall be provided complete with motors and fan guards. Fans and motors shall be mounted on resilient supports and heavy steel frame. Steel angles and plates shall be provided to mount fans and dampers in wall openings. Mounting plates shall be designed to prevent distortion and shall be either turned up at edges or braced with steel angles.

C. Shafts for fans shall be steel. Bearings for fan shafts shall be permanently lubricated, permanently sealed, ball bearings.

D. Fan wheels shall be mounted on either extended motor shafts or ball-bearing hubs that rotate on fixed stub shafts; support shafts by two self-aligning bearings.
E. Fans shall be belt-driven or direct-driven as indicated. Motor mounting for belt driven units shall be resilient and shall be adjustable for correction of belt tension.

F. Propeller fan shall have a motor with nameplate rating not less than the brake horsepower required to drive the fan with a static pressure 0.20 inch greater than the value scheduled on the Contract Drawings.

2.15 COMBINATION FIRE SMOKE DAMPER

A. Manufacturers: Ruskin, Prefco, NCA Mfg, or Air Balance, Inc.

B. General: Labeled to UL 555 "Standard for Fire Damper" for 1-1/2 hour fire damper. Open and close under operating conditions up to 4-inches w.g. in closed position and 2000 fpm in open position. Class 2 leakage rating. Automatic remote reset after test; smoke detection or power failure.

C. Fire Rating: 1-1/2 hours.

D. Fusible Link: Replaceable, 165 degrees F rated unless specifically indicated 212 degrees F or 285 degrees F.

E. Frame: Minimum 16-gauge thick, galvanized, sheet steel.


G. Mounting Sleeve: Factory-installed, minimum 20-gauge thick, galvanized, sheet steel; length to suit wall or floor application.

H. Blade Position Indicator Switch: Provide blade position two-position indicator switch for remote monitoring of blade position.

I. Damper Actuator: Factory installed. 120 Volt, single phase, 60 hertz electric actuators unless otherwise indicated on the electrical Contract Drawings; actuator and linkage located out of air stream; Fail closed. Provide manufacturer’s re-settable fuse link and switch package.

2.16 PUMP CONTROLLER

A. General Requirements: Furnish a programmable logic controller (PLC) for installation in the cross passage no. 31 motor controller panel by the Section 26 29 13, Enclosed Motor and Lighting Controllers, for control and monitoring of the tunnel sump pump station. Identify the system as the Track Drainage Pump Control System. The PLC will be mounted in the motor controller panel as shown on the electrical Contract Drawings.

B. The Track Drainage Pump Control System shall include the stand-alone PLC equipment racks, sensors, operating software, operator training, installation labor, programming, warranty and all other necessary material and labor to provide a complete and workable sump pump control system. Verify PLC power and control interface included on the electrical Contract Drawings. Coordinate interface requirements with electrical Contractor.

C. Use stand-alone PLC controllers, microprocessor-based, with a minimum word size of 16 bits, multi-tasking, multi-user, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules. Controller size: Sufficient to fully meet the requirements
of this specification and Section 26 29 13 and with spare capacity and expandability features as described below.

D. Each PLC controller: Sufficient memory to support its operating system and databases including all required trending, communications, alarm management and manual override monitoring.

E. Each PLC controller: Support monitoring and control of the following types of points:

1. Analog Inputs (AI):
   a. 4-20 mA
   b. 0-50 mVdc
   c. 0-10 Vdc
   d. 100 ohm RTD’s

2. Digital Inputs (DI):
   a. Dry Contact Closure
   b. Pulse Accumulator
   c. Voltage Sensing

3. Digital Outputs (DO):
   a. Contact Closure (Interposing relays as required)

4. Analog Outputs (AO):
   a. 4-20 ma
   b. 0-10 Vdc

F. Each PLC controller: Minimum of two spare of each point type (analog inputs, digital inputs, analog outputs, digital outputs). Provide all processors, power supplies and communication controllers complete so that the implementation of a new point only requires the addition of the appropriate point input/output termination module and wiring. Provide sufficient internal memory for the specified control sequences and have at least 25 percent of the memory available for future use.

G. PLC controllers: Provide local LED status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device. Provide graduated intensity LED’s or analog indication of value for each analog output. Provide communications module capable of communicating all process data via Internet Protocol (IP) over Ethernet or via communication interface indicated on the electrical Contract Drawings.

H. PLC controllers: Provide at least two RS- 232C serial data communication ports for operation of operator I/O devices such as industry standard printers, operator terminals, modems and portable laptop operator’s terminals.

I. The PLC controller: Continuously perform self-diagnostics, communication diagnosis and diagnosis of all associated panel components, and provide local annunciation of any detected component failures or low battery conditions.
J. Provide a flat-panel operator interface terminal mounted on the front of the motor controller panel and connected to the enclosed PLC processor. Furnish terminal with color pixel-based graphics and functionality to dynamically display and modify all process parameters being monitored by the PLC processor. Provide all necessary programming to display process equipment and all associated controlled and monitored process variables including annunciation of alarm conditions. For operator interface terminal use Allen-Bradley Panel View 600 Color, or equal.

K. The Track Drainage Pump Control System: Integrated into the Field Control System. Terminate interface wiring from pump control system located in the motor controller panel to an interface terminal strip as indicated on the electrical Contract Drawings. Pump control panel and Interface Terminal Cabinet are located at Cross Passage No. 31 as shown on the drawings. See the sequence of operation in Part 1 of this Section for interface requirements from the Track Drainage Pump Control System to the Interface Terminal Cabinet.

L. Provide all necessary programming development software and control logic configurations as an integral part of the PLC controllers configure such that they are not dependent upon any higher level computer for execution. All programs: Executed automatically without the need for operator intervention, and flexible enough to allow user customization. Programming logic and configuration: Applied to tunnel equipment as described in Part 3, Execution, herein.

M. Pump Controller: Allen-Bradley Control Logix 1756 or approved equal.

2.17 LEVEL TRANSMITTER:
A. Solid-state, microprocessor-based, head pressure sensing, utilizing a variable capacitance transducer element suitable for continuously submerged operation.
B. Housing: Type 316 stainless steel
C. Sensors:
   1. Rated for operation at negative 40 degrees C to 80 degrees C.
   2. Loop powered
   3. Provide a 0 to 50 mVdc output signal in response to a field adjustable input span (0-30 pounds per square inch gage (psig) maximum).

2.18 FLOAT SWITCHES:
A. High density polyethylene float body
B. Approximately 4.5 inches in diameter
C. Mercury-to-electrode type tilt switch rated at 4.5 Amperes at 120 Volts AC.
D. Float: Permanently marked to identify contacts as normally open or normally closed.
E. Manufacturer: Anchor Scientific Inc. Type S or approved equal.
F. Supply with heavy-duty No. 18/2 type SO cable with synthetic rubber or PVC jacket.
   1. Cable: Long enough to reach track drainage pump control panel without any splices.
2.19 CONTROL WIRING:

A. In accordance with Section 26 05 25, Wire and Cable, and all applicable codes.

B. Ground equipment and devices in accordance with manufacturer's recommendations to prevent ground loops.

C. Control Wiring:
   1. 24 V Circuits: Insulated copper 18 AWG minimum, rated for 300 VAC service.
   2. 120 VAC: 14 AWG minimum, rated for 600 VAC service.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Piping
   1. In accordance with the general requirements for installation of pipelines and with the applicable requirements of ANSI/ASME B31.1, except as otherwise specified or as indicated. Installed piping on supports as indicated, provide additional supports as required by the applicable standards. Coat all flange bolts with anti-seize compound.

B. Pipe Laying and Jointing
   1. Clean pipe and fittings to free from fins and burrs. Before placing in position, clean pipe, fittings, valves, and accessories, and maintain in a clean condition.
   2. Provided equipment for lowering sections of pipe into position. Do not, under any circumstances, drop or dump pipe, fittings, valves, or any other water line material into the work area.
   3. Cut pipe accurately to measurements established at the site and work into place without springing or forcing. Replace pipe or fitting that does not allow sufficient space for installation of jointing material with one of acceptable dimensions.
   4. Provide anchors and support as indicated.
   5. Keep the wet well free of water until force main has been connected and pipe through floor closures have been completed.
   6. Seal open ends of pipe temporarily with plastic or wood end caps or bulkheads.
   7. Repair any erection damage to pipe lining in accordance with AWWA C104.
   8. Repair pipe coatings as recommended by pipe coating manufacturer's recommendations.

C. Flanged Joints
   1. Tighten flanged joints and flanged adapter joints. Avoid undue strain on flanges, valves, fittings, and other equipment and accessories. Align bolt holes for each flanged joint. Use full size bolts for the bolt holes. Do not use undersized bolts. Ensure adjoining flange faces are not out of parallel to such degree that the flanged joint cannot be made watertight without overstraining the flange.
Replace any flanged pipe or fitting whose dimensions do not allow connecting of a flanged joint as specified.

D. Grooved Pipe

1. Where grooved pipe is employed, perform as much grooving as possible in shop under controlled conditions. Make field grooves with equipment recommended by the manufacturer of the couplings. Where required to allow for alignment of piping systems, install pipe with end separation between straight pipe lengths of that listed for flexible radius cut grooves.

E. Valves

1. Install all valves in locations as indicated and in accordance with manufacturer's written instructions.

F. Hanger and Support

1. Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure or the tunnel structure.

2. Support piping at points as indicated with type of hanger indicated and elsewhere as required by the Contract Specifications and the referenced standards

3. Unless otherwise indicated in the Contract Drawings, space attachments within maximum piping span length indicated in MSS SP-69. Install additional supports at concentrated loads, including valves, flanges, guides, strainers, and expansion joints, and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms.

4. Vertical Piping: Support at floor and at not more than 10-foot intervals.

5. Horizontal Piping: Support as indicated. Support the 3-inch diameter cast iron drain line and all other lines smaller than 3 inches in diameter at a maximum spacing of 7 feet. Support cast iron drain with one hanger close to joint on the barrel

G. Pipe Sleeves

1. Provide pipe sleeves where piping passes through walls or ceilings.

2. Determine the required inside diameter of each individual wall opening or sleeve before ordering, fabricating or installing any pipe or sleeve. Size the inside diameter of each wall opening as recommended by the manufacturer to fit the pipe to wall sleeve closure, to ensure a watertight joint. Sizing may be obtained through manufacturer’s catalog.

3. Secure sleeves in proper position and location during construction. Provide sleeves of sufficient length to pass through entire thickness of walls or roofs. Install sleeves in locations as indicated and in locations necessary to install piping.

H. Anchorage

1. Provide anchorage for fastening work securely in place. Set anchors in concrete as the work progresses and space as indicated. If anchors are needed, but not indicated, obtain approval for sizes, types, and spacing of anchors from the Resident Engineer prior to installation. Anchorage not otherwise specified or indicated includes slotted/embedded inserts, expansion shields, drop-in-anchors;
toggle bolts and through bolts for masonry; machine and carriage bolts for steel; through bolts and lag bolts. Provide inserts of suitable and approved types where required for support or anchorage of equipment and finish construction.

a. Inserts: stainless steel unless indicated or specified otherwise
b. Slotted inserts: 12 gauge stainless steel of types required to engage with anchors
c. Anchors and anchor bolts in walls: stainless steel conforming to ASTM A276 or ASTM A493, AISI Type 316 conforming to ASTM F594, AISI Type 316 with stainless nuts. Use stainless steel lock washers under all nuts.

I. Pipe to Wall Penetration Closure

1. Install pipe to wall penetration closure in accordance with manufacturer's written instructions. Bolt heads for wall closures must be inside the pump station, bolt heads for floor closures must be on the inside of the sump.

J. Access Hatches and Covers:

1. Comply with manufacturer's written instructions for installing access doors and frames.
2. Set frames accurately in position with plane of top surface aligned with adjacent finish surfaces.

K. Fire Smoke Dampers

1. Install combination fire/smoke, fire and smoke dampers according to manufacturer's UL-approved written instructions and coordinate with electrical for operation and monitoring requirements.

3.02 LEVEL SENSORS:

A. Install float switches and level transducer per manufacturers installation instructions.

B. Adjust level transmitter and float switches to actuate at levels indicated by temporary pump supplier.

3.03 PLC PROGRAMMING

A. Provide design, programming and graphics generation for PLC control of temporary drainage pumps at Cross Passage no. 31:

1. Provide programming to meet sequence of operation for temporary pumps including the analog inputs for water level from the level transmitter, digital input from float switches
2. Alarm Points: Digital alarm input from float switches for high or low water level shall initiate an alarm.
3. Provide all dynamic graphic display at operator interface terminal.

3.04 FIELD QUALITY CONTROL

A. Hydrostatic Test

1. Pressure Piping:
a. As a minimum, meet the requirements of ANSI B31.1 unless more stringent requirements are indicated herein.

b. Use testing instruments calibrated by a qualified laboratory in accordance with Section 01 45 00.20, Quality Assurance / Quality Control.

c. Provide and dispose of all water necessary for testing. Refer to Section 01 57 24, Temporary Site Water Discharge, for testing water disposal requirements.

2. Ductile Iron Piping:

a. Fit ends of piping being tested with test plugs, caps or blind flanges with a tap of adequate diameter to fill and pressurize the system with water.

   1) Test plugs or caps or blind flanges: Capable of withstanding an internal pressure of 150 psi.

b. Remove any instruments or other items that may be damaged by the test pressure.

c. Fill all piping with water and expel all air from the piping. Tap the piping at high points, if necessary, to release all air from the piping.

d. Apply 30 psi for 8 consecutive hours to allow the cement lining to absorb moisture. Add water as required to make up loss.

3. Ductile Iron Piping and Stainless Steel Force Main Riser to Surface:

a. Test piping at a static pressure of 120 psi over a period of not less than 4 consecutive hours.

b. Considered the test successful when the pressure drop over the test period is 5 psi or less.

c. Repair all leaks and repeat the test until the pressure drop over the test period is 5 pounds per square inch or less.

d. Remove all test equipment and plug all test holes at completion of test. Replace plugs watertight.

B. PLC Testing

1. Demonstrate compliance with sequence of operation and the Contract Drawings. Calibrate instrumentation and controls and verify the specified accuracy using calibrated test equipment. Adjust controls and equipment to operate temporary pumps to meet the sequence of operation. Furnish personnel, equipment, instrumentation, and supplies necessary to perform calibration and site testing. Ensure that tests are performed by competent employees of the PLC system installer or the system manufacturer’s representative regularly employed in the testing and calibration of such systems. Submit a report detailing the results of all performance, functional, and diagnostic tests and calibrations to the Engineer for final system acceptance.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing a well casing and pump station force main piping from Cross Passage No. 31 to the private manhole MH-2 indicated on the Contract Drawings.

B. This Section includes the following:
   1. Rotary drilled, reverse-rotary drilled, or air-rotary drilled well and casing.
   2. Force main piping.

C. Related Sections: The work of the following Sections is related to the work of this Section.
   1. Section 01 57 13, Temporary Erosion and Sediment Control.
   2. Section 01 57 15, Temporary Construction Noise and Vibration Control.
   3. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.
   4. Section 31 20 00, Earth Moving.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

   1. American Society for Testing and Materials (ASTM)
      a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
      b. ASTM A182 Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
      c. ASTM A312 Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
      d. ASTM A403 Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
      e. ASTM A778 Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products
      f. ASTM C33 Standard Specification for Concrete Aggregates
      g. ASTM C150 Standard Specification for Portland Cement

   2. American Society of Mechanical Engineers (ASME)
a. Boiler and Pressure Vessel Code, Section IX: Welding and Brazing Qualifications

3. American Water Works Association (AWWA)
   a. AWWA A100 Standard for Water Wells

4. American Welding Society (AWS)
   a. AWS B2.1 Standard Welding Procedure Specification
   b. AWS D10.4-86, Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing

5. Washington Administrative Code (WAC)
   a. Title 173 WAC

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data:
   1. Indicate the maximum allowable operating pressure and temperature of each component and any related manufacturing standard.
   2. For pipe and fittings.

C. Submit work plan including the drilling method,

D. Shop Drawings: Show layout and connections of casing and force main piping from Cross Passage 31 to manhole MH-2.

E. Project Record Documents: Record the following data for pump station casing and force main:
   a. Casings: Material, diameter, thickness, weight per foot of length, and depth below grade.
   b. Log: Formation log indicating strata encountered.
   c. Alignment: Certification that well casing is aligned and plumb within specified tolerances.

F. Field quality-control reports, including the following:
   1. Substrata formations.
   2. Performance test data.

1.04 QUALITY ASSURANCE

A. Well Driller Qualifications: An experienced water supply well driller licensed in the State of Washington.

B. Comply with Washington Administrative Code (WAC) Title 173 for well casing requirements.
C. Qualify welding processes and welder performance in accordance with AWS B2.2 or ASME Boiler and Pressure Vessel Code, Section IX.

1. Certify that each welder has satisfactorily passed AWS or ASME qualification tests for welding processes involved and, if pertinent, has undergone recertification.

2. Certification of procedures and operators applies for both shop and job site welding of pipe work.

D. Welding procedures shall address cleaning, joint clearance, overlaps, internal purge gas, purge gas flow rate, and filler metal.

1.05 DESCRIPTION OF WELL SITE

A. The Contractor shall drill and install the casing pipe at the location shown on the Contract Drawings.

B. Refer to the Geotechnical Baseline Report.

1.06 PROJECT CONDITIONS

A. Well Drilling Water: Provide temporary water and piping for drilling purposes. Provide necessary piping for water supply.

B. Noise Control: Refer to Section 01 57 16, Temporary Construction Noise and Vibration Control.

C. Allowable Work Times: Refer to Section 01 57 16, Temporary Construction Noise and Vibration Control.

D. Plumbness and Alignment: The completed well and casing shall be drilled in such vertical alignment that a line drawn from the center of the well casing at ground surface to the center of the well casing 150 feet below the ground surface shall not deviate from the vertical more than 6 inches in 100 feet of length.

1.07 PERMITS AND LICENSES

A. The Contractor shall, at his own expense, procure all permits, certificates and licenses required by law for the execution of his work. The Contractor shall comply with all federal, state, and local laws, ordinances, rules, and regulations relating to the performance of the work.

PART 2 - PRODUCTS

2.01 WELL CASINGS

A. Stainless Steel Casing: ASTM A778, 0.25-inch wall, 316L stainless steel pipe, welded joints.

2.02 FORCE MAIN LINER PIPING

A. ASTM A312, Schedule 40, seamless stainless steel, type 304L pipe with ASTM A403, Gr. WP304, butt-weld fittings.

B. Use ASTM A182, Gr. F304, 150 pound flanges with 1/16-inch raised face, serrated face finish and weld neck pattern.
2.03 GROUT
   A. Cement: ASTM C150, Type II.
   B. Aggregates: ASTM C33, fine and coarse grades.
   C. Water: Potable.

2.04 PACK MATERIALS
   A. Coarse, uniformly graded filter sand, maximum 1/8 inch in diameter.

PART 3 - EXECUTION
3.01 PREPARATION
3.02 INSTALLATION
   A. Take samples of substrata formation at 10-foot intervals and at changes in formation throughout entire depth of the well. Carefully preserve samples on-site in glass jars properly labeled for identification.
   B. Rotary Drilled Well: Excavate for mud pit or provide above ground structure, acceptable to Washington State Department of Ecology to allow settlement of cuttings and circulation of drill fluids back to well without discharging to on-site waterways.
   C. Enlarge pilot hole and install permanent casing and grout.
   D. Set casing and liners round, plumb, and true to line.
   E. Join casing pipe as follows:
      1. Ream ends of pipe and remove burrs.
      2. Remove scale, slag, dirt, and debris from inside and outside casing before installation.
      3. Weld joints.
   F. Capture and dispose of any drilling fluid that enters the cross passage.
   G. Mix grout in proportions of 1 cubic foot or a 94-pound sack of cement with 5 to 6 gallons of water. Bentonite clay may be added in amounts of 3 to 5 pounds per cubic foot for a 94-pound sack of cement. If bentonite clay is added, water may be increased to 6.5 gallons per cubic foot of cement.
   H. Perform grouting operation between the casing and force main pipe in two phases. In the first phase, place a suitable temporary sealing material between the casing pipe and the force main pipe to provide a waterproof seal. Place no more than 10 feet of grout in the annulus and allow the grout to harden a minimum of 72 hours. After the initial grout has hardened, fill the remaining annular space in one operation. Care should be taken to monitor that no grout enters the tunnel during initial or final grouting of the annular space. Do not perform other operations in the well within 72 hours after final grouting of the casing. If quick setting cement is used, the wait period between grouting phases and the final grouting and other operations may be reduced to 24 hours.
3.03 JOINTS

A. Welded Joints: Weld joints between sections of pipe and between pipe and fittings using either gas or electric welding equipment. Stainless steel welding shall conform to ANSI/AWS B2.1.005. All pipe surfaces shall be thoroughly cleaned before welding. Each joint, except socket-weld joints, shall be beveled before being welded. The Contractor shall provide a non-flammable mat or blanket to protect adjacent property and adequate fire protection equipment at all locations where welding is done. All elbows shall be long radius where space conditions allow. The use of fittings formed from welded pipe sections will not be permitted.

3.04 CONNECTIONS

A. Piping Installation: Contract Drawings indicate general arrangement of piping, fittings, and specialties.


3.05 COMMISSIONING

A. Perform all testing in accordance with Contract Documents: Refer to Section 01 91 00 Commissioning.

3.06 FIELD QUALITY CONTROL

A. Perform tests and inspections and prepare test reports.

B. Tests and Inspections:

1. Plumbness and Alignment Testing: Comply with AWWA A100 and the following:

   a. Alignment shall be tested by lowering into the well to a depth of at least 150 feet a 40-foot long section of 8-inch PVC pipe.

C. All piping, equipment, and accessories installed under this Contract shall be inspected and tested by the Contractor in the presence of the Resident Engineer, and approved before acceptance. The Contractor shall furnish all labor, material, and equipment required for testing. The Contractor shall be responsible for all repairs and retesting as required. All instruments and other equipment whose safe pressure range is below that of the test pressure shall be removed from the line or blanked off before applying the tests.

D. Hydrostatic Tests

1. Perform pressure tests for force main piping in accordance with the Field Quality Control requirements in Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes general specifications applicable to Division 26, Electrical, wiring devices, disconnect switches, fuses, and control relays.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 50 00, Temporary Facilities and Controls.
2. Section 01 51 15, Temporary Electrical Power.
3. Section 01 60 00, Product Requirements.
4. Section 01 77 00, Closeout Procedures.
5. Section 01 78 39, As-Built Drawings.
6. Division 26, Electrical.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE C2 National Electrical Safety Code (also an ANSI Standard)

2. International Conference of Building Officials:
   a. International Building Code (IBC)

3. National Electrical Contractors Association
   a. NECA 1 Standard Practices for Good Workmanship in Electrical Construction

4. National Electrical Manufacturers Association (NEMA):
   a. NEMA KS 1 Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)
   b. NEMA WD 1 General Requirements for Wiring Devices
   c. NEMA WD 5 Specific-Purpose Wiring Devices
   d. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

5. National Fire Protection Association (NFPA):
a. NFPA 70 National Electrical Code
b. NFPA 130 Fixed Guideway Transit and Passenger Rail Systems

6. Underwriters Laboratories (UL):
   a. UL 198E Class R Fuses

   a. 19.27 RCW Washington State Building Code
   b. 19.28 RCW Electricians and Electrical Installations

   b. 296-46 WAC Safety Standards – Installing Electric Wires and Equipment – Administrative Rules


1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. List of Materials: Submit a list of materials and equipment proposed for use. Give name of manufacturer, brand name, and catalog number of each item. Submit the list complete at one time, with items arranged and identified in numerical sequence by Specifications Section and Article numbers.

C. Compliance with Applicable Standards:

1. Where equipment or materials are specified to conform to the standards of organizations such as ANSI, ASTM, IEEE, and NEMA, submit evidence of such conformance for review and record purposes.

2. The label and listing of the specified agency will be acceptable evidence.

3. Instead of the label or listing, the Contractor may submit a written certificate from an approved, nationally recognized testing organization, adequately equipped and competent to perform such services, stating that the items have been tested and that the units conform to the specified standard provided the certification is approved by the authority having jurisdiction.


D. Factory Test and Inspection Certification:

1. Where factory tests and inspections for materials and equipment specified in referenced documents are waived, provide certified copies of reports for tests performed on previously manufactured identical materials or equipment within the previous 12 months.

2. Accompany test reports by signed statements from the manufacturer certifying that the previously tested material or equipment is physically, mechanically, and
electrically identical to that proposed for the Project. Include wiring and control diagrams.

E. Shop Drawings showing equipment layouts and fabricated work being provided under these Specifications. Submit such drawings before rough-in work, fabrication, and within ample time to prevent delays in the work. Include electrical diagrams for equipment and equipment installation.

F. Certified Field Test Reports of field tests, verifying compliance of equipment and systems with Specification requirements.

G. Operation and Maintenance Manuals and instructions and data for equipment provided under this Division, in accordance with the requirements of Section 01 78 23, Operation and Maintenance Data. Include recommended maintenance materials and spare parts list for installed equipment.

1.04 QUALITY ASSURANCE

A. Qualifications: Workers performing shall meet the qualification and licensing requirements of Chapter 19.28 RCW (Electricians and Electrical Installations).

B. Perform work in compliance with the following industry standards and regulations.

1. NFPA 70 National Electrical Code.
2. NECA 1, Standard Practices for Good Workmanship in Electrical Construction.
4. State of Washington Business Regulations and Administrative Codes:
   a. Chapter 19.27 RCW
   b. Chapter 19.28 RCW
   c. Chapter 51-40 WAC
   d. Chapter 296-46 WAC
5. Relevant amendments to Washington State regulations and codes adopted by local jurisdictions.

1.05 COORDINATION

A. Coordinate any items that effect any existing University of Washington system with UW facilities department.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General

1. Furnish materials and equipment of design, sizes, and ratings as indicated and suitable for the intended purpose.
2. Furnish materials and equipment acceptable to the authority having jurisdiction bearing label or classification listing of a nationally-recognized testing laboratory where product labeling or listing is available.

3. Methods of fabrication, assembly, and installation are optional unless otherwise indicated.

4. Provide products that are free from defects, which may impair performance, durability, or appearance.

5. For tunnel installation, use materials including exposed raceways, boxes, cabinets, luminaires, equipment enclosures, and their surface finish material which are capable of being subjected to temperatures up to 932 degrees F for 1 hour and do not support combustion as required by NFPA 130.

B. Receptacles

1. Receptacle Standards: Connector and outlet receptacles shall conform to NEMA WD 1, heavy-duty general use type.

2. Convenience Receptacles:
   a. Provide receptacles with fire-resistant, nonabsorptive, hot-molded phenolic composition bodies and bases and with metal plaster ears integral with supporting member.
   b. Use receptacles that are 20R configuration, single- or duplex-type as indicated. Use receptacles that are back- and side-wired with screw or combination screw-clamp terminals.
   c. For contacts of the receptacles, including the grounding contact, use double-grip bronze type with spring steel backup clips so that both sides of each male prong of the plug will be in firm contact.

3. Ground Fault Circuit Interrupter (GFCI) Receptacles: For ground fault circuit interrupter (GFCI) duplex receptacles use 120 V, 60 Hertz, 20 A with built-in test, reset buttons, and ground fault tripped indication that interrupts the circuit within 1/30 second on a 5 milliampere earth leakage current. Use GFCIs designed for end of run installation or with provisions for feeding through to protect other outlets on a 20 A Circuit. Furnish receptacles with necessary wire connectors, clips, mounting screws, and instructions.

C. Cover Plates

1. Provide multi-gang plates where required. Segmented cover plates are not acceptable.

2. Finished area device covers: brushed, stainless steel, 0.040-inch thickness.


4. For special purpose outlets, provide plates of brushed stainless steel and of a design for the particular application.

5. Weatherproof cover plates: die-cast, copper-free aluminum listed for wet locations with self-closing spring door and rubber gasket. Provide accessories for locking cover with a padlock.

D. Disconnect Switches
1. Provide enclosed, heavy-duty safety switches, conforming to NEMA KS 1.

2. Heavy-duty Safety Switches (600 V AC):
   a. Provide switches having electrical characteristics, ratings, and accessories as required or as indicated. Provide fuse rejection devices either factory-installed or field-installed.
   b. Tunnel, cross-passages and areas exposed to weather: Provide NEMA 250 Type 4X, stainless steel enclosures.
   c. General Locations: Provide NEMA 250 Type 12 industrial duty enclosures.
   d. Provide handle with visible blades; reinforced fuse clips; nonteasible, positive, quick-make, quick-break mechanism; and padlockable in the OFF and ON positions.

E. Individual Control Relays

1. Use control relays which have convertible contacts rated a minimum of 10 A, 600 V. Verify coil voltage, and number and type of contacts. Provide NEMA 250 Type 1 enclosures.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install products in accordance with product listings, manufacturer’s recommendations, relevant codes and regulations, and standard industry practice for electrical installations.

B. Install electrical materials, equipment, appurtenances, and accessories in locations as indicated, in accordance with NECA 1, to provide a complete and operable system. Do not weld electrical materials for attachment or support.

C. Provide anchor bolts and anchorage items as required, and field check to ensure proper alignment and location. Provide templates, layout drawings, and supervision at the jobsite to ensure correct placing of anchorage items in concrete. Check embedded items for correctness of location and detail before concrete is placed.

D. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, and angles as required to set and connect the work rigidly.


F. Electrical equipment: Conform to IBC Section 1621, Architectural, Mechanical, and Electrical Component Seismic Design Requirements.

G. Control erection tolerance requirements so as to not impair the strength, safety, serviceability, or appearance of the installations.

H. Install switches, receptacles, special purpose outlets, and cover plates complete in accordance with NECA 1, the National Electrical Code, and local electrical codes.

I. Seal equipment enclosures against dust, whenever dusty conditions are present inside the rooms or outside, during the construction period.

J. Wiring
1. Provide wiring systems complete as indicated and required for proper service.

2. Provide ample slack wire for motor loops, service connections, and extensions.

3. In outlet or junction boxes provided for installation of equipment by others, tape ends of wires and install blank covers.

K. Wiring Devices and Cover Plates

1. Locate wiring devices at heights in accordance with NECA 1, except as otherwise indicated.

2. For exterior and damp locations including passenger stations, mount receptacles in watertight cast metal outlet boxes with threaded hubs or bosses and provide with weatherproof cover plate.

3. Provide water-tight, locking-type male plugs protected by a ground-fault circuit interrupter for equipment subject to spray or hose cleaning.

4. Provide GFCI duplex receptacles in public areas and trainways.

5. Provide cover plates for each switch, receptacle, and special purpose outlet.

6. Provide brushed stainless steel cover plates in finished areas.

7. Provide galvanized steel cover plates in ancillary spaces, mechanical rooms, fan rooms, electrical closets, electrical rooms, traction power substations, and unfinished areas.

3.02 INTERFACE WITH OTHER WORK

A. Coordinate the work of this Section with the other Specification Sections of this Division 26, Electrical, as required to provide a complete and operable electrical installation.

B. Coordinate electrical services and work with the serving utility company and Sound Transit, as applicable.

C. Coordinate with work completed or in progress or to be performed under other Sections of these Specifications or by other contractors. Make indicated connections to previously completed work. Where future connections to or extensions of the work are indicated, provide safe and convenient provisions for such future connections and extensions.

D. Contract Drawings show electrical equipment, ductbanks, raceways, and other electrical facilities diagrammatically and do not show all accessories or fittings that are required because of obstructing structural features and architectural finishes, interfering utilities, ducts, and mechanical equipment. Investigate such conditions and determine the need for locating equipment and materials and routing electrical raceways clear of such obstructions and interferences. Provide complete and operable electrical systems and installations in conformance with these Specifications.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing low voltage copper wires and cables, wiring connections, and terminations. All wires with insulation level 600 V and below which includes power, control, instrumentation, and for grounding purposes are included in this section.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

Section 01 78 23, Operation and Maintenance Data.

Section 26 05 00, Common Work Results for Electrical.

Section 26 05 26, Grounding and Bonding for Electrical Systems.

Section 26 05 33, Raceway and Boxes for Electrical Systems.

Section 26 05 53, Identification for Electrical Systems.

Section 26 08 00, Commissioning of Electrical Systems.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

   a. ASTM B3 Specification for Soft or Annealed Copper Wire
   b. ASTM D1000 Test Methods for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications
   c. ASTM D1518 Test Method for Thermal Transmittance of Textile Materials
   d. ASTM D3005 Specification for Low-Temperature Resistant Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape
   e. ASTM D5034 Breaking Force and Elongation of Textiles Fabrics (Grab Test)

2. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE 383 Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations

3. National Electrical Contractors Association
a. NECA 1 Standard Practices for Good Workmanship in Electrical Contracting

4. National Electrical Manufacturers Association (NEMA):
   a. NEMA WC 70 Non-Shielded Power Cable 2000 V or Less

5. National Fire Protection Association (NFPA)
   a. NFPA 70 National Electrical Code
   b. NFPA 130 Fixed Guideway Transit and Passenger Rail Systems

1.03 SUBMITTALS
   
   A. Procedures: Section 01 33 00, Submittal Procedures.
   
   B. Before installation of wire and cable, submit the following information for each type and size of wire and cable:
      
      1. Manufacturer of wire and cable, and certificate of compliance;
      2. Number and size of strands composing each conductor;
      3. Average overall diameter of finished wire and cable;
      4. Minimum insulation resistance in megohms per 1000 feet at 30 degrees C ambient;
      5. Jacket composition and thickness in mils;
      6. Total number of conductors per cable;
      7. Shield material, if any, and thickness;
      8. Conductor resistance and reactance in ohms per 1000 feet at 25 degrees C ambient; and
      9. Conductor ampacity at 30 degrees C ambient for 600 volt (V) wire and cable.
     10. Conductor overall diameter (OD) and weight per 1000 feet of cable.

1.04 DELIVERY, STORAGE, AND HANDLING
   
   A. Ship each unit securely wrapped, packaged, and labeled for safe handling in shipment and to avoid damage.
   
   B. Store wire and cable in secure and dry storage facility, in accordance with NECA 1.

1.05 WARRANTY
   
   A. Submit manufacturer's standard warranty.

PART 2 - PRODUCTS

2.01 MATERIALS
   
   A. Wire and Cable Markings
1. Verify that wire and cable markings are in accordance with applicable NEMA and National Electrical Code requirements.

B. 600 Volts Single Conductor Cable

1. Conductor Material: ICEA stranded or solid copper meeting requirements of ASTM B3, soft drawn.

2. Conductor Type:
   a. No. 12 American Wire Gauge (AWG) and Smaller: Solid conductor.
   b. No. 10 AWG and Larger: Class B stranded.
   c. No. 14 to 1/0 AWG: Type XHHW-2, cross-linked polyethylene insulated in accordance with NEMA WC 70.
   d. No. 2/0 AWG and Larger: Type XHHW-2, cross-linked polyethylene insulated in accordance with NEMA WC 70 or type RHH/RHW, ethylene-propylene-rubber-insulated in accordance with NEMA WC 70.

3. Temperature Rating: Use cables temperature rated not less than 75 degrees C.

4. Fire-Retardant Properties:
   a. Power cable for emergency fans and related equipment and all tunnel lighting cables shall meet the flame propagating criteria of IEEE 383, the requirements of NFPA 130, and have a minimum circuit time of five minutes in the flame test of IEEE 383. The listed cable system shall have a minimum 1-hour fire-resistive rating in accordance with UL 2196.
   b. Fire ventilation fans cabling shall meet high temperature rating in accordance with applicable NFPA 130 requirements.
   c. Provide type test certificate for every shipment of cables.

5. Insulation Rating: 600 V.

C. Multiple Conductor, Low-Voltage Cable

1. Provide multiple conductor cable conforming to NEMA WC 70, approved for use in cable tray, with the following additional requirements:
   a. Number of Insulated Conductors: As indicated.
   b. Provide multiple conductor cable for all power applications, except receptacles when installed in cable tray for sizes up to No. 4/0 AWG, as indicated.
   c. Insulation: As specified above for single conductor cable.
   d. Overall Covering: Jacket cable over the insulation.
   e. Multiple conductor for control wire use minimum of No. 14 AWG stranded copper.
   f. Insulation Rating: 600 V.
2. Make multi-conductor cable by assembling individual or twisted pairs of insulated conductors into a tight cylindrical form using fillers that are compatible with other materials in the cable. Use the jacket to fit tightly to form a firm assembly.

D. Fixture Wire
   1. Provide fixture wire conforming to the following requirements:
      a. Type: SF-2 silicone rubber insulated.
      b. Conductor: Stranded copper conductor No. 16 AWG or larger as indicated.

E. Bare Conductor
   1. Use ASTM B3, Class B stranded, annealed soft-drawn copper conductor unless otherwise indicated. Size as indicated. Use bare conductor for ground wire only and as specified in Section 26 05 26.

F. Color Coding of Conductors (600 V)
   1. Identify individual conductors of multi-conductor cables by means of solid colors, stripes, or printing, unless otherwise approved by the Resident Engineer.
      a. Jacket Printing: Use cables which have printing on the jacket or a printed marker tape under the jacket. Verify that jacket printing includes, but is not be limited to, the number of conductors, conductor size, voltage rating, name of manufacturer, manufacturer's type, and date of manufacture; and that this information appears at intervals of not more than 30 inches.
      b. Footage Marker Tape: Provide cables with a footage marker tape under the jacket or hot-foil footage printing on the jacket.
      c. Power Cables: Conform to the following color coding for power cables:

<table>
<thead>
<tr>
<th>Conductor</th>
<th>480Y/277 V</th>
<th>208Y/120 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase A</td>
<td>Brown</td>
<td>Black</td>
</tr>
<tr>
<td>Phase B</td>
<td>Orange</td>
<td>Red</td>
</tr>
<tr>
<td>Phase C</td>
<td>Yellow</td>
<td>Blue</td>
</tr>
<tr>
<td>Neutral</td>
<td>Gray</td>
<td>White</td>
</tr>
<tr>
<td>Ground</td>
<td>Green</td>
<td>Green</td>
</tr>
</tbody>
</table>

2. Use solid color insulation or solid color coating for branch circuit phase conductors No. 10 AWG and smaller and all neutral and equipment ground conductors.

3. Use a background color other than white or green for phase conductors with colored tracers.

4. For solid color coatings and tracers, use a strongly adherent paint or dye not injurious to the insulation which will not be obliterated by pulling into a conduit or raceway.
5. Resident Engineer may permit on-site coloring of ends of conductor upon receipt of satisfactory evidence that the Contractor is unable to order color-coded wire and cable as specified. Provide certification from the cable manufacturer that the paint or dye proposed for field application is non-injurious to the insulation.

G. Connectors and Insulating Tapes

1. Splice and Terminal Connectors:
   a. Provide termination fittings listed for use with the cable furnished, NEMA standard.
   b. For termination and splice fittings on No. 10 and smaller conductors use compression type or insulated, expanding-spring type. Make wire splices either self-insulating or provided with an insulating cap or heat-shrink insulating sleeve.
   c. For termination and splice fittings on No. 8 and larger conductors use tool-applied compression connectors of material and design compatible with the conductors for which they are used.
   d. For terminal connectors on conductors size No. 4/0 and larger use long-barrel, double-compression type, and furnish with two NEMA standard bolt holes in the tongue.

2. Insulating Material for Splices and Terminations:
   a. Provide insulating material for splices and terminations of type accepted by the Resident Engineer for the particular use, location, and voltage.
   b. For general use electrical insulating tape use vinyl plastic with rubber based pressure sensitive adhesive, which is pliable from temperatures of minus 18 degrees C to 105 degrees C. Verify the tape has the following minimum properties when tested in accordance with ASTM D3005:
      1) Thickness: 7 mils.
      2) Breaking Strength: 15 pounds per inch.
      3) Elongation: 200 percent.
      4) Dielectric Strength: 10 kV/millimeters.
      5) Insulation Resistance (Direct method of electrolytic corrosion): 10 Mega-ohms
   c. For rubber electrical insulating tape for protective over-wrapping use silicone rubber with a silicone pressure-sensitive adhesive. Verify the tape has the following minimum properties when tested in accordance with ASTM D1000:
      1) Elongation: 525 percent.
      2) Dielectric Strength: 13 kilovolts (kV).
      3) Insulation Resistance (Indirect Method of Electrolytic Corrosion): 10 (Mega-ohms)

H. Conductor Bundling Straps
1. Provide conductor bundling straps formed from self-extinguishing nylon having a temperature range of negative 40 degrees F to 185 degrees F.

2. Equip each strap with a locking hub or head with a stainless steel locking barb on one end and a taper on the other end.

3. Ensure all wire and cable ties installed outdoors and in exposed locations are made of ultraviolet-resistant material.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Coordinate installation of wires and cables with the requirements of Section 26 05 00 Common Work Results for Electrical, Section 26 05 33 Raceway and Boxes for Electrical Systems, Section 26 05 26 Grounding and Bonding for Electrical Systems and Section 26 05 53 Identification for Electrical Systems.

B. Furnish wires and cables to the site in unbroken standard coils or reels upon which a tag is attached bearing the manufacturer's name, trade name of the wire, and listing information.

C. Complete wiring as indicated. Provide ample slack for field terminated wires and preformed cables with connections, including wires for motor loops, service connections, and extensions. In outlet or junction boxes provided for installation of equipment by others, tape ends of wires and install blank covers.

D. Do not bend cables during installation, either permanently or temporarily, to radii less than twelve times the outer diameters, except where conditions make the specified radius impractical and shorter radii are permitted by the manufacturer.

E. Bundle cable and conductors neatly and securely with nylon straps in branch circuit panelboards, cabinets, control boards, and motor control centers. Bundle power cables separately from control cables.

F. Install motor feeders, service connections, and extensions in accordance with the referenced codes. Install motor feeder in liquid-tight flexible conduit of 18 inches minimum length at motor conduit box.

G. For wire pulling, comply with NECA 1 and the following:

1. Install wire and cable in conduit as indicated. Do not use block and tackle or other mechanical means for pulling conductors smaller than No. 2 AWG in raceways.

2. Provide suitable installation equipment to prevent cutting and abrasion of conduits and wire during the pulling of feeders. Use lubricant and installation procedure as recommended by the cable manufacturer.

3. Do not exceed the manufacturer’s recommended pulling tension. For conduit runs with three bends, and cable sized larger than No. 2 AWG, provide cable tension measuring equipment and record the highest cable tension. Notify Resident Engineer 48 hours prior to such pulling operations and adjust schedule as necessary to permit observation.

4. Provide masking or other means to prevent obliteration of cable identifications when solid color coating or colored tracers are used.
H. Power and Control Cable Installation in Manholes and Pullboxes: Route cables along the manhole or handhole walls providing the longest possible slack. Form cables closely parallel to the walls. Prevent cable interference with duct entrances, and support cables on brackets and cable insulators, spaced at a maximum of 4 feet. In existing manholes and handholes where new ducts are to be terminated or where new cables are to be installed, modify the existing locations of cables, cable supports, and grounding as required to provide a properly arranged and supported installation. Ensure minimum bending radius of the cables is not exceeded inside the manholes. Allow sufficient cable coil length based upon the design requirements. Perform dielectric test before performing continuity test. Provide cable identification markers inside the manholes and pull boxes when there are more than one circuit cables routed thru manholes and pull boxes.

I. Splices and Terminations:

1. Make wire and cable splices only in outlet, junction or pull boxes, or in equipment cabinets. Splice in multi-conductor cables in accordance with the cable and splice-kit manufacturers’ recommendations. Insulate splices to a level equal to that of the cable.

2. Use splice and terminator installation tools and installation techniques recommended by the manufacturer.

3. For conductor sizes through No. 6 AWG, use mechanical hand tools, with dies as recommended by the manufacturer.

4. For conductor sizes larger than No.6 AWG, use hydraulic tools with hexagonal or circumferential dies as recommended by the manufacturer.

5. Use compression tools which permanently imprint die information on the completed connection.

6. Use continuous lengths of wire and cable between power source and equipment. Where splices are required, make them only in approved fittings or junction boxes. Splices are subject to approval by the Resident Engineer. Follow manufacturer’s instructions in splicing wire and cable.

7. Fixture Wire: Make splices in lighting circuits with insulated crimp-type connectors.

8. Control Cables: Terminate each wire held with screw-type terminals using an insulated sleeve (nylon), ring-tongue-type or locking spade-type, crimp-on lugs.

3.02 FIELD QUALITY CONTROL

A. Inspect wire and cable for physical damage and proper connections.

B. Perform continuity test on power and equipment branch circuit conductors. Perform dielectric test before performing continuity test on all circuits after installation.

C. Verify phasing for circuits to three-phase loads.

D. Test for insulation resistance in accordance with Section 26 08 00, Commissioning of Electrical Systems.

1. Test after splices and terminations are complete. Do not connect equipment to the cable system during tests.

2. Acceptance Criteria for 600 V wire and cable: 10,000,000 ohms
3. Test Failure: In case insulation resistance values are unacceptable, correct deficiency and retest. If the test fails again, replace the entire wire or cable segment.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for power system grounding, electrical equipment and raceway grounding and bonding, and bonding of metallic objects near the trackway.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 00, Common Work Results for Electrical.
2. Section 26 05 25, Wire and Cable.
3. Section 26 05 33, Raceway and Boxes for Electrical Systems.
4. Section 26 08 00, Commissioning of Electrical Systems.
5. Section 26 24 16, Panelboards.
7. Section 26 29 13, Enclosed Motor and Lighting Controllers.
8. Section 26 51 14, Lighting Systems.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

   a. ASTM B3 Specification for Soft or Annealed Copper Wire
   b. ASTM B187 Specification for Copper Bar, Bus Bar, Rod and Shapes

2. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE 837 Qualifying Permanent Connections Used in Substation Grounding

3. Underwriters Laboratories Inc. (UL):
   a. UL467 Grounding and Bonding Equipment

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Shop Drawings: Where grounding system is not detailed on the Contract Drawings, submit shop drawings showing locations of ground rods, grounding connections, locations of embedded and buried grounding conductors and locations of stub outs and
pigtails for future connections to the grounding system by others. Indicate on drawings the locations of test points to measure grounding resistance.

C. Manufacturers' product data of grounding materials and coal-tar epoxy protective coating.

1.04 QUALITY ASSURANCE

A. Provide training for electricians involved in the selection, maintenance and operation of exothermic welding materials and equipment.

B. Resistance testing shall be performed by personnel trained in grounding system installation and testing.

1.05 DELIVERY, STORAGE AND HANDLING

A. Ship each item of equipment and materials securely wrapped, packaged, and labeled for safe handling in shipment and to avoid damage.

B. Store equipment and materials in secure and dry storage facility.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Ground Rods: Medium carbon steel core, copper-clad by the molten weld casting process, size of 3/4-inch diameter by 10 feet long or as indicated.

B. Bare Conductors: ASTM B3, Class B stranded, annealed copper conductor, unless otherwise indicated, size as indicated. Refer to Section 26 05 25 Wire and Cable.

C. Bus Bar: ASTM B187, 98 percent conductivity copper, size as indicated.

D. Single Conductor Insulated Wire: Refer to Section 26 05 25, Wire and Cable.

E. Terminal Lugs: Exothermically-welded or compression-type approved for the application.

F. Jumpers: Tin-plated copper, braided, flexible jumper.

G. Exothermic Welding System: Provide dual-component exothermic welding system with molds and accessories of a single manufacturer. Erico, Thermoweld, or approved equal.

H. Compression Connections: Provide connectors and compression tools from a single manufacturer. Use Connectors which have an inspection port for checking proper conductor insertion.

I. Compression Tools: For field quality control, use compression tools that emboss the die index number into the connector as the crimp is completed.

J. Coal Tar Epoxy Coating: Coal tar polyamide epoxy, high-build corrosion resistant coating. Tnemec Series 46H-413, High-build Tnemec-Tar or approved equal.

K. Provide markings on grounding wire, cable, and other grounding components in accordance with applicable standards. Each item shall be UL- Labeled where applicable.
PART 3 - EXECUTION

3.01 INSTALLATION

A. Coordinate installation of grounding and bonding with the requirements of Section 26 05 00 Common Work Results for Electrical Systems, Section 26 05 25 Wire and Cable, Section 26 05 33 Raceway and Boxes for Electrical Systems, Section 26 05 53 Identification for Electrical Systems, Section 26 24 16 Panelboards, Section 29 26 13 Enclosed Motor and Lighting Controllers and 26 51 14 Lighting Systems.

B. Ground Connections:

1. Buried or embedded connections: Exothermically welded or compression-type terminal lugs using materials qualified in accordance with IEEE 837. Do not bury or embed bolted connections.

2. Exposed connections: Exothermically welded or compression-type terminal lugs using materials qualified in accordance with IEEE 837. Make connections in accordance with the manufacturer’s instructions. Bolted connections are permitted only in secured locations not accessible to the public.

3. Make connections in accordance with the manufacturer’s requirements. Clean ferrous structures and piping and coat with a coal-tar epoxy for a distance of 6 inches from the grounding attachment point.

4. Do not bond buried metallic piping systems or structures to grounding electrode systems unless specifically directed.

5. Provide continuous ground conductor or splice using connections qualified in accordance with IEEE 837.

6. For connections from a grounding bus to grounding electrode system, provide a ground lug fastened with stainless steel bolts and locking hardware. Provide exothermically-welded or compression lug on grounding electrode conductor.

7. Provide waterstops on stranded, ground conductors where they enter a structure.

C. Ground Rods:

1. Bury ground rods vertically with top of rod a minimum of 12 inches below grade or as indicated. If extensive rock formation is encountered, relocate ground rods to a new location as approved by the Resident Engineer.

2. Interconnect ground rods with minimum No. 1 AWG stranded, bare copper cable or as indicated.

D. Station Electrical System Grounding Electrode

1. Provide ground ring with multiple ground rods or concrete-encased grounding electrode system. Unless otherwise indicated, bury conductors of the grounding ring in native fill not less than 36 inches below final grade.

2. Provide minimum No. 1 AWG stranded, bare copper conductor for grounding ring and concrete-encased electrode.

3. Measure grounding electrode resistance of the installed system and provide additional bonded ground rods as necessary to meet the maximum acceptable ground resistance as specified herein.

E. Communications and Train Control System Grounding Electrode
1. Provide two ground rods separated by 8 feet and bonded to communications and train control systems cabinets and bond to electrical system grounding electrode with number six insulated copper conductor. Isolated connections to structure reinforcing/ concrete-encased grounding electrode system are also acceptable.

2. Measure grounding electrode resistance of the installed system and add additional bonded ground rods as necessary to meet the maximum acceptable ground resistance as specified herein.

F. Equipment Grounding Requirements

1. Install insulated copper equipment-grounding conductor with phase conductors in each raceway and bond to metallic raceways and boxes at access and pull points.

2. Size equipment grounding conductors in accordance with the National Electrical Code to provide adequate conduction path for ground faults. Increase size as required to allow for circuit voltage drop.

3. Ground metallic raceways, boxes, cabinets, exposed expansion joints, lighting fixtures, motors, transformers, MCC and receptacles. Provide grounding bushings or compression connectors attached with machine screws for bonding.

G. Facility and Tunnel Bonding Requirements: Bond metallic objects within 15 feet of the track centerline to the station grounding electrode. This includes but is not limited to station and tunnel structures, equipment cabinets, handrails, fences, bollards, cable or chain barriers, and art objects. Do not make bonding connections below or above ground at an inconspicuous location on the object. Protect exposed connections and grounding conductor from damage and theft. Bond continuous metallic objects, such as fences, at a minimum, every 30 feet.

H. Trackway Bonding Requirements: Bond reinforced concrete rebar embedded in separate sections of the tunnel segments by grounding jumpers as indicated in systems grounding plan. Track rails shall not be used for temporary or permanent grounding.

3.02 FIELD QUALITY CONTROL

A. Test the installed grounding system in accordance with Section 26 08 00, Commissioning of Electrical Systems

B. Acceptance Criteria:

1. Station Grounding System: 10 ohms, maximum.

2. Equipment Grounding: Not to exceed 5 ohms

3. Communications and Train Control System Grounding Electrode: 5 ohms, maximum.

4. Traction Power Substation or Tie Station Grounding Electrode: 5 ohms, maximum.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing electrical raceways including conduit, ducts, outlet, junction and pull boxes, manholes, hand-holes and electrical cabinets.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 00, Common Work Results for Electrical.
2. Section 26 05 25, Wire and Cable.
3. Section 26 05 26, Grounding and Bonding for Electrical Systems.
4. Section 26 05 43, Underground Ducts and Raceways for Electrical Systems.
5. Section 26 05 53, Identification for Electrical Systems.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American National Standards Institute (ANSI):
   a. ANSI C80.1 Rigid Steel Conduit - Zinc Coated

   b. ASTM A153/A153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

3. National Electrical Contractors Association (NECA)
   a. NECA 1 Standard Practices for Good Workmanship in Electrical Contracting

4. National Electrical Manufacturers Association (NEMA):
   a. NEMA RN1 Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
   b. NEMA TC2 Electrical Polyvinyl Chloride (PVC) Tubing and Conduit
   c. NEMA TC3 PVC Fittings for Use with Rigid PVC Conduit and Tubing
   d. NEMA TC6 & 8 PBC Plastic Utilities Duct for Underground Installations
e. NEMA TC14 Reinforced Thermosetting Resin Conduit (RTRC) and Fittings
f. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

5. National Fire Protection Association (NFPA):
   a. NFPA 70 National Electrical Code
   b. NFPA 130 Fixed Guideway Transit and Passenger Rail Systems

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. List of Materials: Submit a list of materials proposed for use. Give name of manufacturer, brand name, and catalog number of each item. Submit the list complete at one time, with items arranged and identified in numerical sequence by Specifications Section and Article numbers.

C. Compliance with Applicable Standards:

1. Where equipment or materials are specified to conform to the standards of organizations such as NFPA, NECA, ANSI, ASTM and NEMA, submit evidence of conformance. The label or listing of the specified agency will be acceptable evidence.

2. Instead of the label or listing, the Contractor can also submit a written certificate from an approved, nationally recognized testing organization, stating that the items have been tested and that the units conform to the specified standard.

D. Shop Drawings:

1. Showing the exact location and arrangement of conduits, cabinets, and pullboxes installed under this Contract.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Conduit and Duct

1. Galvanized Rigid Steel (GRS) Conduit and Accessories: ANSI C80.1; hot-dip galvanized inside and out after threading; ensure each length bears UL label.

   a. Fittings and Accessories:

      1) Bushings: Nylon-insulated, metallic, grounding type.

      2) Conduit straps, clamps, and clamp backs: Galvanized malleable iron.

      3) Conduit Seals: Suitable for Class 1, Division 2, Group D hazard location.

      4) Conduit Outlet Bodies: Feraloy iron alloy electrogalvanized with aluminum acrylic paint or approved equal.
2. PVC-Coated GRS Conduit (PVC/GRS or PGRSC): NEMA RN1, with corrosion resistant internal coating.

3. Shipping: Thread protectors installed on both ends of conduit, with couplings packaged separately.

4. PVC Electrical Conduit and Fittings: NEMA TC2, EPC-40-PVC; heavy wall, high impact strength, rigid PVC.
   a. Fittings: NEM TC3, EPCA-40-PVC.

5. Plastic Utilities Duct: NEMA TC6 & 8, Schedule 20 type EB.

6. Epoxy and Phenolic Fiberglass Conduit and Fittings: NEMA TC14; standard-wall
   a. Conduit joints and fittings: Tapered or untapered; all of one type.

7. Innerduct
   a. Premanufactured multi-cell raceway assembly:
      1) Four 1.25-inch inside-diameter, pre-lubricated PVC innerducts pre-installed in each 4-inch, 10 or 20-foot outer ducts. Verify that individual innerducts meet the requirements for separate innerduct raceways below.
      2) Manufacturer’s standard product including necessary spacers, couplers and pre-manufactured ells.
      3) Acceptable manufacturer: Carlon Multi-Gard or approved equal.
   b. Separate innerduct raceways
      1) 1-inch inside diameter smooth- or longitudinal-ribbed-wall, flexible PVC or polyethylene tubing with 0.125-inch wall thickness.
      2) Suitable for pulling into conduit and provided with fittings necessary to make up a complete raceway system.
      3) Acceptable manufacturer: Carlon, Pyramid or approved equal.

8. Liquidtight Flexible Metallic Conduit and Fittings:
   a. Core: Flexible galvanized steel with a continuous copper bonding conductor spiral wound between the convolutions.
   b. Jacket: Extruded liquid-tight plastic or neoprene; moisture- and oil-proof, capable of conforming to the minimum radius bends of flexible conduit without cracking; self-extinguishing with low halogen containing material.
   c. Fittings: Zinc-coated.

9. Conduit Expansion Fittings:
   a. Factory installed packing ring, designed to prevent the entrance of moisture.
   b. Pressure ring.
c. Grounding ring or a grounding conductor for metallic expansion couplings.

d. Use fittings which maintain a constant inside diameter in every position and provide a smooth wireway for protection of wire insulation.

B. Galvanized Steel Field Coating

1. Organic cold galvanizing coating: minimum 95 percent metallic zinc by weight in dried film; manufactured by ZRC Products Company, or approved equal.

C. Oxide inhibiting joint compounds

1. Petroleum-based compound with evenly suspended zinc particles.

2. Burndy, Penetrox A, or approved equal.

D. Conduit Trapeze Hangers and Framing Channel

1. Hangers:

   a. Two or more steel hanger rods, a steel horizontal member, U-bolts, clamps, and other attachments as necessary for securing hanger rods, and conduits.

   b. Capable of supporting a load equal to the sum of the weights of the conduits and wires, the weight of the hanger itself, plus 200 pounds

2. Steel hanger rods: Galvanized, not smaller than 3/8-inch diameter, threaded either full length or for a sufficient distance at each end to permit at least 1-1/2 inches of adjustment

3. Horizontal member:

   a. Structural grade steel, 1-1/2 by 1-1/2 inches or 1-5/8 by 1-5/8 inches, 12 gage, cold-formed, lipped channel, designed to accept special spring-held hardened steel nuts for securing hanger rods and other attachments. Ensure nuts and clamps are compatible with the channel.

   b. Weld together two or more channels to form horizontal members of greater strength.

   c. Hot-dip galvanized after fabrication in accordance with ASTM A123/A123M or ASTM A153/A153M, as applicable.

   d. Manufacturer: Unistrut, Allied Tube and Conduit or approved equal.

E. Wireways

1. Type 4X stainless steel feed-through wireways.

2. Covers and bodies: 16 gauge type 304 stainless steel.

3. Flanges: 10 gauge stainless steel.

4. Seems continuously welded and ground smooth, no holes or knockouts.

5. Oil resistant gaskets and adhesives.

6. Manufacturer: Hoffman or approved equal.
F. Outlet Boxes; Junction and Pull Boxes

1. Provide electrical boxes of the material, finish, type, and size indicated and as required for the location, kind of service, number of wires, and function. For boxes located in tunnels and cross-passages use NEMA 4X stainless steel unless otherwise approved.

2. Provide boxes complete with accessible covers designed for quick removal and suitable for the purpose for which they will be used.

3. Equip boxes in which, or on which, no devices or fixtures are to be installed with flat or raised blank covers as required.

4. For boxes below 100 cubic inches in size or boxes for embedment in concrete use cast metal. Conform to the requirements for cabinets for boxes over 100 cubic inches in size, except when boxes in interface pull boxes are cast metal with gasketed cast metal covers. Use Type FD boxes for surface mounted wiring devices.

5. Ensure covers are the same thickness as boxes and are secured in position by means of No. 10-24 stainless steel machine screws. Arrange covers to be readily and conveniently removed.

6. Ensure Junction boxes are galvanized inside and outside. Where outlet boxes are used as junction boxes, do not use boxes smaller than 4 inches square by 1-1/2 inches deep. Provide such boxes with flat blank covers.

7. For exposed installation, use outlet and switch boxes made of cast metal, not smaller than 4 inches square by 2-1/8 inches deep.

8. Provide brackets, supports, hangers, fittings, bonding jumpers, and other installation accessories as required.

9. Provide neoprene gaskets 1/8-inch thick for boxes subjected to weather.

10. Ground each box as specified in Section 26 05 26, Grounding and Bonding for Electrical Systems.

11. Ensure boxes for systems control and communications applications conform to NEMA 250 Type 4 and provided with NEMA Type 4 labels.

12. Provide conduit outlet bodies mogul type.

G. Electrical Cabinets and Boxes to be NEMA 4X or as indicated.

1. Cabinet Boxes: Galvanized or stainless steel, size as noted on Contract Drawings. Provide white, galvanized steel interior mounting panel for mounting terminal blocks and relays in interface terminal cabinets.

2. Cabinet Fronts: Steel, surface or recessed type as required for the application with continuous hinge and flush lock. Supply locks for cabinets from a single manufacturer with standard key blank that are field-keyable.

3. Electrical Service and Distribution Cabinets: Stainless steel with non-directional brushed finish and accessories shown on Contract Drawings. Provide metering provisions meeting the requirements of the serving electric utility for Service Cabinets. Provide lock mechanism as required above.
PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Coordinate installation of raceways and boxes with the requirements of Section 26 05 00 Common Work Results for Electrical, Section 26 05 25 Wire and Cable, Section 26 05 26 Grounding and Bonding for Electrical Systems, 26 05 26 Grounding and Bonding for Electrical Systems and Section 26 05 43 Underground Ducts and Raceways for Electrical Systems, Section 26 05 53 Identification for Electrical Systems.

B. General Requirements

1. Install electrical raceway, boxes and accessories in locations as indicated, in accordance with NFPA 70, NFPA 130 and NECA 1, to provide a complete and operable system.

2. Ensure conduit, support fittings, boxes and conduit fittings are of compatible materials that will not corrode when subjected to moisture or standing water.

3. Provide anchor bolts and anchorage items as required, and field check to ensure proper alignment and location.

4. Install conduit so as to avoid conflicts with other work. Install horizontal raceways close to the ceiling or ceiling beams and above water or other piping wherever possible.

C. Conduit and Duct Type Requirements

1. Above grade exterior or potentially-wet areas: GRS or fiberglass conduit.

2. Below grade interior spaces (tunnels, cross passages, shafts, and stations):
   a. Embedded conduit - PVC conduit and accessories.
   b. Exposed conduit – GRS conduit and accessories.

3. Conduits for emergency loads (such as emergency lighting and fire alarm system): GRS or PVC/GRS.

4. Below grade exterior areas: PVC/GRS conduit, PVC electrical conduit encased in concrete ductbanks, fiberglass conduit, or plastic utility duct encased in concrete ductbanks.

5. Install PVC electrical conduit only when it will be embedded in slabs and walls or where required in short sections for electrical isolation. Do not leave PVC conduit exposed unless specifically shown on Contract Drawings. Terminate PVC within concrete walls or slabs with a male adapter and PVC/GRS coupling installed flush with the finished surface.

6. Provide PVC/GRS conduit section for transition between an embedded conduit and the above-ground metallic conduit. Ensure that the above-ground PVC-coated metallic conduit extends 1 foot minimum above ground or to box termination, whichever is less.

7. Install liquid tight flexible metal conduit only where required for flexibility such as connections to vibrating equipment and across joints subject to differential movement.

8. Do not use running thread.
D. Conduit Minimum Sizes

1. GRS: 3/4-inch diameter for exposed locations and 1-inch diameter for embedded locations.

2. PVC/GRS: 3/4-inch diameter for exposed locations and 1-inch diameter for embedded locations.

3. PVC Conduit: 3/4-inch diameter for exposed locations, 1-inch diameter for embedded locations.

4. EB Duct: 4-inch diameter.

5. Fiberglass Conduit: 3/4-inch diameter for exposed locations and 1-inch diameter for embedded locations.


7. Liquidtight Metallic Flexible Conduit: 1/2-inch diameter.

E. Conduit and Duct Bends

1. Install conduit runs with not more than 270 degrees total bends between pull boxes. Where more bends are required in a particular run, install pull boxes as required to facilitate pulling conductors even if not indicated.

2. Minimum Bending Radius Within Structures: In accordance with NEC Table 2, Chapter 9.
   a. PVC Conduit Bending Restrictions
   b. Hot bend bends with radii less than 100 feet using a heater recommended by the conduit manufacturer. Bends with radius 100 feet or larger be cold bent.
   c. Do not bend PVC conduit used in ductbanks with a radius less than 6 feet.

3. Minimum Bend Radius Underground
   a. 1-inch conduit: 18-inch radius
   b. 1-1/4-inch conduit: 20-inch radius
   c. 1-1/2-inch conduit: 22-inch radius
   d. 2-inch conduit: 27-inch radius
   e. 2-1/2-inch conduit: 30-inch radius
   f. 3-inch conduit: 30-inch radius
   g. 3-1/2-inch conduit: 33-inch radius
   h. 4-inch conduit: 36-inch radius
   i. 5-inch conduit: 42-inch radius

4. EB Duct Bending Restrictions
   a. Do not hot bend Type EB duct.
b. Type EB duct can be cold bent for slight offsets or changes in direction. Do not cold bend EB duct for radii less than 120 feet.

F. Conduit and Duct installation

1. Install conduit in accordance with NFPA 130, local codes and ordinances and as indicated.

2. Prevent material and water from entering the conduit, or pull and junction boxes. Provide threaded cap or similar closure designed for the purpose on conduits that are not terminated immediately. Tape is not acceptable for temporary sealing.

3. Match extensions to existing work to existing size.

4. Where conduit passes across an expansion or contraction joint in the structure, install the conduit at right angles to the joint, and provide liquid tight flexible metal conduit or an approved conduit expansion/deflection fitting at the joint.

5. Provide expansion fittings in conduit runs where required to compensate for thermal expansion.

6. Where conduit is exposed to different temperatures, seal the conduit to prevent condensation and passage of air from one area to the other.

7. If PVC conduit or type EB duct is not fully encased at one time, leave one end of the raceway free until encasing is restarted, or a PVC expansion joint is installed in the run.

8. When field threading of conduit is required, clean threads with a solvent to remove oil as recommended by coating manufacturer, and coat threads with organic cold galvanizing coating, in accordance with manufacturer’s instructions.

9. Coat threads with oxide inhibiting compound for metal-to-metal threaded joints. Take care that compound is not present on interior of conduit after installation.

10. Seal conduits with watertight duct sealing system, where waterproofing is required.

11. Install liquid tight flexible metal conduit so that liquids tend to run off the surface and are not drain toward fittings. Provide sufficient slack to reduce the effects of vibration.

12. Terminated stubbed conduits for future in a male pipe plug with provisions for pulling cord attachment. Install wrench-tight into the flush coupling.

13. Seal all conduit penetrations with approved 2-Hr. fire stop material between cross passage and tunnel.

14. Seal all conduit penetrations between sump pump pit and unclassified area.

G. Conduit Grounding And Bonding

1. Install metallic conduits to be electrically and mechanically continuous and connected to ground by bonding to the grounding system.

2. In dry areas, provide two locknuts, one inside and one outside of box or enclosure, for rigid conduit terminating at steel box, panelboard, cabinet, or similar enclosure. In exposed areas and damp and wet locations provide threaded hubs with sealing o-rings at conduit terminations.
3. Terminate the conduit in appropriate boxes at motors, switches, outlets, and junction points.

4. See Section 26 05 26, Grounding and Bonding for Electrical Systems, for requirements.

H. Raceway Support

1. Support individual wall mounted horizontal conduits not larger than 1 inch in diameter by means of one-hole conduit straps with back spacers or individual conduit hangers.

2. Space conduits installed against concrete surfaces 1/4 inch away from the surface by clamp backs or other approved means.

3. Support individual horizontal conduits larger than 1 inch in diameter by individual hangers and forged steel conduit strap for vertical runs.

4. Conduit Hangers:
   a. Support parallel conduits at the same elevation on multiple conduit hangers or channel inserts. Secure each conduit to the hanger or channel insert member by U-bolt, one-hole strap, or other specially designed and approved fastener suitable for use with the hangers or channel inserts.
   b. Support conduit using conduit hangers anchored to the structure. Verify suitability of structure for anchoring with Resident Engineer.

5. Apply cold galvanizing coating to the field-cut ends of steel hanger rods and steel channel.

6. Support rigid metal conduit in accordance with Table 344.30(R)(2) of the National Electrical Code.

7. Support rigid non-metallic conduits in accordance with Table 352.30(R) of the National Electric Code.

I. Outlet, Junction, and Pull Boxes

1. Securely attach outlet, junction, and pull boxes to the structure. Do not use conduits entering the box as supports for the box.

2. Mount outlet, junction, and pull boxes so as to prevent moisture from entering or accumulating within the boxes.

3. Junction and Pull Boxes:
   a. Install so that covers are readily accessible after completion of the installation.

END OF SECTION
1.01 SUMMARY
A. This Section includes specifications for underground electrical conduits, ductbanks, and underground utility structures.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 03 05 15, Portland Cement Concrete.
   2. Section 03 11 00, Concrete Forming.
   3. Section 03 20 00, Concrete Reinforcing.
   4. Section 03 30 00, Cast-in-Place Concrete.
   5. Section 26 05 33, Raceway and Boxes for Electrical Systems.
   6. Section 31 23 33, Trenching and Backfilling.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
      a. ASTM C33 Specification for Concrete Aggregates
   2. National Fire Protection Association (NFPA)
      a. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.

B. Shop Drawings:
   1. For fabrication and installation of precast concrete structures, cast-in-place concrete structures, and concrete-encased underground ductwork, including the following:
      a. Excavation and shoring plans with required structural calculations;
      b. Cast-in-place and precast detailed steel reinforcement drawings;
      c. Details of reinforcing steel used to tie ductbank to rigid underground structures it enters;
d. Cast-in-place and precast manufacturer's concrete mix designs for structures and colored concrete as indicated;

e. Dimensions and details of structure; and

f. Vault covers, including inscription.

2. Shop drawing information may be combined on a single drawing if clarity is not thereby impaired.

3. Drawings shall fully demonstrate that the work to be performed and the materials to be provided comply with the provisions of these Contract Specifications.

C. Manufacturer’s Qualifications.

D. Product Data.

1. Complete materials list of items proposed to be provided under this Section.

2. Manufacturers' specifications and other data required to demonstrate compliance with these Contract Specifications.

3. Catalog cuts for the following products:

   a. Raceways.

   b. Ductbank tie-downs.

   c. Underground duct system including manholes, pull boxes, handholes, cable junction boxes, and termination boxes.

   d. Manhole, pull box, and handhole covers and frames.

   e. Related miscellaneous hardware and metal items for cable trenches and wireways.

   f. Trench and wireway covers including composition of fiberglass reinforced plastic materials, divider partition panels, method of joining sections, expansion joint mounting, and support details.


1.04 QUALITY ASSURANCE

A. Qualification of Manufacturers:

1. 5 years minimum of experience in the manufacture of similar products.

2. Completed five projects which required products of similar scope and complexity to those indicated.

3. Inspection: Completed facilities shall be approved by the Resident Engineer before installation of cable and equipment.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Materials to be temperature rated in accordance with applicable NFPA 130 requirements.
B. Raceways
   1. Conduit and duct: In accordance with Section 26 05 33, Raceways and Boxes for Electrical Systems.

C. Precast Concrete Electrical Boxes, Pullboxes, and Vaults
   1. Reinforce concrete in a manner which is regularly provided in standard products of the manufacturer.
   2. Standard manufactured structures which meet project requirements will be acceptable.
   3. Provide concrete inserts for mounting cable support brackets as indicated.
   4. Provide pullbox covers with two lifting eyes and two hold-down bolts.

D. Cast-In-Place Concrete for Ductbank Encasements, Manholes, Pull Boxes, and Vaults
   1. Concrete: 3000 pounds per square inch (psi) with 4-inch slump in accordance with Section 03 05 15, Portland Cement Concrete.
   2. Red concrete: As specified in Section 03 05 15, Portland Cement Concrete, using 100 pounds of iron oxide for 8 cubic yards of concrete.
   3. Construct formwork and place concrete in conformance with applicable requirements of Section 03 11 00, Concrete Forming, and Section 03 30 00, Cast-in-Place Concrete.
   4. Install reinforcing steel, as indicated, in conformance with applicable requirements of Section 03 20 00, Concrete Reinforcing.
   5. Frames, Covers, Gratings, Steps and Sumps: as indicated.
   6. Cover Identification: Provide covers with embossed or engraved identification as indicated.

E. Sand
   1. Clean, graded, washed, passing a No. 4 U.S. sieve, and conforming generally to ASTM C33 for fine aggregate.

F. Warning Tape
   1. Heavy gage, yellow, plastic for direct burial, material resistant to corrosive soil, 6-inch minimum width, minimum 4 mils thick.
   2. Printed with warning that an electrical circuit is located beneath the tape.

G. Ductbank Tie-Down
   1. Non-metallic rod or stake with sufficient friction to prevent ducts from pulling rod out of ground and floating when concrete is placed.
PART 3 - EXECUTION

3.01 PREPARATION

A. Before beginning construction or installation of a section of underground conduit or ductwork, verify that the site is in suitable condition for installing conduit or ductwork.

3.02 CONSTRUCTION

A. Excavation, Trenching, and Backfilling

1. Perform excavation, bedding, and backfilling for underground conduits and structures in accordance with Section 31 23 33, Trenching and Backfilling.

B. Ductbanks

1. Group individual conduits together to form a ductbank in conformance with the requirements indicated.

2. Inspect ducts and couplings to ensure that only clean and undamaged pieces are incorporated in the work.

3. Install ducts, joints, and space separators according to manufacturer's printed instructions and recommendations.

4. Do not use spacers or space separators which transmit any vertical load to the conduit.

5. Install ductbanks or conduits with a minimum slope of 3 inches to each 100 feet away from buildings and towards manholes, pull boxes, and handholes.

6. Terminate conduits and ducts in end-bells in vaults.

7. Where ductbank enters rigid underground structures, provide reinforcing steel to tie the ductbank to the structure.

8. Construct the concrete-encased ductbank with 3-inch minimum cover on all sides.

9. Protection: when installation of conduits and ducts is temporarily suspended or terminated, close ends of ducts with caps or plugs fitted to prevent entry of water or debris. Use caps or plugs designed for that purpose by the conduit manufacturer.

10. Mandrelling: As each section of a duct line is completed between manholes, handholes, or pullboxes, use testing mandrel, not more than 1/4 inch less than the size of the conduit and brush to clear ducting.

   a. Draw mandrel through each conduit, after which draw a brush with stiff bristles through until the conduit is clear of particles of earth, sand, or gravel.

   b. Install conduit caps or plugs immediately thereafter.

   c. Notify the Resident Engineer prior to mandrelling any conduit.

   d. Prepare a written report providing a conduit identification number, size, material, location, the type and size of mandrel used, and indicate whether the conduit is tagged. Indicate on the report the acceptance date and initials of the Resident Engineer and the Contractor's foreman.
11. Install 1/8 inch or larger diameter polypropylene pulling cord in all ducts including those ducts designated for innerducts. Fasten each cord to pull iron anchorage in pull box, manhole, or vault with 2 feet minimum slack.

12. For conduit penetrations into UW utility tunnels and manholes:
   a. Locate conduit penetrations to avoid existing reinforcement.
   b. Seal all conduit penetrations with approved waterstop material.

C. Innerduct System:

1. Provide three raceways within the Signal/Communications raceways with four 1.25-inch inside diameter innerducts each. Unless noted otherwise on the Contract Drawings, provide innerduct in the three right-most ducts (facing toward increasing stationing) for segments south of U District Station and Roosevelt Station.

2. Install innerduct in accordance with manufacturer's installation instructions and recommendations.

3. Innerducts may be installed as part of a multi-cell raceway assembly or separately after installation of the ductbank is complete.

4. If installed separately, avoid excessive tension and deformation of the innerduct during placement in communications conduits. Replace damaged or necked down innerduct.

5. Couple corresponding innerducts together within intermediate vaults.

D. Precast Concrete Structures

1. Install precast electrical boxes, pullboxes, handholes, manholes, and vaults as indicated.

2. Place boxes on 4 inches of compacted sand bedding.

3. Place manholes on 6 inches of compacted aggregate base as specified in Section 33 46 00, Subdrainage.

4. Seal unused openings with cement mortar.

E. Cast-In-Place Concrete Structures

1. Ensure the location of each pull box, manhole, and vault are approved by Resident Engineer before construction of structure is started.

2. Construct the top, walls, and bottom of reinforced concrete. Place concrete for walls and bottom monolithically.

3. Place concrete for pull boxes, manholes, and vaults in tunnel to accommodate space requirement and clearance of system elements including walkway etc. as shown on plan.

4. Provide steel frames and covers as indicated in systems tunnel handhole and manhole details. Provide a machine-finished cover seat to ensure a matching joint between the frame and cover.
5. Where duct lines enter pull boxes, manholes, and vaults, the sections of duct may be either cast in the concrete or may enter through a square or rectangular opening of suitable dimensions provided in the utility structure.

6. Provide a cable-pulling iron anchorage in the wall opposite each ductbank entrance.

7. Install vault or pullbox covers flush with sidewalks or curbs.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing electrical equipment nameplates, wire and cable markers, and conduit color coding.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 09 90 00, Painting and Coating.
2. Section 26 05 00, Common Work Results for Electrical.
3. Section 26 05 25, Wire and Cable.
4. Section 26 05 33, Raceways and Boxes for Electrical Systems.
5. Section 26 24 16, Panelboards.

1.02 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Manufacturer’s product data for mounting adhesive.
C. Schedule for nameplates.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Nameplates: Engraved three-layer melamine laminated plastic, not less than 3/32-inch thick, black letters on a white background.

B. Wire and Cable Markers:

1. Non-fading, plastic, printed sleeve labels.
2. Non-fading, plastic, printed cable tag with holes for attachment to cable with plastic cable ties.

C. Mounting Screws: Stainless steel machine screws.

D. Mounting Adhesive: Permanent.
PART 3 - EXECUTION

3.01 INSTALLATION

A. Coordinate identification for electrical systems with the requirements of Section 26 05 00, Common Work Results for Electrical, Section 26 05 25, Wire and Cable, Section 26 05 33, Raceway and Boxes for Electrical Systems, Section 26 24 16, Panelboards, Section 26 29 13, Enclosed Motor and Lighting Controllers.

B. Degrease and clean surfaces to receive nameplates.

C. Install nameplates parallel to equipment lines.

D. Secure nameplates to equipment fronts using screws or adhesive. Secure nameplate to inside face of recessed panelboard or cabinet doors in finished locations.

E. Conduit Color Coding

1. Coordinate color of paint with Section 09 90 00, Painting and Coating, to identify conduit by system.

2. Low-voltage Distribution System: Unpainted or black

3. Fire Alarm System: Red

3.02 IDENTIFICATION SCHEDULE

A. Conductors: Provide sleeve wire markers on each conductor in panelboard, gutters, pull boxes, manholes, and at load connection. In gutters, pull boxes, and manholes, if cables are not spliced, use a cable tag. Attach tag securely to cable with plastic cable tie.

1. Power and Lighting Circuits: Identify with branch circuit or feeder number.

2. Control Wiring: Identify with control wire number as indicated on the Contract Drawings.

B. Provide nameplates of minimum letter height as scheduled below.

1. Panelboards, Uninterruptible Power Supplies, Motor Control Centers, Lighting Controllers: 3/8 inch, identify equipment designation; 1/4 inch, identify voltage rating and source.

2. Disconnect Switches: 3/8 inch, identify equipment designation; 1/4 inch, identify voltage rating, source, and load served.


4. Motor Starters in Motor Control Centers: 1/4 inch; identify circuit and load served, including location.


6. Transformers: 3/8 inch; identify equipment designation. 1/4 inch; identify primary and secondary voltages, primary source, and secondary load and location.
7. Devices: 1/4 inch; identify device. These devices may be the devices included in the assembly of the equipment such as MCC and may be standard of the manufacturing company, in which case, manufacturer will submit his standard devices nameplate for approval by the resident engineer for deviation from this specification.

   a. Control devices
   b. Pushbutton stations
   c. Selector switches
   d. Hand-off-Auto switches

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes: commissioning process requirements for electrical systems:
   1. Commissioning activities for electrical systems
   2. Providing qualified personnel to assist in commissioning tests.
   3. Providing equipment, materials, and labor necessary to correct issues found during the commissioning process which fulfill contract and warranty requirements.

B. Related Sections

   1. Section 26 05 25, Wire and Cable
   2. Section 26 05 26, Grounding and Bonding for Electrical Systems
   3. Section 26 29 13, Enclosed Motor and Lighting Controllers
   4. Section 26 28 15, Enclosed Switches and Fuses
   5. Section 26 33 53, Static Uninterruptible Power Supply
   6. Section 26 51 14, Lighting Systems

C. Cooperate with the Commissioning Authority in the following manner:

   1. Allow sufficient time before functional completion date so that test and balance (TAB) and commissioning testing can be completed.
   2. Provide labor and material to make corrections when required without undue delay.
   3. Coordinate all required support of that equipment which is provided and installed by the Division 21 (Fire Suppression), Division 22 (Plumbing), and Division 23 (HVAC) contractors that requires electrical involvement.

1.02 REFERENCES

A. This Section incorporates by reference in individual sections of Division 26 the latest revisions of the following documents and standards. Refer to individual specification sections for greater detail.

   1. NACE International
   2. Institute of Electrical and Electronic Engineers (IEEE)
   3. National Fire Protection Association (NFPA)
   4. International Electrical Testing Association (NETA)
1.03 SYSTEM DESCRIPTION

A. Commissioning work includes: Furnish labor and material to accomplish commissioning as specified herein, including:

1. Provide to the Commissioning Coordinator preliminary O&M information for submittal.
2. Assist the Commissioning Coordinator in developing commissioning activity procedures and data forms submittals for work specified in this Section.
3. Perform commissioning activities specified in this Section, including installation verification, static tests, start-up, component tests, equipment tests, systems tests.
4. Operate equipment and system during commissioning activities as required by the Commissioning Coordinator.
5. Perform and document commissioning tests to verify readiness for commissioning test demonstration. Commissioning tests are specified herein.
6. Correct issues and repeat commissioning tests when results do not meet acceptance criteria.
7. Perform commissioning test demonstration specified herein to verify acceptable performance.
8. Record and submit commissioning test demonstration data and issues.
9. Provide personnel to support commissioning test demonstration specified herein as requested by the Commissioning Coordinator.
10. In the event that a commissioning test demonstration fails, assist in determining the cause of failure. Make corrections as necessary.
11. Cooperate with Commissioning Coordinator to make equipment and systems ready for commissioning tests specified herein as early in the construction schedule as possible.
12. Provide factory start-up services for key equipment and systems specified in Division 26. Coordinate this work with the manufacturer and the Commissioning Authority.
13. Commissioning is intended to begin upon completion of a system. Commissioning may proceed prior to the completion of systems and/or subsystems, if expediting this work is in the best interests of the Owner and approved by the Owner. Commissioning activities and schedule will be coordinated with the Contractor. Start of commissioning before system completion will not relieve the Contractor from completing those systems as per the schedule.
B. Cooperate with Commissioning Coordinator to accomplish commissioning work on schedule and in coordination with other trades.

1.04 SUBMITTALS

A. Procedures: Refer to Section 01 33 00, Submittal Procedures and Section 01 33 23 Photographic Documentation Shop for submittal requirements and procedures.

1.05 TESTING LABORATORY

A. General: The terms used herein such as Test Agency, Test Contractor, Testing Laboratory, or Contractor Test Company, shall be construed to mean testing firm.

B. The lead, on site, technical person shall be currently certified by NETA in Electrical Power Distribution System Testing.

C. All instruments used by the testing firm to evaluate electrical performance shall meet NETA’s Specifications for Test Instruments.

1.06 TEST REPORTS

A. Prepare test reports, including description of project, description of equipment tested, description of test, test results, conclusions and recommendations, re-testing results, and list of test equipment used and calibration date.

B. Test reports shall be typewritten.

C. Insert a copy of each test report in the operation and maintenance manuals.

1.07 LABELS

A. Upon completion of tests by a testing firm, a NETA label shall be attached to all serviced devices. These labels shall indicate date serviced and the testing company.

PART 2 - PRODUCTS

2.01 TEST EQUIPMENT

A. Provide test equipment and instrumentation, including consumable supplies, required to execute commissioning activities. Unless noted otherwise, test equipment and instrumentation remain the property of the Contractor.

B. Standard certified test equipment for commissioning shall be provided by Division 26.

C. Electrical Megohmmeter for Insulation Testing:

1. 1000 volts(V) Direct Current(dc) output voltage suitable for resistance measurement from 500 kilohm to 500,000 megohms. Use a megohmmeter with an internal bleeder resistor for discharge.

2. Approved Manufacturer: Hipotronics or approved equal.

3. Thermographic equipment NETA Table 100.18 for testing loose connections.

D. High-Potential Test Set:

1. Portable high-potential dc test set, 0 to 130 kilovolts(kV) dc, 10 milliamperes (mA). with regulated output.
2. Internal shorting solenoid and discharge resistor.
3. Two percent full-scale accuracy capable of measuring cable insulation resistance up to 5,000,000 megohms.
4. Approved Manufacturer: Hipotronics or approved equal.

E. Ground Resistance Tester:
1. Three-terminal ground resistance tester with direct reading display.
2. Approved Manufacturer: Biddle (by AVO International) or approved equal.

2.02 PROPRIETARY TEST INSTRUMENTS
A. Provide proprietary test instruments or tools required by the equipment manufacturer. Provide and operate the proprietary test instruments or tools as required for commissioning work.

PART 3 - EXECUTION

3.01 PARTICIPATION IN COMMISSIONING
A. Provide skilled technicians to start-up and debug all systems with the division of work. These same technicians shall be made available to assist the Commissioning Coordinator in completing the commissioning program as it relates to each system and their technical specialty. Work schedules, time required for testing, etc., shall be requested and coordinated by the Commissioning Coordinator. Contractor shall ensure the qualified technician(s) are available and present during the agreed-upon schedules and of sufficient duration to complete the necessary tests, adjustments, and/or problem resolutions.

3.02 COMMISSIONING ACTIVITIES REQUIREMENTS
A. Commissioning activities scope: Technical requirements for commissioning of electrical systems are specified herein.
C. Scope of electrical systems commissioning activities applies to all portions of the electrical systems installation described in the test. Where sampling is specified, it applies only to the commissioning test demonstration.
D. Preparation
1. Certify that electrical systems, components, and equipment have been completed, calibrated, and started; and are operating in accordance with to Contract Documents.
2. Ensure that all enclosures for electrical equipment are clean and debris free.
3. Set systems, subsystems, and equipment into operating mode to be tested (e.g., normal shut down, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions) in accordance with accepted commissioning test procedures as directed by the Commissioning Coordinator.
E. Test all operating modes, interlocks, control responses, responses to abnormal or emergency conditions, and verify proper response of interconnected sensors.
F. Tests will be performed using design conditions whenever possible.

G. Simulated conditions may need to be imposed using an artificial load when it is not practical to test under design conditions. Provide equipment to simulate loads. Set simulated conditions in accordance with accepted commissioning test procedures as directed by the Commissioning Coordinator. Document simulated conditions and methods of simulation. After tests, return settings to normal operating conditions.

H. Request approval to alter set points when simulating conditions is not practical.

I. Request approval to alter sensor values with a signal generator when design or simulating conditions and altering set points are not practical.

J. If tests cannot be completed because of a deficiency outside the scope of the electrical system, document the deficiency and report it to the Owner. After deficiencies are resolved, reschedule tests.

3.03 COMMISSIONING ACTIVITY PROCEDURES

A. Submit level 1 commissioning activity test procedures and data forms for the following types of commissioning activities, requirements for which are specified herein.

1. Commissioning activities:
   a. Installation verification
   b. Static tests
   c. Start-up procedures
   d. Component tests
   e. Equipment tests
   f. System tests

3.04 INSTALLATION VERIFICATION CHECKLIST REQUIREMENTS

A. Scope: Installation verification requirements apply to the following:

1. Section 26 05 25, Wire and Cable
2. Section 26 05 26, Grounding and Bonding for Electrical Systems
3. Section 26 29 13, Enclosed Motor and Lighting Controllers
4. Section 26 28 15, Enclosed Switches and Fuses
5. Section 26 33 53, Static Uninterruptible Power Supply
6. Section 26 51 14, Lighting Systems

B. Installation Verification Scope: Technical requirements for Installation Verification of electrical systems are specified herein.

C. Installation verification checklist forms shall include the following:

1. Organized to prompt the installer to check off quality criteria for each discrete portion of the Work.
2. Identify the system or features to which the installation verification checklist applies at the top of the form.

3. Section for verification of delivery of accepted materials.

4. Section for condition of materials at delivery.

5. Section for installation. Include manufacturer’s installation instructions.

6. Space at the end of the form for the installer to print their name and company name, fill in the date, and sign or initial.

7. Space to identify the area of work for which the installer is executing the Installation Verification Checklist.

8. Description of the quality criteria as it pertains to the specific work. Include a check-box for each criterion.

D. Quality Criteria: Installation verification checklists shall address the following quality criteria.

1. Make and model match accepted submittals.

2. Equipment is installed without visible damage.

3. Location is as indicated on drawings.

4. Equipment is accessible for maintenance using safe work practices.

5. There is sufficient space to remove and replace components intact without demolishing other work.

E. Fill out and sign installation verification checklists for electrical systems while the Work is being installed. The intent is for the installing tradesperson to fill out and sign the installation verification checklist as work proceeds to improve the quality of the installation. Retain completed installation verification checklists on site for review.

F. Before performing a commissioning test, submit completed installation verification checklists for work included in the commissioning test.

3.05 INSTALLATION VERIFICATION

A. Installation verification checklists are required for the following, minimum:

1. 2608-IV-01 Molded-case Circuit Breakers (100 amps and above or feeding mechanical equipment)

2. 2608-IV-03 Grounding Systems

3. 2608-IV-05 Dry-Type Transformers

4. 2608-IV-07 Panelboards

5. 2608-IV-08 Motor Control Equipment (FVNR and Soft-Start )

6. 2608-IV-11 Uninterruptible Power Supply

7. 2608-IV-12 Lighting Controllers and Contactors
3.06 STATIC TESTS

A. 2608-ST-01: Insulation Resistance

1. System/Equipment to be tested:
   a. Insulation of conductors rated 100 amperes or greater.
   b. Insulation of conductors for all motor loads.

2. Functions to be tested:
   a. Insulation resistance

3. Conditions of the Test:
   a. Perform insulation resistance test on each conductor with respect to ground and adjacent conductors. Applied potential shall be 500 volts dc for 300 volt rated cable and 1000 volts dc for 600 volt rated cable.
   b. Test duration shall be one (1) minute.
   c. Include in Static Test Procedures and Data Forms submittal.

4. Acceptable Results:
   a. Insulation resistance tests shall meet the requirements of Table 26 08 00 D13

B. 2608-ST-02: Bolted Connection Torque

1. System/Equipment to be tested:
   a. Bolted connections for conductors rated 100 amperes or greater.

2. Functions to be tested:
   a. Bolted connection torque

3. Conditions of the Test:
   a. Perform torque test for each conductor tested and terminated in an overcurrent device or bolted type connection.
   b. Include in Static Test Procedures and Data Forms submittal.

4. Acceptable Results:
   a. Bolted connection torque values shall meet the manufacturer’s published values or the requirements of Table 26 08 00 D12

C. 2608-ST-05: Lighting Systems Illuminance Levels

1. Equipment/Systems to be tested:
   a. Lighting Levels throughout.

2. Functions to be tested:
a. Measure footcandle levels selecting random locations at the finished floor level. Measurements shall be taken at the following areas and documented.

1) In front of all Emergency Signage.
2) Along all designated exit routes.

3. Conditions of Test:
   a. Areas are complete and cleaned.

4. Acceptable Results:
   a. Light levels meet criteria for Sound Transit design. See Appendix D, Table D-18 for required footcandle levels.

3.07 COMPONENT TESTS (NOT USED)

3.08 EQUIPMENT TESTS

A. 2608-E-01: Molded Case Circuit Breakers

1. System/Equipment to be tested:
   a. Molded case circuit breakers serving panelboards, uninterruptible power supplies, and mechanical equipment.
   b. Molded case circuit breakers 70 amperes and greater.
   c. All circuit breakers serving mechanical equipment.

2. Functions to be tested:
   a. Contact resistance.
   b. Insulation resistance.
   c. Verification of adjustments for final settings.
   d. Tightness of electrical connections.
   e. Performance characteristics of trip units.

3. Conditions of the test:
   a. Perform a contact resistance test or millivolt drop across contacts at rated current.
   b. Perform primary current injection tests to ensure performance characteristics of trip units.
   c. Check trip unit reset operation.

4. Acceptable Results:
   a. Compare microhm or millivolt drop values to adjacent poles and similar breakers. Investigate, correct and re-test deviations of greater than 50 percent.
   b. Insulation resistance shall be per Table 26 08 00 D13
B. 2608-E-05: Dry Type Transformers

1. Systems/Equipment to be tested:
   a. Dry type transformers

2. Functions to be tested:
   a. Insulation resistance
   b. Phase rotation
   c. Reference: Section 26 05 17 for additional detail.

3. Conditions of test:
   a. Perform insulation resistance test. Measurements shall be made from winding-to-winding and winding-to-ground.

4. Acceptable Results:
   a. Test voltages and minimum resistances shall be in accordance with Table 26 08 00 D13. Results to be temperature corrected in accordance with Table 26 08 00 D14
   b. Verify taps and connect transformer to desired tap.
   c. Verify correct phase rotation.

C. 2608-E-08: Motor Control Equipment

1. Systems/Equipment to be tested:
   a. Motor starters (Soft Start) for sump pumps.
   b. Enclosed motor controllers (general purpose, across-the-line starters)

2. Functions to be tested (All motor control equipment):
   a. Insulation resistance
   b. Overload unit operation
   c. Control devices
   d. Phase rotation

D. 2608-E-11: Uninterruptible Power Supplies – False Load

1. System/Equipment to be tested:
   a. Uninterruptible Power Supplies (UPS)

2. Functions to be tested:
   b. Communications.
   c. Battery supply.
d. Overload capacity.
e. Output voltage.
f. Battery monitoring.
g. Connection torque.

3. Conditions of test:
   a. Test the manual and automatic operation of the UPS using resistive and reactive load banks to simulate all types of load conditions.
   b. Test protective and alarm functions.
   c. Test monitoring capabilities locally and remotely.
   d. Perform battery rundown tests to ensure 90 minute capability.
   e. Test overload capacity of unit at 125% of full load rating for 15 minutes. Test at 150% for 30 seconds.
   f. Install power recording meters to record all unit parameters under actual load conditions. Meters to be installed at UPS and at panelboard load served by UPS. Ten (10) day test duration.

4. Acceptable Results:
   b. Remote monitoring location receives correct information regarding Unit Status, Unit Parameters and Unit Alarms.
   c. Batteries are able to provide 90 minutes supply to loads under simulated full load when the UPS is disconnected from its power source.
   d. Overload capacity meets design criteria.
   e. Power measurement recordings, under actual load conditions, indicate satisfactory power quality over complete 10 day test duration.

E. 2608-E-12: Lighting Controllers

1. Systems/Equipment to be tested:
   a. Lighting Controllers and all sub-components.

2. Functions to be tested:
   a. Automatic control of lighting loads.
   c. Relay status
   d. Power failure and subsequent Power Up
   e. Occupancy Sensing controller.

3. Conditions of the test:
a. Demonstrate automatic control via controller CPU.

b. Manually override all automatic functions to control lights regardless of any possible control signals.

c. Verify relay status.

d. Fail the incoming power to the controller for a period of 30 minutes. Restore power to the controller to verify controller functions -will be automatically re-activated.

e. Demonstrate occupancy sensing control responding to presence of designated test personnel within rated range of sensors.

4. Acceptable Results:

   a. Automatic control satisfactorily respond to control signals.

   b. Manual override bypasses normal controller operation and turns on connected lights.

   c. Relay status feedback monitors actual current status of each relay.

   d. The controller activates in the correct operating status following failure of power.

   e. Occupancy sensor shall respond to test personnel being present within sensor rated range. Measure light levels before and after inhibiting sensor.

F. 2608-E-13: Receptacles

1. Equipment to be tested:

   a. Receptacles standard

   b. Receptacles GFCI

2. Functions to be tested:

   a. Open ground

   b. Reverse polarity

   c. Open hot

   d. Open neutral

   e. Hot and ground reversed

   f. Ground Fault Receptacle Circuit Interrupter when so equipped.

3. Conditions of the test:

   a. Perform all tests with adjustable GFCI and circuit tester

   b. GFCI “TEST” button on receptacle not acceptable for test.

4. Acceptable Results:

   a. Tester indicates correct wiring.
b. GFCI trips on ground fault current 5 milliamperes or greater.

c. GFCI does not trip on ground fault current less than 5 milliamperes

3.09 SYSTEM TESTS (NOT USED)

3.10 ATTACHMENTS

A. EXAMPLE SYSTEM DESCRIPTION
B. EXAMPLE INSTALLATION VERIFICATION FORM
C. EXAMPLE TEST PROCEDURE
D. TEST PARAMETER TABLES

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 26 24 16
PANELBOARDS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing enclosed circuit breakers, circuit breaker panelboards and mini power centers.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 00, Common work Results for Electrical.
2. Section 26 05 25, Wire and Cable.
3. Section 26 05 26, Grounding and Bonding for Electrical Systems.
4. Section 26 05 33, Raceway and Boxes for Electrical Systems.
5. Section 26 05 53, Identification for Electrical Systems.
6. Section 26 08 00, Commissioning of Electrical Systems.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American National Standards Institute (ANSI):
   a. ANSI C89.2 Dry-Type Transformers for General Applications

   a. ASTM A653/A653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
   b. ASTM B187 Specification for Copper Bar, Bus Bar, Rod and Shapes

3. National Electrical Manufacturers Association (NEMA):
   a. NEMA PB1 Panelboards
   b. NEMA AB-1 Molded Case Circuit Breakers and Molded Case Switches
   c. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)
   d. NEMA ST20 Dry-Type Transformers for General Applications

   a. NFPA 70 National Electrical Code
5. Underwriters Laboratories (UL):
   a. UL 67 Panelboards

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Manufacturers' product data for specified equipment and materials. Include the following information for each item:
   1. Manufacturer's model number or item identification;
   2. UL listing and rating;
   3. Critical dimensions and mounting arrangement; and
   4. Replacement parts list.

C. Shop Drawings and electrical diagrams as follows:
   1. Panelboards and Mini Power Center:
      a. Show general arrangement, location, and identification of the enclosure.
      b. Identify each circuit.
      c. Show location and identification of terminals,
      d. Show location of barriers.
      e. Provide wiring diagrams.
      f. Enclosures: Show materials and methods of construction, door arrangement, conduit hubs, and knockout locations.
      g. Transformer:
         1) Transformer ratings including:
            a) KVA
            b) Primary and secondary voltage
            c) Taps
            d) Primary and secondary continuous current
            e) Insulation class and temperature rise
            f) Sound level
   2. Circuit Breakers: Show circuit for which intended, voltage ratings, insulation level, current rating, and interrupting ratings.

D. Test Reports: Submit copies of certified reports of factory and field tests performed in accordance with the applicable referenced standards and specification requirements.

E. Shipping Record: Submit impact record chart to the Resident Engineer.
1.04 QUALITY ASSURANCE
A. Select a manufacturer who has been regularly engaged in the manufacture of similar equipment and has met UL requirements.
B. Conform to NEMA AB-1, NEMA PB1, UL 67 and National Electrical Code, as applicable.
C. Provide interchangeable components of the same type, size, rating, functional characteristics, and manufacture.
D. Verify each item is UL labeled.

1.05 DELIVERY, STORAGE, AND HANDLING
A. Ship each unit securely wrapped, packaged, and labeled for safe handling in shipment and to avoid damage or distortion.
B. Store in secure and dry storage facility.

1.06 WARRANTY
A. Submit manufacturer’s standard warranty.

PART 2 - PRODUCTS

2.01 EQUIPMENT
A. ENCLOSED CIRCUIT BREAKERS
   1. Enclosed Circuit Breakers:
      a. NEMA AB-1, molded case, quick-make quick-break bolt-on type, with thermal-magnetic type overload trip, interchangeable unit for frame rated 125 Amperes(A) and above.
      b. Enclosure: NEMA 250 Type 3R, fabricated from galvanized steel, surface-mounted unless otherwise indicated.
      c. Finish: metallic surface thoroughly cleaned, degreased, primed with an approved corrosion-inhibitive primer, and then finished with heavy-duty, industrial-grade polyurethane enamel.
   2. Remote Operated Circuit Breakers.
      a. Operating mechanism: trip-free 24Vdc mechanism with manual override and contact status indication located on the front of the circuit breaker listed for minimum 200,000 cycles.
      b. Overcurrent protection: UL listed 489 thermal trip element.
      c. Remote control: contacts cannot be closed remotely when the handle is in the OFF position or the circuit breaker is tripped. Motor drive can open and close contacts when the circuit breaker handle is in the ON position.
B. PANELBOARDS AND MINI POWER CENTERS
   1. Panelboards and Mini Power Centers: NEMA PB1 or UL 67
a. Enclosure: NEMA 250 Type 4X, fabricated from stainless steel, surface-mounted unless otherwise indicated, tamperproof, with the following additional requirements:

1) Gutter size:

<table>
<thead>
<tr>
<th>Rating (Amperes)</th>
<th>Main Bus</th>
<th>End Gutter</th>
<th>Side Gutter</th>
</tr>
</thead>
<tbody>
<tr>
<td>225 and below</td>
<td>6</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>400 and over</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

2) Provide backplate of reinforced steel for mounting of interior components.

3) Provide device or mechanism for enclosure grounding.

b. Cover and Trim:

1) Designed for surface or flush mounting as indicated.

2) Adjustment: Provide flush-mounted panelboards with means to plumb and align the front of the panel with respect to the adjacent finished surfaces.

3) Door: Hinged, fitted with a combination latch and door lock, accommodating a master key. Provide one flat key tumbler cylinder-type, nickel-plated door lock conforming to the station master key system, two keys per lock.

4) Circuit Directory: Provide a directory frame with acrylic plastic face mounted on the back of the door.

5) Finish: metallic surface thoroughly cleaned, degreased, primed with an approved corrosion-inhibitive primer, and then finished with heavy-duty, industrial-grade polyurethane enamel.

c. Bus Bars: ASTM B187, 98 percent conductivity copper, with silver-plated contact surface.

1) Provide neutral bus of the same rating as that of phase bus.

2) Provide a grounding bus.

d. Circuit Breakers

1) Bolt on type.

2) Auxiliary contacts: Ensure circuit breakers in tunnel lighting and power panels have auxiliary contacts and that these contacts are paralleled to provide a common panel trouble alarm locally and monitoring by SCADA (SCADA interface by others).

e. Mini Power Center

1) Each mini power center to include a primary main breaker, an encapsulated dry-type transformer and a load center with a secondary main breaker.
2) Primary main, secondary main and feeder breakers to be enclosed with a pad-lockable hinged door.

3) Insulate transformers with a 185 degrees C insulator system and rated at 115 degrees C

4) All insulation materials to be flame retardant and not to support combustion as defined in ASTM standard test method D635.

5) Provide transformer with two primary winding taps 2-1/2 inches above and below nominal

6) Provide two winding energy efficient taps with copper winding type transformers.

2.02 SOURCE QUALITY CONTROL

A. In addition to the manufacturer's standard tests, as a minimum perform the following tests at the manufacturer's plant:

1. 60 Hertz dielectric tests;
2. Mechanical operations tests;
3. Grounding of instruments;
4. Transformer case tests;
5. Electrical operation tests; and
6. Control wiring checks.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Coordinate installation of panelboards and mini power centers with requirements of Section 26 05 00, Common Work Results for Electrical, Section 26 05 25, Wire and Cable, Section 26 05 26, Grounding and Bonding for Electrical Systems, Section 26 05 33, Raceway and Boxes for Electrical Systems and 26 08 00, Commissioning of Electrical Systems.

B. Panelboard, Mini Power Center, and Enclosed Circuit Breaker

1. Mounting Height: Install with top 6 feet, 6 inches above the floor and the bottom not less than 12 inches above the floor, unless specifically indicated otherwise. Use multisectional panelboards and load centers to meet these spacings if necessary. Line up tops of trims to present neat appearance.

a. Anchor in accordance with seismic requirements in Section 26 05 00, Common Work Results for Electrical.

2. When a feeder serves more than one panelboard or panelboard section, install a separate junction box or provide adequate gutter area for termination of feeders and bus taps.

3. Connect neutral wires of branch circuits to the neutral bar of the same panelboard as the branch circuit.
4. When circuit breakers are located in spaces other than the main electrical distribution system equipment rooms and used to protect conductors serving emergency equipment motors (such as fans, dampers, and pumps), emergency lighting, and communications equipment, ensure they not be tripped by the thermal element. Use thermal element contact to indicate an alarm condition.

5. Provide nameplates or other permanent identification for each circuit breaker, mounted on the cover or trim adjacent to each breaker, in accordance with Section 26 05 53, Identification for Electrical Systems.

6. Provide each panelboard and mini power center with an accurate typewritten circuit directory. Install in the factory-provided directory frame mounted on the back of the door.

3.02 FIELD QUALITY CONTROL

A. Provide equipment for testing power and control circuits after installation. Test under the observation of the Resident Engineer.

1. Panelboards and Circuit Breakers:
   a. Test circuits for connections in accordance with the wiring diagram.
   b. Test that insulation resistance to ground of nongrounded conductors is a minimum of 10 megohms.
   c. Test panelboard and mini power center enclosures for continuity to the grounding system.
   d. Test operation of circuits and controls. When testing, operate each control a minimum of ten times and each circuit continuously for a minimum of 1/2 hour.
   e. Test that each panel has a balanced load.
   f. Maintain a log of tests.

3.03 DEMONSTRATION

A. Perform pre-energizing checkout procedure in accordance with NECA 400 prior to energizing switchboards.

B. Notify Resident Engineer prior to energizing switchboards.

C. Energize switchboards in accordance with NECA 402.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing and installing enclosed switches and fuses.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 26 05 00, Common Work Results for Electrical.
   2. Section 26 05 26, Grounding and Bonding for Electrical Systems.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. American National Standards Institute (ANSI)
      a. UL 198C High Interrupting-Capacity Fuses; Current-Limiting Types
      b. UL 198E Class R Fuses
   2. National Electrical Manufacturers Association (NEMA):
      a. NEMA KS 1 Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)
      b. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Submit manufacturers' product data for specified equipment and materials. Include the following information for each item:
   1. Outline drawings with dimensions
   2. Equipment ratings for voltage, capacity, horsepower, and short circuit withstand.

PART 2 - PRODUCTS

2.01 COMPONENTS
A. Enclosed Switches
1. Fusible Switch Assemblies: NEMA KS 1; quick-make, quick-break, load
interrupter enclosed knife switch with externally operable handle interlocked to
prevent opening front cover with switch in ON position. Handle lockable in OFF
position. Fuse Clips: Suitable for Class R or J fuses with fuse rejection devices
installed.

2. Nonfusible Switch Assemblies: NEMA KS 1; quick-make, quick-break, load
interrupter enclosed knife switch with externally operable handle interlocked to
prevent opening front cover with switch in ON position. Handle lockable in OFF
position.

3. Enclosures: NEMA KS 1; NEMA 250 Type 1, 3R, or 4X as required for the
environment or as designated on the Contract Drawings.

B. Fuses

1. Fuses, 600 Amperes or Less: UL 198C, Class J or UL 198E Class RK1 or as
indicated on Contract Drawings. 600 V rated, one-time, time delay, current-
limiting type.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install disconnect switches where indicated on Contract Drawings with external handle
centered 60 inches above finish floor or grade level.

B. Install fuse-rejection devices in fuse clips if required.

C. Install fuses in fusible disconnect switches.

D. Install enclosure grounding and test ground resistance to be within specified values listed
in Section 26 05 26, Grounding and Bonding for Electrical Systems.

END OF SECTION
SECTION 26 29 13
ENCLOSED MOTOR AND LIGHTING CONTROLLERS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing individual motor starters, motor controllers, lighting contactors, and lighting controllers.

B. This section includes specifications for the factory installation in the Panelboards specified in Section 22 24 16.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 78 23, Operation and Maintenance Data.
2. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.
3. Section 26 05 00, Common Work Results for Electrical.
4. Section 26 05 25, Wire and Cable
5. Section 26 05 26, Grounding and Bonding for Electrical Systems
6. Section 26 05 33, Raceway and Boxes for Electrical Systems
7. Section 26 05 53, Identification for Electrical Systems.
8. Section 26 08 00, Commissioning of Electrical Systems
9. Section 26 24 16, Panelboards

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

   a. ASTM A653/A653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
   b. ASTM D2092 Guide for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting

2. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE 344 Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

3. National Electrical Contractors Association (NECA)
a. NECA 402 Recommended Practice for Installing and Maintaining Motor Control Centers

4. National Electrical Manufacturers Association (NEMA):
   a. NEMA ICS2 Industrial Control Devices Controllers and Assemblies
   b. NEMA ICS6 Industrial Controls and Systems Enclosures
   c. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Shop Drawings: Submit shop drawings and electrical diagrams. Identify all electrical equipment technical data, ATS, breaker, starter, contactor, control transformers, and relay characteristics and settings data, including inrush current ratings of all coils, on shop drawings.

C. Manufacturer's product data of manufactured materials and equipment.

D. Operational and Maintenance Data: Submit maintenance data and operating instructions in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
   1. Summary of the equipment and its components;
   2. Manufacturer's operating and maintenance instructions, parts list, illustrations, and diagram of components;
   3. Recommended list of spare parts; and
   4. Wiring diagrams.

E. Test Reports: Certified test reports of factory and field tests performed, verifying that performance of equipment meets specification requirements.

1.04 DELIVERY, STORAGE AND HANDLING

A. Ship each unit securely wrapped, packaged, and labeled for safe handling of shipment and to avoid damage or distortion.

B. Store individual components and enclosed controllers in secure and dry storage facility.

1.05 WARRANTY

A. Submit manufacturer's standard warranty.

PART 2 - PRODUCTS

2.01 EQUIPMENT

A. Motor Starters
   1. Ensure motor starters meet the requirements of NEMA ICS2, general purpose Class A, and the following additional requirements:


1) Type:
   a) For dry and dust-free indoor location: NEMA 250, Type 1 with drip shield.
   b) For damp and dusty indoor location: NEMA 250, Type 12.
   c) For areas subject to corrosion: NEMA 250 Type 4X


3) Finish: Painted finish for all ferrous and galvanized metal surfaces.
   a) Prepare ferrous metal surfaces for painting in accordance with standard industry practice.
   b) Prepare galvanized metal surfaces for painting in accordance with ASTM D2092.
   c) After pretreatment, prime-paint surfaces with an approved corrosion-inhibitive metal primer for ferrous or galvanized surfaces, as applicable.
   d) For the finish coat use heavy-duty, industrial-grade polyurethane enamel.

c. Provide auxiliary devices at each contactor meeting the following requirements:

1) Auxiliary devices shall be manufacturer’s standard products. Control diagrams shall show actual configuration including auxiliary devices.

2) Heavy-duty type relay: Select devices with a Contact rating of 20 amperes (A) at 120 volts (V) alternating current (AC) or rating indicated on Contract Drawings which operate satisfactorily at 120 degrees F.

d. Mount terminal blocks used at the contactor in the enclosure. Verify that each terminal block is able to accommodate two 14 American Wire Gauge (AWG) wires.

e. Wiring:

1) For the control wiring inside the controller enclosure use minimum 16 AWG, stranded, thermoplastic-insulated wire, rated 105 degrees C, with red color for ac.
2) Use power cable of the same type and rating as control wiring, black color, and with capacity compatible with the contactor or breaker rating.

2. Manual Starters: Quick-make quick-break toggle mechanism, trip-free manual reset thermal overload relay, position indicator showing ON, OFF, and TRIPPED positions, and red indicating light showing the CLOSED position.

   a. 480 V primary to 120 V secondary control transformer with one fuse in the secondary circuit.
   b. Two NO and two NC auxiliary contacts with provision for addition of two NO or NC contacts.
   c. Indicating pilot lights on each unit enclosure. De-energized: GREEN; and energized: RED.
   d. Control selector switch: HAND/OFF/AUTO

4. Combination Motor Starters: Rated 480 V, three phase or single phase, 60 Hertz. Meet the requirements for magnetic motor starters with the following additional requirements:
   a. Provide one 480 V, three-pole, motor circuit protector type circuit breaker with current limiter with adjustable trip-point.
   b. Provide externally mounted operating handle with position indicator showing ON, OFF, or TRIPPED condition of the circuit breaker or disconnect switch as applicable. Install operating handle that is interlocked to prevent opening and closing of the door when the circuit breaker or disconnect switch is in the ON position. Provide defeater to bypass the interlock.

B. Enclosed Motor Controllers

1. Combination Motor Starter with Solid State Soft Starters for Sump Pumps in a single enclosure: rated at 480 V, three phase with current ratings as shown on Contract Drawings. Meet the requirements for motor starters and other control devices with the following additional requirements:
   a. Provide all necessary components, devices and interconnecting wiring for the intended application preassembled inside single enclosure for sump pump power supply and control.
   b. Provide one main breaker and three individual feeder breakers, one for each pump soft starter. Feeder breakers to be 480 V, three-pole, motor circuit protector type with current limiter and with adjustable trip-points.
   c. Provide completely assembled soft starter combining all necessary elements such as SCRs, bypass contactor, and overload in one very compact unit for each pump control based upon sensed water level. These starters to be fully wired and tested inside the motor controller panel.
d. Soft starter shall be current limiting type adjustable to allow starting inrush current to be controlled to minimize system voltage dip during pump starting mode. Include standard Kick start features that provide a current and torque “kick” for 0 to 2.0 seconds allowing greater initial current to develop torque needed during pump starting.

e. Include all motor protection and control features which includes, 1) built in overload, 2) selectable phase reversal protection 3) selectable current limit or ramp start 4) adjustable ramp times 5) adjustable torque control, 6) adjustable kick start control 7) Digital Interface Module, 8) control transformer with proper fuse protection, 9) 24V dc power supplies for the soft starters 10) Panel mounted indicating lights, 11) device name plates 12) selector switches for individual pump starter 12) common selector switch for all three pumps 13) internal wiring and terminal strips as needed and 14) PLC interface control as indicated in Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances.

f. Motor controller assembly to contain triplex pump control system which will include three individual soft starters, PLC, level sensors and level transducer (See Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances and the Contract Documents) and three motor circuit protectors. Fully wire and test all equipment at the factory. Provide a terminal strip for remote alarm and indication of the pump running and high level alarm conditions. To the Building Management System (BMS) as indicated on Contract Drawings.

g. Provide externally mounted operating handle with position indicator showing ON, OFF, or TRIPPED condition of the circuit breaker. Pump running indication, pump selector switch as applicable. Install operating handle that is interlocked to prevent opening and closing of the door when the circuit breaker or disconnect switch is in the ON position. Provide defeater to bypass the interlock.

2. Motor Controllers Wiring: NEMA; Class II, Type B.

3. Feeder Tap Units: Molded case thermal-magnetic circuit protectors as described above.

4. Voltage Rating: 480 volts, three phase, three wire, 60 hertz.

5. Horizontal Bussing: Tin plated insulated Copper with a continuous current rating as indicated Include tin plated copper ground bus for the entire length of the control center.

6. Vertical Bussing: NEMA ICS2; Tin plated insulated Copper

7. Integrated Equipment Short Circuit Rating: 65,000 amperes root-mean-square (RMS) symmetrical at 480 volts unless indicated otherwise on Contract Drawings.

8. Configuration: Units front mounting only, accessible from the front only.


10. Finish: Manufacturer’s standard gray enamel or as scheduled.

11. Seismic Requirements: IEEE 344; Class I.

C. Lighting Contactors
1. **Contactors**: NEMA ICS2; electrically-held, two-wire control.

2. **Coil Operating Voltage**: 277 volts, 60 Hertz.

3. **Contacts**: Silver alloy, fully rated for tungsten lighting loads, 20 A, 600 Vs or as noted on Contract Drawings.

4. **Enclosure**: NEMA 250, Type12. When mounted within equipment enclosures as a listed assembly, use open-type contactors.

5. **Provide** screw-terminals for termination of circuit conductors unless shown otherwise on Contract Drawings.

### D. Enclosed Lighting Controllers

1. **Provide** industrial lighting controllers in NEMA 250 Type 12 cabinet for control of lighting systems. Ensure lighting controller includes interface with Building Management System (BMS)-based network lighting controls as indicated on Contract Drawings, individual switches rated for 20 A tungsten lighting or inductive loads, and ancillary equipment.

   a. Provide number of relays or control outputs/inputs as noted on Contract Drawings but a minimum of 12 outputs and 8 inputs at each controller.

   b. Ensure lighting controller has the capability to manually override automatic controls.

   c. Provide accessory equipment including, auxiliary relays, local and remotecontrol switches, and terminal strips for interface with field wiring.

   d. Ensure lighting controller has the following automatic and remote functions:

      1) Local switches to bypass remote control of lighting.


### PART 3 - EXECUTION

3.01 **INSTALLATION**

A. Coordinate installation of enclosed controllers with requirements of Section 26 05 00, Common Work Results for Electrical, Section 26 05 25, Wire and Cable, Section 26 05 26, Grounding and Bonding for Electrical Systems, Section 26 05 33, Raceway and Boxes for Electrical Systems, and Section 26 08 00, Commissioning of Electrical Systems.

B. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping, and install individual motor starters and contactors as indicated and as recommended by the manufacturer.

C. Install motor controllers as recommended by the manufacturer and in accordance with NECA 402.

D. Anchor equipment in accordance with the seismic requirements in Section 26 05 00, Common Work Results for Electrical.
E. Select and install heater elements in motor starters to match installed motor characteristics.

F. Motor Data: Provide label on each motor starter enclosure door in accordance with Section 26 05 53, Identification for Electrical Systems

G. Install lighting contactors and lighting controllers in accordance with Contract Drawings and make field connections to remote switches and pilot devices.

3.02 FIELD QUALITY CONTROL

A. Provide equipment and instruments and perform the following tests:

1. Test circuits for connections in accordance with accepted wiring diagrams.

2. Test that insulation resistance to ground of non-grounded conductor is a minimum of 10 meg-ohms.

3. Test equipment enclosures for continuity to the grounding system.

4. Test operation of circuits and controls. When testing, operate each control a minimum of ten times and each circuit continuously for a minimum of 1/2 hour.

3.03 DEMONSTRATION

A. Perform pre-energizing checkout procedure in accordance with NECA 402 prior to energizing motor controllers.

B. Notify Resident Engineer prior to energizing motor controllers.

C. Energize motor controllers in accordance with NECA 402.

D. Perform tests to demonstrate lighting controllers capability of local and remote automatic control of connected lighting.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This section includes specifications for three-phase, on-line, static-type, uninterruptible power supply (UPS), complete with transient voltage surge suppression, input harmonics reduction, rectifier-charger, battery, battery disconnect device, inverter, static bypass transfer switch and maintenance bypass/isolation switch.

B. Related sections: the work of the following sections is related to the work of this section. Other sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 26, Grounding and Bonding for Electrical Systems
2. Section 26 05 53, Identification for Electrical Systems
3. Section 26 08 00, Commissioning of Electrical Systems

1.02 REFERENCES AND STANDARDS

A. This Section incorporates by reference the latest revision of the following documents.

B. Applicable provisions of the following standards applies to the work of this Section, except as modified herein, and are hereby made a part of these Specifications to the extent required:

1. American National Standards Institute (ANSI):

2. National Electrical Manufacturers Association (NEMA):
   b. NEMA 250: Enclosure for Electrical Equipment.

3. Underwriters Laboratories Inc. (UL):
   a. UL 1778: Uninterruptible Power Supply Equipment.


5. Institute of Electrical and Electronic Engineers (IEEE):


7. Federal Communications Commission (FCC):
   a. FCC Part 15 Class A.

8. National Institute of Standards and Technology (NIST)

1.03 DEFINITIONS

A. EMI: Electromagnetic interference.

B. LCD: Liquid-crystal display.

C. LED: Light-emitting diode.

D. THD: Total harmonic distortion.

E. UPS: Uninterruptible power supply.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Furnish the following:

1. Product Data: Include data on features, components, ratings, and performance for each uninterruptible power supply component indicated.

2. Shop Drawings: Detail assemblies of equipment indicating dimensions, weights, components, and location and identification of each field connection. Show access, workspace, and clearance requirements; details of control panels; and battery arrangement.

3. Wiring Diagram: Detail internal and interconnecting wiring, power, signal, and control wiring. Differentiate between field-installed and factory-installed wiring and components.

4. Dimensioned Outline Drawings of Equipment Unit: Identify weight and center of gravity and locate and describe mounting and anchorage provisions for each individual cabinet or enclosure.

5. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

6. Manufacturer Certificates: Signed by manufacturers certifying that they comply with requirements.

7. Qualification Data: For firms and persons specified in “Quality Assurance” Article.

8. Factory Test Reports: Comply with specified requirements.

9. Field Test Reports: Indicate test results compared with specified performance requirements, and provide justification and resolution of differences if values do not agree.
10. Maintenance Data: Provide Operation and Maintenance Manuals as specified in Section 01 78 23, include the following:
   
a. List of spare parts and replacement components recommended being stored at project site for ready access.

b. Detailed operating instructions covering operation under both normal and abnormal conditions.

c. Warranties: Special warranties specified in this Section.

d. Required periodic maintenance documentation and procedures.

11. Manufacturer Seismic Qualification Certification: Submit certification that UPS equipment will withstand seismic forces in accordance with Uniform Building Code (UBC) for Washington State seismic zone three requirements.

1.05 QUALITY ASSURANCE

A. Source Limitations: Obtain the UPS and associated components specified in this Section from a single manufacturer with responsibility for entire UPS installation.

B. The supplier has a local service organization with factory-trained technicians and a local part inventory, and is capable of providing training, parts and emergency maintenance and repairs for equipment at the Contract site with 8 hours maximum response time.

C. Installer Qualifications: An experienced installer who is an authorized representative of UPS manufacturer for both installation and maintenance of units required for this Contract for at least 5 years.

D. Listing and Labeling: Provide electrical components, devices, and accessories that are Listed and Labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to the Authority Having Jurisdiction, and marked for intended use for the location and environment in which they are installed. The equipment is labeled “Suitable for use on emergency system” in accordance with NEC 700-3.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver equipment in fully enclosed vehicles after specified environmental conditions have been permanently established in spaces where equipment is to be placed.

B. Store equipment in spaces with environments controlled within manufacturer’s ambient temperature and humidity tolerances for non-operating equipment.

1.07 PROJECT CONDITIONS

A. Environmental Conditions: UPS is capable of operating continuously in the following environmental conditions without mechanical or electrical damage or degradation of operating capability, except battery performance.

1. Ambient Temperature for Electronic Components: 32 to 104 degrees F.

2. Ambient Temperature for Battery: 41 to 104 degrees F.

3. Relative Humidity: 5 percent to 95 percent, noncondensing.

4. Altitude: Sea level to 500 feet.
1.08 **WARRANTY**

A. **Warranties, General:** Special warranties specified in this Article is in addition to, and run concurrent with, other warranties made under requirements of these Specifications.

B. **Special Battery Warranties:** Written warranty, signed by manufacturer and Installer agreeing to replace UPS system storage batteries that fail in materials or workmanship within specified warranty period.

C. **Warranted Cycle Life for Sealed Valve Regulated Lead-Acid (VRLA) Batteries:** Equal to or greater than 20 years based on annual average battery temperature of 77 degrees F.

D. **Warranted Cycle Life for Sealed Lead-Acid Batteries:** Equal to or greater than 5 years based on annual average battery temperature of 77 degrees F.

E. **Special UPS Warranties:** Written warranties, signed by manufacturer and Installer agreeing to replace components that fail in materials or workmanship within special warranty period.

F. **Special Warranty Period:** two years from date of Substantial Completion.

**PART 2 - PRODUCTS**

2.01 **MANUFACTURERS**

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. SolidState controls Inc.
2. Powerware.
3. Liebert Corp.
4. Controlled Power Company
5. Approved Equal

2.02 **MANUFACTURED UNITS**

A. **Output Load Capacity:** 1) Three Phase, 0.8 lagging power factor.  2) Single Phase, 0.8 lagging power factor. Refer to the Contract Drawings for the UPS ratings (voltage and KVA).

B. **UPS will perform as specified in this Article while supplying rated full-load current, composed of any combination of linear and nonlinear load, up to 100 percent nonlinear load with a load crest factor of 3.0, under the following conditions or combinations of the following conditions:**

1. Inverter is switched to battery source.
2. Steady-state ac input voltage deviates up to plus or minus 10 percent from nominal voltage.
3. Steady-state input frequency deviates up to plus or minus 5 percent from nominal frequency.
4. THD of input voltage is 15 percent or more with a minimum crest factor of 3.0, and the largest single harmonic component is a minimum of five percent of the fundamental value.

5. Output Frequency: 60 Hz plus/minus 0.5 percent over full range of input voltage, load and battery voltage.

6. Load is 50 percent unbalanced continuously.

C. Minimum Duration of Supply: If battery is sole energy source supplying UPS-rated full-output load current at 80 percent power factor, duration of supply is 90 minutes.

D. Input Voltage Tolerance: System steady state and transient output performance remains within specified tolerances when steady-state ac input voltage varies plus 10, minus 20 percent from nominal voltage.

E. Maximum Acoustical Noise: 65 dBA measured one meter from the surface of the UPS.

F. Maximum Energizing Inrush Current: Six times the full-load current.

G. Maximum AC Output-Voltage Regulation for Loads up to 50 percent Unbalanced: Plus or minus 2 percent over the full range of battery voltage.

H. Output Frequency: 60Hz, plus or minus 0.5 percent over the full range of input voltage, load, and battery voltage.

I. Maximum Harmonic Content of Output-Voltage Waveform: Five percent RMS total and three percent RMS for any single harmonic, for 100 percent rated nonlinear load current with a load crest factor of 3.0.

J. Minimum Overload Capacity of UPS at Rated Voltage: 125 percent of full-load rating for 10 minutes without bypass source, and 150 percent for 30 seconds without bypass source.

K. Input Power Factor: A minimum of 0.85 lagging when supply voltage and current are at nominal rated values and UPS is supplying rated full-load current.

L. EMI Emissions: Comply with FCC Rules and Regulations, 47 CFR 15 for Class A

M. Electronic Equipment: Solid-state devices using hermetically sealed, semiconductor elements. Devices include rectifier-charger, inverter, static bypass transfer switch, and system controls.

N. Enclosure: Comply with NEMA 250, Type 1, unless otherwise indicated.

1. The cabinet doors and louvers require tools for access.

2. Provide casters and leveling feet.

3. Front access only for servicing.

4. The overall enclosure width and depth will not exceed the space allocated on the Contract Drawings.

O. Control Assemblies: Mount on modular plug-ins, readily accessible for maintenance.

P. Surge Suppression: Protect internal UPS components from surges that enter at each ac power input connection including main disconnect, static bypass transfer switch, and maintenance bypass/isolation switch. Protect rectifier-charger, inverter, controls, and output components.
1. Use factory-installed surge suppressors tested according to IEEE C62.41, Category B.

2. Additional Surge Protection: Protect internal UPS components from low frequency, high-energy voltage surges described in IEEE C62.41. Design the circuits connecting with external power sources and select circuit elements, conductors, conventional surge suppressors, and rectifier components and controls so input assemblies will have adequate mechanical strength and thermal and current-carrying capacity to withstand stresses imposed by 40-Hz, 180 percent voltage surges described in IEEE C62.41.

Q. Seismic-Restraint Design: UPS assemblies, subassemblies, and components; and fastenings and supports, mounting, and anchorage devices for them, are designed and fabricated to withstand static and seismic zone three forces in all directions.

R. UPS Cabinet Ventilation: Cooling of the UPS is by forced air. Low-velocity fans are used to minimize audible noise output. Fan power is provided by the UPS output. UPS cabinet ventilation shall be in compliance with the Seattle Mechanical Code Section 502.5.

S. Output Circuit Neutral Bus, Conductor, and Terminal Ampacity: Rated phase current times a multiple of 2.0, minimum.

T. Capacity Upgrade Capability
   1. Selected systems shall be capable to accept a field installed power upgrade to the next higher power rating without an increase in cabinet size.
   2. Capacity Upgrade Capability: Arrange wiring, controls, and modular component plug-in provisions to permit future 25 percent increase in UPS capacity.

U. Extra Materials
   1. Local field service organization shall stock extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
   2. Provide qualified service personnel available around-the-clock 365 days a year.
   3. Provide toll free direct phone number.
   4. Fuses: One for every ten of each type and rating, but not less than one of each.
   5. Cabinet Ventilation Filters: One complete set.
   6. One spare circuit board for each critical circuit.

2.03 COMPONENTS

A. Rectifier-Charger
   1. Capacity: Adequate to supply the inverter during full-rated output load conditions and simultaneously recharge the battery from fully discharged condition to 95 percent of full charge within ten times the rated discharge time for duration of supply under battery power at full load.
   2. Output Ripple: Limited by output filtration to less than 0.5 percent of rated current, peak to peak.
3. Rectifier-Charger Control Circuits: Immune to frequency variations within rated frequency ranges of normal and emergency power sources.
   a. Response Time: Field adjustable for maximum compatibility with portable generator-set power source.

4. Battery Float-Charging Conditions: Comply with battery manufacturer written instructions for battery terminal voltage and charging current required for maximum battery life.

B. Inverter
   1. Description: Pulse-width modulated, with sinusoidal output.
   2. Description: Pulse-width modulated, with sinusoidal output. Include a bypass phase synchronization window adjustment to optimize compatibility with portable engine-generator-set power source.

C. Static Bypass Transfer Switch
   1. Description: Solid-state switching device providing uninterrupted transfer. A contactor or electrically operated circuit breaker automatically provides electrical isolation for the switch.
   2. Switch Rating: Continuous duty at the rated full-load current of the UPS, minimum.

D. Battery - Sealed Valve Regulated Lead-Calcium (VRL)
   1. Description: Sealed, valve-regulated, recombinant, lead-calcium units, factory assembled in an isolated compartment of UPS cabinet compliant with local seismic codes requirements.
   2. Provide complete battery unit sufficient to supply power for minimum 90 minutes to UPS units with ratings as shown on drawings or specified herein with all necessary hardware and components including battery disconnect switch.

E. Battery - Sealed Valve Regulated Lead-Acid (VRLA)
   1. Description: Sealed, valve-regulated, recombinant, lead-acid units, with lead-calcium plates, AGM (absorbent glass mat) separator and a sulfuric acid electrolyte encased in a flame retardant polypropylene container complying with UL94.
   2. Provide complete battery unit sufficient to supply power for minimum 90 minutes to UPS units with ratings as shown on drawings or specified herein with all necessary hardware and components including battery disconnect switch.
   3. Cells shall be factory installed with one (1) or two (2) cells per modular steel can.
   4. Terminal posts shall be a lead casting with a threaded copper insert. The terminal seal shall be a ring burn with a secondary epoxy resin seal. Terminals shall be top mounted on batteries.
   5. Relief valve shall operate at 2-3 psi, complete with integral flame arrestor.
   6. Inter-unit connectors and terminal plates shall be tin-plated copper.
   7. Clear flame retardant safety shields shall allow visual inspection without removal.
8. Rack system (assembled by Contractor) shall provide total flexibility for system configuration. Rack system shall be anchored to floor with seismic bracing to wall compliant with local seismic codes requirements.

9. Total front access for easy maintenance.

F. UPS Control and Indication

1. Provide system power flow diagram on front of cabinet.

2. Description: Group displays, indications, and basic system controls on a common control panel on front of UPS enclosure.

3. Minimum displays, indicating devices, and controls include those in lists below. Provide sensors, transducers, terminals, relays, and wiring required to support listed items. Alarms include an audible signal and a visual display.

4. Indications: Plain-language messages on a digital LCD or LED.

5. Dry-form “C” contacts are available for remote indication of the following conditions:
   a. UPS on battery.
   b. UPS on-line.
   c. UPS load-on bypass.
   d. UPS in alarm condition.
   e. UPS off (maintenance bypass closed).

G. Maintenance Bypass/Isolation Switch

1. Description: Manually operated switch or arrangement of switching devices with mechanically actuated contact mechanism arranged to route the flow of power to the load around the rectifier-charger, inverter, and static bypass transfer switch.
   a. Switch are interlocked to prevent interrupting power to the load when switching to the bypass mode.
   b. Switch shall isolate other UPS components electrically to permit safe servicing.

2. Comply with NEMA PB 2 “Dead-Front Distribution Switchboards” and UL 891 “Dead-Front Switchboards”.

3. Switch Rating: Continuous duty at rated full-load current of UPS.

4. Mounting Provision: Internal to system cabinet or external wall mount.

5. Key interlock requires unlocking maintenance bypass/isolation switch before switching from normal position with key that is released only when the UPS is bypassed by static bypass transfer switch. Lock is designed specifically for electrical component interlocking.

H. Monitoring by Remote Computer

1. Description: Communication module in unit control panel would provide capability for remote monitoring of status, parameters, and alarms. The remote
computer and the connecting signal wiring are not included in this Section. Include the following features:

a. LON Mark compatible network interface units, or Approved Equal.

b. Software designed for control and monitoring of UPS functions and to provide on-screen explanations, interpretations, diagnosis, action guidance, and instructions for use of monitoring indications and development of meaningful reports. Permit storage and analysis of power-line transient records. Design for Microsoft Windows or approved equal application in an IBM-compatible computer, which is not included in this Section.

I. Basic Battery Monitoring

1. Battery Ground-Fault Detector: Initiates visual and audible alarm when resistance to ground of positive or negative bus of battery is less than 5000 ohms.

2. Battery compartment smoke/high-temperature detector initiates a visual and audible alarm when smoke or a temperature greater than 75 degrees C occurs within the compartment.

3. Annunciation of Alarms: At UPS control panel.

J. Additional Battery Monitoring

1. Monitoring features and components include the following:

a. Factory-wired sensing leads to cell and battery terminals and cell temperature sensors. Provide fuses as required for proper protection of conductors.

2. Functional Performance: Automatically measure and electronically record the following parameters on a routine schedule and during battery discharge events. During discharge events record measurements timed to the nearest second. Include measurements of the following parameters:

   a. Total battery voltage and ambient temperature;

   b. Individual cell voltage, impedance, and temperature; Measure battery and cell voltages and time to the nearest second during battery discharging events such as utility outages;

   c. Individual cell electrolyte levels.

K. Battery Cycle Warranty Monitoring

1. Description: Electronic device, acceptable to battery manufacturer as a basis for warranty action, for monitoring of charge-discharge cycle history of batteries covered by a life-cycle warranty.

2. Basic functional Performance: Automatically measures and records each discharge event, classifies it according to duration category, and totals discharges according to warranty criteria, displaying remaining warranted battery life on integral LCD.

3. Additional monitoring functions and features include the following:
a. Measuring and Recording: Total voltage at battery terminals, providing alarm for excursions outside the proper float voltage level.

b. Monitors: Ambient temperature at battery and initiates an alarm if temperature deviates from normally acceptable range.

c. Keypad on Device Front Panel: Provides access to monitored data using front panel display.

d. Alarm Contacts: Arranged to provide local alarm for abnormal temperature, abnormal battery voltage, or temperature.

e. Memory: Device stores recorded data in nonvolatile electronic memory.

f. RS-232 or USB Port: Permits downloading data to a portable personal computer.

g. Modem: Makes measurements and recorded data accessible to remote personal computer via telephone line. Computer is not specified in this Section.

2.04 SOURCE QUALITY CONTROL

A. Factory test complete UPS, including battery, before shipment. Include the following tests:

1. Functional test and demonstration of all functions, controls, indicators, sensors, and protective devices.

2. Full-load test.


4. Overload test.

5. Power failure test.

B. Observation of Test: Give 14 days advance notice of test and provide opportunity for Resident Engineer to observe tests.

C. Report test results. Include the following data:

1. Description of input source and output loads used. Describe actions required to simulate source load variation and various operating conditions and malfunctions.

2. List of indications, parameter values, and system responses considered satisfactory for each test action. Include tabulation of actual observations during test.

D. List of instruments and equipment used in factory tests.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine elements and surfaces to receive equipment for compliance with installation tolerances and other conditions affecting performance, including, but not limited to,
ambient temperature, cooling air circulation, contaminants and disassembly and maintenance space.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.02 INSTALLATION

A. Install system components on concrete floor. Cast-in-place concrete, reinforcing, and formwork are specified in Division 03, Concrete.

B. Maintain minimum clearances and workspace at equipment according to manufacturer’s written instructions and NFPA 70.

C. Connections: Interconnect system components. Make connections to supply and load circuits according to manufacturer’s wiring diagrams, unless otherwise indicated.

D. GROUNDING

1. Comply with Section 26 05 26, Grounding and Bonding for Electrical Systems, for materials and installation requirements.

2. Comply with NFPA 70 for grounding and bonding requirements for Separately Derived Systems.

E. IDENTIFICATION

1. Identify components and wiring according to Section 26 05 53, Identification for Electrical Systems.

2. Equipment is labeled “Suitable for use on emergency systems” in accordance with NEC 700-3.

3. Instructional signs: Install approved legend where instructions or explanations are required for system of equipment operation.

F. BATTERY EQUALIZATION

1. Equalize charging of battery cells according to manufacturer’s written instructions. Record individual-cell voltages.

3.03 FIELD QUALITY CONTROL

A. Manufacturer’s Field Service: Engage the services of a factory-authorized service representative to supervise UPS installation, startup, and preliminary testing and adjustment and to participate in final tests, inspections, and adjustments.

B. Electrical Tests and Inspections: Perform tests and inspections according to manufacturer’s written instructions and as listed below to demonstrate condition and performance of each component of the UPS:

1. Comply with requirement of Section 26 08 00. Commissioning of Electrical Systems

2. Inspect interiors of enclosures, including the following:
   a. Integrity of mechanical and electrical connections.
   b. Component type and labeling verification.
   c. Ratings of installed components.
3. Test manual and automatic operational features and system protective and alarm functions.

4. Test communication of status and alarms to remote monitoring equipment.

5. Load the system using a variable-load bank to simulate kilovolt amperes, kilowatts, and power factor of loads for the unit’s rating. Use instruments calibrated, within the previous 6 months according to National Institute of Standards and Technology (NIST) standards.
   a. Simulate malfunctions to verify protective device operation.
   b. Test duration of supply on emergency, low-battery voltage shutdown, and transfers and restoration due to normal source failure.
   c. Test harmonic content of input and output current less than 25, 50, and 100 percent of rated loads.
   d. Test output voltage under specified transient-load conditions.
   e. Test efficiency at 50, 75, and 100 percent rated loads.
   f. Test remote status and alarm panel functions.
   g. Test battery-monitoring system functions.
   h. Test resistance to ground of battery negative pole.

C. Seismic-restraint inspections include the following:

1. Inspect type, size, quantity, arrangement, and proper installation of mounting or anchorage devices.

2. Test mounting and anchorage devices.

3. Verify batteries are properly mounted and secured to battery racks.

D. Correct deficiencies until specified requirements are met.

E. Record of Inspections: Maintain and submit documentation of inspections, including references to manufacturers written instructions and inspection criteria. Include results of inspections.

3.04 CONSTRUCTION

A. Sequence Of Operations

1. Automatic operation includes the following:
   a. Normal Conditions: Supply the load with ac power flowing from the normal ac power input terminals, through the rectifier-charger and inverter, with the battery connected in parallel with the rectifier-charger output.
   b. Abnormal Supply Conditions: If normal ac supply deviates from specified and adjustable voltage, voltage waveform, or frequency limits, the battery supplies energy to maintain constant, regulated inverter ac power output to the load without switching or disturbance.
c. If normal power fails, energy supplied by the battery through the inverter continues to supply-regulated ac power to the load without switching or disturbance.

d. When power is restored at the normal supply terminals of the system, controls automatically synchronize the inverter with the external source before transferring the load. The rectifier-charger then supplies power to the load through the inverter and simultaneously recharges the battery.

e. If battery becomes discharged and normal supply is available, the rectifier-charger charges the battery. On reaching full charge, the rectifier-charger automatically shifts to a float-charge mode.

f. If any element of the UPS system fails and power is available at the normal supply terminals of the system, the static bypass transfer switch switches the load to the normal ac supply circuit without disturbance or interruption of supply.

g. If a fault occurs in the system supplied by the UPS and current flows in excess of the overload rating of the UPS system, the static bypass transfer switch operates to bypass the fault current to the normal ac supply circuit for fault clearing.

h. When the fault has cleared, the static bypass transfer switch returns the load to the UPS system.

i. If battery is disconnected, the UPS continues to supply power to the load with no degradation of its regulation of voltage and frequency of the output bus.

2. Manual operation includes the following:

a. Turning the inverter off causes the load to be transferred by the static bypass transfer switch directly to the normal ac supply circuit without disturbance or interruption.

b. Turning the inverter on causes the static bypass transfer switch to transfer the load to the inverter.

3. Maintenance Bypass/Isolation Switch Operation: Switch is interlocked so it cannot be operated unless static bypass transfer switch is in the bypass mode. Device provides manual selection between the following three conditions without interrupting supply to the load during switching:

a. Full Isolation: Load is supplied, bypassing the UPS. Normal UPS AC input circuit, static bypass transfer switch, and UPS load terminals are completely disconnected from external circuits.

b. Maintenance Bypass: Load is supplied, bypassing the UPS. UPS ac supply terminals are energized to permit operational checking, but system load terminals are isolated from the load.

c. Normal: Normal UPS ac supply terminals are energized and the load is supplied through either the static bypass transfer switch and UPS rectifier-charger and inverter, or the battery and the inverter.
3.05 DEMONSTRATION

A. Engage a factory-authorized service representative to train Sound Transit maintenance personnel to adjust, operate, and maintain the UPS.

B. Train Sound Transit maintenance personnel in the procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment.

C. Review data in maintenance manuals. Refer to Section 01 78 23, Operation and Maintenance Data.

D. Schedule training with Resident Engineer with at least 7 days advance notice.

E. Monitoring and Testing Schedule: Perform monitoring and testing in a single 10-day period.

1. Schedule monitoring and testing activity with Resident Engineer. Provide at least 7 days advance notice.

2. Schedule monitoring and testing after substantial Completion, when UPS in supplying power to its intended load.

F. Monitoring and Testing Instruments: Three-phase, recording power monitors. Instruments provide continuous simultaneous monitoring of electrical parameters at input terminals of the UPS and at input terminals of a load served by the UPS. Instruments would monitor, measure, and graph voltage current and frequency simultaneously and provide full-graphic recordings of the values of those parameters before and during power line disturbances that cause the values to deviate from normal beyond the adjustable threshold values. Instruments are capable of recording either on paper or on magnetic media and have a minimum accuracy of plus or minus 2 percent for electrical parameters. Parameters to be monitored include the following:


2. Voltage: Phase to phase, phase to neutral, phase to ground, and neutral to ground.

3. Frequency transients.

4. Voltage swells and sags.

5. Voltage impulses, phase-to-phase, phase-to-neutral, phase-to-ground, and neutral-to-ground.

6. High-frequency noise.

7. Radio-frequency interference.

8. THD of the above currents and voltages.

9. Harmonic content of currents and voltages above.

G. Monitoring and Testing Procedure:

1. Exploratory Period: For the first 2 days, make recordings at various circuit locations and with various parameter-threshold and sampling-interval settings. Make these preliminary measurements with the objective of identifying optimum UPS, power system, load, and instrumentation set-up conditions for subsequent test and monitoring operations.
2. Remainder of Test Period: Perform continuous monitoring of at least two circuit locations selected on the basis of data obtained during exploratory period.
   a. Set thresholds and sampling intervals for recording data at values selected to optimize data on performance of the UPS with respect to values specified in Part 2 of this Section, and to highlight any need to adjust, repair, or modify the UPS or any distribution system or load component that may influence its performance or that may require better power quality.
   b. Perform load and UPS power source switching and operate the UPS on generator power during portions of the test period.
   c. Operate the UPS and UPS loads in each mode of operation permitted by UPS controls and by the power distribution system design.
   d. Create and simulate unusual operating conditions, including outages, voltage swells and sags, and voltage, current, and frequency transients that can be performed using loads and devices available as part of the facility's installed systems and equipment. Maintain normal operating loads in operation on system to maximum extent possible during tests.
   e. Make adjustments and repairs to UPS, distribution, and load equipment to correct deficiencies disclosed by monitoring and testing and repeat appropriate monitoring and testing to verify success of corrective action.

H. Correlation with Specified UPS Monitoring Functions: Obtain printout recordings of built-in monitoring functions specified for UPS and UPS components in this Section that are simultaneous with those made with portable instruments in this Article.
   1. Provide the temporary use of an appropriate personal computer and printer equipped with required connections and software for recording and printing if such units are not available on-site.
   2. Correlate printouts with recordings for monitoring performed according to this Article; resolve and report anomalies in and discrepancies between the two sets of records.

I. Documentation: Record test point and sensor locations, instrument settings, and circuit and load conditions for each monitoring summary and power disturbance recording. Correlate simultaneous recordings made on UPS input and load circuits.

J. Analysis of Recorded Data and Report: Review and analyze test observations and recorded data and submit a detailed written report. Include the following in final report:
   1. Description of corrective actions performed during monitoring and survey work and their results;
   2. Recommendations for further action to provide optimum performance by the UPS;
   3. Copies of monitoring summary graphics and graphics illustrating harmonic content of significant voltages and currents;
   4. Copies of graphics of power disturbance recordings that illustrate findings, conclusions, and recommendations;
   5. Recommendations for operating, adjusting, or revising UPS controls;
   6. Recommendation for alterations to the UPS installation;
7. Recommendation for adjusting or revising generator-set or automatic transfer switch installations or their controls;

8. Recommendations for power distribution system revisions;

9. Recommendations for adjusting or revising electrical loads, or their connections or controls.

K. Interim and Final Reports: Provide an interim report at the end of each test period and final comprehensive report at the end of the final test and analysis period.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for corrosion control monitoring systems and electrical continuity for tunnel structures.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 33, Raceways and Boxes for Electrical Systems.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. NACE International (NACE)
   a. NACE RP0187-2002 Design Considerations for Corrosion Control of Reinforcing Steel in Concrete

2. National Electrical Manufacturers Association (NEMA)
   a. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

3. National Fire Protection Association (NFPA)
   a. NFPA 70 National Electrical Code

4. Underwriters Laboratories (UL)
   a. UL 50 Enclosures for Electrical Equipment

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures

1. Assembly, erection, and installation drawings. Coordinate submittal with requirements of 26 05 33, Raceways and Boxes for Electrical Systems.

2. A complete list of tunnel corrosion control equipment and material, including name and manufacturer, catalog number, size, finish, and any other pertinent data necessary for proper identification and to determine conformance with the specifications.

3. Certification by the cable manufacturer covering conformance of cable insulation to the designated specification.

5. Qualifications of personnel performing and providing quality assurance for electrical tests required herein.

6. Quality control test procedure which includes the personnel to be utilized for the project, resumes and certifications, data sheets, procedures, test equipment calibration certificates, and other pertinent data for approval by the Resident Engineer.

7. Test Plan
   a. Preliminary Approval: Submit a detailed testing plan based upon the testing requirements included in these Specifications. Include:
      1) Measurement methodology in high resistance environments;
      2) Sample calculation formats;
      3) Expected range of values for each test procedure;
      4) QA/QC procedures;
      5) Sample data sheet and spreadsheet file showing the proposed format for test data documentation.
   b. Instruments: Submit list of instruments to be used. Include manufacturer, model number, serial number and calibration certificate for each instrument.

8. Parts and special tools list

B. Test Results and Calculations:
  1. Submit to the Resident Engineer within 10 Days of the performance of the test.
  2. Provide five copies of test results in typed format and signed by the NACE Specialist or Technologist performing the test procedure and the quality control review individual.

1.04 QUALITY ASSURANCE

1. An independent corrosion control organization shall supervise installation and perform installation testing of the corrosion control system including, but not limited to, electrical continuity testing. The organization shall have been continuously engaged in the field of corrosion control testing for a minimum of five years and shall have the following qualifications:
   a. NACE International Certified Cathodic Protection Specialists and Corrosion Technicians available to perform the required field testing.

2. Work to be performed under the direct supervision of a NACE International Cathodic Protection Specialist.

3. Testing organization employed for field quality control shall have a minimum of five years experience in the testing of corrosion control systems for tunnel structures of similar type and complexity as the system specified and indicated.

4. Testing shall be performed by personnel with at least five years of employment experience with testing corrosion control systems.
1.05 DELIVERY, STORAGE AND HANDLING

A. Materials and equipment to be used in construction shall be stored in such a manner to be protected from detrimental effects from the elements. If warehouse storage cannot be provided, materials and equipment shall be stacked well above ground level and protected from the elements with plastic sheeting or as appropriate.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Materials shall conform to the requirements set forth herein or as designated on the drawings, unless otherwise specified. Materials must be new, free from defects, and shall be of the best commercial quality for the purpose specified. Necessary items and accessories not shown on the Contract Drawings or specified herein, but which are required to fully carry out the specified intent of the work, shall be provided.

B. Steel Collector Cable
   1. One inch diameter, unlubricated, bare, as shown on the Contract Drawings.

C. Wire and Terminations
   1. Test Leads
      a. Type: Type XHHW-2 or RHH/RHW, unless otherwise indicated.
      b. Cables for steel cable test leads shall be #4 AWG, stranded, copper. Two test leads are required at each test box.
      c. Cables for electrically continuous reinforcing steel test leads shall be #4 AWG, stranded, copper. Two test leads are required at each test box.
      d. Terminations: Compression type ring tongue or spring spade terminals with insulated ferrules. Quick-connect terminations are not acceptable.

D. Test Boxes
   1. Corrosion Control Test Box
      a. Provide test boxes sized and located as indicated on the Contract Drawings.
      b. Approved manufacturer and product: Hoffman, Inc., Model Q181813PCE, or approved equal.
   2. Terminal Board
      a. Provide manufacturer standard, non-metallic, interior mounting panel.
      b. Provide nickel-plated brass termination hardware.
      c. Approved manufacturer and product: Hoffman, Inc., Model Q1818PE, or approved equal.

E. Reference Electrodes
   1. Silver/Silver Chloride Reference Electrode

b. Provide with factory installed and sealed No.14 AWG red RHH-RHW insulated wire of sufficient length to reach to junction box termination point without splicing.

c. Approved manufacturer and product: Borin, Model CRE-020-SCB or approved equal.

F. Exothermic Molds and Charges

1. Approved manufacturers: Cadweld by Erico Products, Inc., Thermoweld by Continental Industries, Inc., or approval equal.

2. Cartridge, sleeves and molds shall be furnished by the same manufacturer.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General

1. Materials, workmanship, and installation shall as a minimum meet requirements of the National Electric Code and other applicable State, County, or City codes and regulations. Nothing in the Contract Documents is to be construed to permit work not conforming to these regulations and codes.

B. Wire and Cables

1. Cables shall be continuous in length and free of joints or splices. Care shall be exercised during installation to avoid punctures, cuts, and similar damage to insulation. Damage to insulation will require replacement of the entire cable length. Pull boxes and splice boxes shall be installed where shown and where otherwise required to facilitate installation of conductors and to comply with code requirements.

2. Provide compression terminals for wire terminations using tool recommended by manufacturer of terminations. Ensure connections withstand normal use without damage.

C. Exothermic Welds

1. Provide connections between copper conductors and steel cable and/or steel reinforcing using exothermic welding process, as recommended by manufacturer of exothermic weld equipment.

2. Provide copper sleeve on cables prior to welding. Materials for welding shall be sized in accordance with recommendations in manufacturer's literature.

3. Weld Testing: After the weld has cooled and the slag material has been removed, test the weld by striking with a two-pound hammer at an angle of approximately 45 degrees to the surface while maintaining tension on the wire. Replace defective welds with new welds at no cost to Sound Transit. Maintain a minimum distance of 6 inches between exothermic welds unless otherwise approved.
4. Exothermic Weld Protective Coating: Coat welds and all steel within 2 inches of the weld with an approved coating material and provide mechanical protection. Coat exposed surfaces of copper. Provide surface preparation and apply coating as indicated by the coating manufacturer.

D. Test Boxes and Cables

1. Route test wires and reference electrode wires in conduit to designated test box.
2. Install test box wiring without tension on the wiring.
3. Terminate wire at both ends unless indicated otherwise.
4. After termination, test wires for electrical continuity by measuring resistance between same colored wires at test box. Acceptable resistance is no more than 1.10 times the theoretical resistance of the two wires after temperature compensation. Replace wires that do not pass test at no cost to Sound Transit.
5. Seal conduits and openings in test box, and install cover in accordance with manufacturer’s recommendations, to make a watertight enclosure.

E. Reference Electrodes

1. Install reference electrodes where indicated and route connecting wire to junction or test box as indicated on the Contract Drawings.

F. Steel Collector Cable

1. Install steel collector cable in one continuous length without splices between test boxes or between steel reinforced concrete and test boxes.

G. Reinforcing Steel

1. Where steel reinforced concrete slab is utilized, the top layer of steel reinforcement shall be made electrically continuous through the use of lap splices along the longitudinal reinforcement and the installation of transverse bonding bars, as shown on the Contract Drawings. Transverse bonding bars shall be installed at each end of the slab, and at intermediate locations not to exceed 500 feet.

3.02 FIELD QUALITY CONTROL

A. Notify the Resident Engineer a minimum of two days before the performance of electrical testing.

B. After installation of the corrosion control facilities, the system shall be tested by a qualified Corrosion Engineer to ensure conformance with these Contract Specifications. Testing shall include adequacy of test stations and electrical continuity of the steel collector cable and steel reinforcing mat. Upon completion of the tests, a detailed written report shall be submitted describing any deficiencies detected. Deficiencies shall be corrected by the Contractor at its cost and retested prior to final acceptance. Retesting shall be at no cost to Sound Transit.

C. Reference Electrode Testing

1. Test each reference electrode before placement of concrete. Place the calibrated electrode and the reference electrode in a non-metallic container containing ambient temperature tap water and use a high impedance voltmeter to measure the voltage between the two electrodes. If the voltage measured is
more than plus/minus 15 millivolts from the manufacturer's recommended differential voltage, reject the reference electrode.

2. Replace reference electrodes that fail the test at no cost to Sound Transit.

D. Steel Collector Cable Continuity Testing

1. Verify electrical continuity of the steel collector cable by measuring the longitudinal resistance. Acceptable resistance is no more than 1.10 times the theoretical resistance of the steel cable.

2. Testing shall be performed before and after concrete installation.

3. Any portion of the cable found which does not meet the above criteria shall be replaced at no cost to Sound Transit.

E. Reinforcing Steel Continuity Testing

1. Verify electrical continuity of the steel reinforcing collector mat by measuring the longitudinal resistance. Acceptable resistance is no more than 1.10 times the theoretical resistance of the steel reinforcing mat.

2. Testing shall be performed before and after concrete installation.

3. Any portion of the reinforcing mat found, which does not meet the above criteria shall be replaced at no cost to Sound Transit.

F. Final Approval: The Resident Engineer will observe the initial field tests. Should the procedures appear valid after two separate tests, final approval will be given. Do not vary or change the approved testing techniques without written approval from the Resident Engineer. Submittal of test results for non-approved test plans will be rejected.

G. Record results related to acceptance criterion, conditions at the work site, personnel performing the test, points of electrical connection, equipment and instrumentation used for the testing, specific measurement procedures, and general weather conditions.

H. Provide review of all test results and procedures performed by the NACE Specialist or Technologist for completeness and accuracy by an individual with qualifications and experience equal to or greater than the individual performing the testing.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing, testing, and commissioning lighting systems including tunnel lighting, tunnel exit signs, cross passage lighting, tunnel sump lighting, and perimeter lighting as shown on the contract plans.

B. Related Work: Related information is included in, but not limited to, the following:
   1. Section 01 33 00, Submittal Procedures
   2. Section 01 78 23, Operations and Maintenance Data
   3. Section 26 05 00, Common Work Results for Electrical.
   4. Section 26 05 25, Wire and Cable.
   5. Section 26 05 26, Grounding and Bonding for Electrical Systems.
   6. Section 26 05 33, Raceway and Boxes for Electrical Systems.
   7. Section 26 05 48, Vibration and Seismic Control.
   8. Section 26 05 53, Identification for Electrical Systems.
   9. Section 26 08 00, Commissioning of Electrical Systems.
   10. Section 26 24 16, Panelboards.
   11. Section 26 28 15, Enclosed Switches and Fuses
   12. Section 26 29 13, Enclosed Controllers and MCC.
   13. Section 26 42 50, Tunnel Corrosion Control

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Association of State Highway and Transportation Officials (AASHTO)
      a. ANSI C2 National Electrical Safety Code
      b. ANSI C136.10 – American National Standard for Roadway and Area Lighting Equipment – Locking-Type Photocontrol Devices and Mating Receptacles – Physical and Electrical Interchangeability and Testing
c. ANSI C78.Series Electric Discharge Lamps (Fluorescent), High Intensity Discharge Lamps (High Pressure Sodium), Method of Designation

d. ANSI C78.377 Specifications for the Chromaticity of Solid State Lighting Products

e. ANSI C81.62 Lampholders for Electric Lamps

f. ANSI C82.4 American National Standard for Ballasts for High-Intensity-Discharge and Low Pressure Sodium Lamps (Multiple-Supply Type)

g. ANSI C82.11 American National Standard for Lamp Ballasts – High Frequency Fluorescent Lamp Ballasts

h. ANSI C83.77 Harmonic Emission Limits – Related Power Quality Requirements for Lighting


j. ANSI C136-22 Standard for Roadway Lighting, Internal Labeling of Luminaires

k. ANSI C136-15 Standard for Roadway Lighting, High Intensity Discharge and Low Pressure Sodium Lamps in Luminaires Field Identification

l. ANSI C136-14 Standard for Roadway Lighting, Enclosed Side-Mounted Luminaires for Horizontal Burning High Intensity Discharge Lamps

m. ANSI C136-31 Standard for Roadway Lighting Equipment Luminaire Vibration


b. ASTM A167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

c. ASTM A366/A366M Standard Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled

d. ASTM D714-87 Standard Test Method for Evaluating Degree of Blistering of Paints

e. ASTM D1654-92 Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments

f. ASTM D3359-97 Standard Test Methods for Measuring Adhesion by Tape Test


4. Institute of Electrical and Electronics Engineers (IEEE)
5. Illuminating Engineering Society of North America (IES):
   a. IES Lighting Handbook, Reference and Application, 10th Edition
   b. RP-8-00 American National Standard Practice for Roadway Lighting
   c. RP-16-96 Nomenclature and Definition
   d. LM-5 Photometric Measurements of Area and Sports Lighting Installations
   e. LM-10 Photometric Testing of Outdoor Fluorescent Luminaires
   f. LM-31-95 Photometric Testing for Roadway Luminaires Using Incandescent Filament and High Intensity Discharge Lamps
   g. LM-41 Photometric Testing of Indoor Fluorescent Luminaires
   h. LM-64 Photometric Measurements for Parking Garages
   i. LM-63 ANSI Approved Standard File Format for Electronic Transfer of Photometric Data and Related Information
   j. LM 71 Photometric Measurements of Tunnel Lighting Installations
   k. LM-79 Approved Method Electrical and Photometric Measurements of Solid State Lighting Products
   l. LM-80 Approved Method: Measuring Lumen Maintenance of LED Light Sources

6. National Electrical Manufacturer Association (NEMA)
   a. NEMA 410 Performance Testing for Lighting Controls and Switching Devices with Electronic Fluorescent Ballasts
   b. NEMA LE 4 Recessed Luminaires, Ceiling Compatibility

7. National Electrical Contractors Association (NECA)
   a. NECA 1 Standard for Good Workmanship in Electrical Construction
   b. NECA 500 Standard for Installing Indoor Commercial Lighting Systems
   c. NECA 501 Recommended Practice for Installing Exterior Lighting Systems
   d. NECA/IESNA 502 Recommended Practice for Installing Industrial Lighting Systems

   a. NFPA 70 National Electrical Code
   c. NFPA 130 Fixed Guideway Transit and Passenger Rail Systems including City of Seattle Amendments
d. NFPA 502  Life Safety Code in Tunnels

   a. PEI-1001 Specifications for Architectural Porcelain Enamel

10. U.S. Environmental Protection Agency (EPA)
    a. 22 CCR Section 66260.200 (e) Toxic Characteristic Leaching Procedure (TCLP).

11. Underwriters Laborites Inc. (UL)
    a. UL 542 Lamp holders, Starters, and Starter Holders for Fluorescent Lamps
    b. UL 844 Luminaires for Use in Hazardous (Classified) Locations
    c. UL 924 Emergency Lighting and Power Equipment
    d. UL 935 Fluorescent Lamp Ballasts
    e. UL 1029 High-Intensity-Discharge Lamp Ballasts
    f. UL 1570 Fluorescent Lighting Fixtures
    g. UL 1572 High intensity Discharge lighting Fixtures.
    h. UL 1598 The Standard for Safety of Luminaires

1.03 UL 8750 LIGHTING EMITTING DIODE (LED) EQUIPMENT FOR USE IN LIGHTING PRODUCTSSUBMITTALS

A. General

1. Procedures: Section 01 33 00, Submittal Procedures

2. It should be noted that all items listed to be submitted within this section shall be included in the submission prior to the review of any products. Failure to provide will result in the submittal package being returned and designated incomplete.

3. Data, shop drawings and reports shall employ the terminology, classifications, and methods prescribed by the IES

B. Shop Drawings and Product Data: Submit luminaire shop drawings and data documenting that luminaires, ballast and lamps fully comply with Contract Documents and indicating luminaire construction, photometric performance, installation, and maintenance requirements. Prepare the submittal to include the following information:

1. Clear and legible product specifications, drawings, and illustrations of sufficient detail to describe the following:
   a. Physical description of fixture, including dimensions and verification of indicated parameters
   b. Luminaires’ weight including lamp, effective projected area, details of attaching luminaires, accessories, and installation and construction details
   c. Provisions for conduit entry
d. Electrical Components including:
   (i) Ballast and/or Driver including description, operating characteristics, electrical data, component/capacitor temperature rating and reliability testing report from an independent laboratory.
   (ii) Lenses, Louvers, Baffles, and/or other light controllers
   (iii) Lamp and LED specification
   (iv) Lamp Holders, Printed Circuit Board Construction, and all other electrical components

e. Mounting equipment

f. Manufacturer's recommended replacement parts list

2. Procedures for installation of the complete lighting unit in its final service location(s). Provide dimensions to locations of openings and parts interfacing with remote systems, such as mounting hardware, auxiliary electrical equipment, lighting control equipment, and lamps.

3. Light Loss Factors (lumen depreciation as a function of operating current, temperature and operating hours): Provide measurement bases for these factors.

4. Photometric reports for each luminaire, both hardcopy and electronic, certified by a National Voluntary Laboratory Accreditation Program (NVLAP) lab or independent testing agency. Photometric reports shall be in IES LM-763 standard format and completed within 5 years.

5. Independent laboratory IESNA LM-79 & LM-80 Reports.

6. Vibration and/or Seismic Test Reports showing compliance with requirements in the IBC unless the requirements shown in this section are more stringent.

7. Water Spray Tests, as required.

8. UL Listing. Provide verification that the fixture is UL Listed as required for stated use.

9. Product Drawings shall be submitted for the following:
   a. Each luminaire type shall include complete fabrication and assembly drawings as well as a bill of materials.
   b. Complete fabrication and assembly drawings of each luminaire shall also include details and drawings of the mounting systems and/or brackets
   c. Complete mounting diagrams, with suggested mounting procedures.

10. Operations and maintenance requirements in accordance with Section 01 78 23, Operation and Maintenance Data, and the following information:
    a. Materials and components clearly indicated in the parts list;
    b. Relamping methods;
    c. Special tools required; and
d. Frequency of inspection, tightening, or other service recommended for preventative maintenance.

11. Include within the submittal a list of manufacturer’s representatives (including mailing address, e-mail address, and telephone and fax numbers) identifying which luminaire types they represent.

12. Structural calculations for each luminaire pole

13. Certificate for poles and accessories including documentation that the products are suitable for the luminaire to be installed and comply with designated structural design criteria.

14. Field quality control reports including test report indicating measured illumination levels in tunnels and cross passages.

C. Samples: Submit one complete luminaire of each type indicated on Contract Drawings. Submit one complete tunnel luminaire mounting bracket and one complete perimeter lighting mounting bracket. Each sample requires the Resident Engineer's approval and, once submitted, become the property of Sound Transit. Approved samples will become the Resident Engineer's control samples. Provide samples complete with all housing and trim components in color specified, support accessories, ballast.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Receive, handle and store products in accordance to NECA/IESNA 502 Industrial Lighting, and manufacturer written instructions.

B. Handle and transport products in a manner that prevents damage.

C. Indelibly mark each carton with minimum 1/2-inch high letters containing the following information:

1. Luminaire, lamp, or component type.
2. Quantity.
3. Manufacturer's name and product number.

D. Store products in a clean, dry, and secure storage area pending installation.

E. Keep products in original manufacturer packaging and protect from damage until ready for installation.

1.05 WARRANTY

A. Provide manufacturer's standard warranty. Warranties shall meet or exceed luminaires listed on the Contract Drawings.

PART 2 - PRODUCTS

2.01 GENERAL

A. The lighting design including light level calculations, energy consumption, tunnel clearance, and general aesthetics are based on the luminaires outlined in the lighting fixture schedule and these specifications. Substitutions to the manufacturers and catalog numbers require prior approval of the owner, electrical engineer, and lighting designer, and shall meet or exceed the luminaires in this specification. Acceptance of substitutions shall require that the contractor submit photometric files to be verified by the engineer.
and lighting designer. If substitutions are accepted, it shall be the contractors responsibility to make all changes to the design drawings and installations required at his/her own cost.

B. Each luminaire and mounting systems shall be certified by the manufacturer to meet all Sound Transit and Seattle vibration and seismic requirements for each of the areas in which they are installed.

2.02 MATERIALS AND EQUIPMENT

A. General:

1. All materials, equipment, and devices shall, as a minimum, meet the requirements of UL where UL standards are established for those items, and the requirements on NFPA70.

2. Supply products of thicknesses, gauges, and tempers as indicated, and as recommended by the manufacturer for the specific finish, proper forming operations, and structural requirements.

3. For reflector material use prefinished, copper-free aluminum alloy, minimum thickness of 0.032 inch, architectural type 1 with class m1 anodic coating providing minimum of 85% reflectivity.

4. Stainless steel shall be type 316 conforming to ASTM A167 unless otherwise specified.

5. Aluminum components shall be formed, extruded or cast with a maximum copper content of 0.1.

6. Lenses and diffusers:
   a. Acrylic – shall be UV stabilized, 100% virgin acrylic, clear or diffuse, scratch resistant, with high resistance to yellowing or other aging issues. Fabricated so that any optical components, i.e. Prisms, etc. Are enclosed within the luminaire housing, unless otherwise specified. Thickness shall be as specified for each luminaire.
   b. Polycarbonate – shall be sign-quality type with high resistance to yellowing and other changes due to aging, exposure to heat and UV radiation, scratch resistant, with any optical component enclosed within. Thickness shall be as specified for each luminaire.
   c. Glass shall be tempered borosilicate pressed or spun glass, minimum 0.13 inch thick, unless otherwise specified.

B. Luminaires General:

1. Free of any light leaks and designed to provide required ventilation for electrical components. Verify control temperature of lamps such that lamps reach full light output under installed environmental conditions.

2. For adjustable luminaires, provide positive locking devices to fix aiming angle. Verify luminaires are capable of being relamped without affecting aiming angles.

3. Provide safety devices for removable luminaire elements (cones, reflectors, lenses, louvers and other accessories) to support removable elements when not in normal operating position. Provide safety devices that are detachable if necessary and do not interfere with luminaire performance, maintenance, or the seating of any luminaire element, and not be visible during normal operation.
C. Luminaire Components:

1. Recessed luminaires: comply with NEMA LE4 for ceiling compatibility for recessed luminaires.

2. Fluorescent luminaires shall be UL 1598 listed.


4. Led luminaires shall have the department of energy star label and the D.O.E. lighting facts label.

5. Fixtures shall be clearly marked with the manufacturer’s name and catalog number, voltage, lamp type, maximum wattage and ballast or driver type.

6. Metal parts shall be free of burrs, sharp corners and edges.

7. Housings shall be rigidly formed, weather-tight and light-tight enclosures that will not warp, sag or deform in use.

8. Doors, frames and other internal access shall be smooth operating, free of light leakage under operating conditions, and designed to permit lamp changing without the use of tools. All components and their supports shall be designed to prevent falling accidentally during lamp changing and other maintenance activity as well as when secured in operating position.

9. All luminaire components to be finished in such a way to minimize corrosion in all environments.

D. Luminaire Finishes:

1. Provide luminaires completely factory-finished in colors to match the resident engineer’s control samples and in accordance with the manufacturer’s recommendations for the specific application.

2. Do not start finishing operations until fabrication and forming operations have been completed.

3. Finish ferrous mounting hardware and accessories to prevent corrosion and discoloration of adjacent materials. Full gasketing is required between all dissimilar metals to prevent corrosion of metal parts.

4. Anodized aluminum: class 1 anodic coating.

5. Polyester powder coat paint process. Clean metal before painting using at least a five stage phosphating system consisting of alkali cleaner, hot water rinse, zinc phosphatizing solution with toner, water rinse at room temperature, and chromic acid rinse for neutralizing, unless otherwise specified. Apply to a finished thickness of 2.5 mils, then oven cure at 450 degrees f.

2.03 BALLASTS & DRIVERS

A. Fluorescent Electronic Ballasts – Linear lamps – Instant Start:

1. Shall be installed in fluorescent luminaires in all unconditioned spaces and shall comply with ANSI C82.11 and the following:

   a. Sound rating A

   b. Total harmonic distortion rating: less than 10 percent
c. Transient voltage protection: IEEE C62.41, category a or better

d. Operating frequency: 50/60 KHZ or higher

e. Lamp current crest factor: 1.7 or less

f. Parallel lamp circuits.

g. Starting temperature of -20 degrees F

h. Shall be a high ballast factor type with 1.15 to 1.2 ballast factor unless otherwise specified.

B. Compact Fluorescent Electronic Ballasts – Programmed Rapid Start – 2 Lamp Type:

1. Shall be installed in fluorescent luminaires in conditioned and unconditioned spaces and shall comply with ANSI C82.11 and the following:

   a. Sound rating A

   b. Total harmonic distortion rating: less than 10%

   c. Transient voltage protection: ANSI 62.41 cat. A

   d. Operating frequency: 50/60 kHz

   e. Lamp current crest factor (CCF): 1.7 or less

   f. Starting temperature of -5 degrees F

   g. Ballast efficiency factor: 1.01

   h. High power factor: .98 or higher

   i. Universal voltage

C. Electronic metal halide ballasts – 20 to 150 watts:

1. Shall be installed in metal halide luminaires in conditioned and unconditioned spaces and shall comply with ANSI codes M130, M139, C98, C140, C102, C142 (depending on lamp wattage) and the following:

   a. Sound rating A

   b. Total harmonic distortion rating: less than 15%

   c. Shall have a lamp end-of-life detection and shutdown circuit

   d. Operating frequency: 50/60 KHZ

   e. Shall have a lamp current crest factor of 1.2 or less

   f. Starting temperature of -22 degrees F

   g. Ballast factor of 1.00

   h. Shall be thermally protected

   i. Universal voltage

D. Electronic Metal Halide Ballasts – 200 to 400 Watts:
1. Shall be installed in metal halide luminaires in conditioned and unconditioned spaces and shall comply with ANSI codes 131 and the following:
   a. Sound rating A
   b. Total harmonic distortion rating: less than 15%
   c. Shall have a lamp end-of-life detection and shutdown circuit
   d. Operating frequency: 50/60 KHZ
   e. Shall have a lamp current crest factor of 1.2 or less
   f. Starting temperature of -22 degrees f
   g. Ballast factor of 1.00
   h. Shall be thermally protected
   i. Universal voltage

E. LED Drivers:
   1. LED drivers used in the luminaires shall be of the luminaire manufacturer's specification, subject to the same operating requirements, quality assurance program and terms of warranty as the luminaire.
   2. Type: switching-type with constant current output: commercial grade with a capacitor life rating of 100,000 hours or better at 63 degrees C case temperature.
   3. Other components with limited shelf life or subject to degradation over time shall not be used on the driver circuit board minimum operating life for the driver shall not be less than the operating life of the overall led package measured to 24% depreciation of initial lumen output.
   4. Input voltage: led drivers signed for multi-voltage input (120-277V) shall automatically select for the connected voltage or shall be clearly marked at the point of connection for the particular voltage.
   5. Drivers shall be overload/overcurrent protected on the ac line side connection preferably with an electronic resettable device or a fuse. Fuses shall be protected in tool-less, finger-safe holders and shall be replaceable without removing incoming power.
   6. A shielded and replaceable surge protective device (rated ANSI C62.41CATEGORY C) shall be provided integral with the luminaire/driver package to dissipate transient voltage appearing on the ac input.
   7. The led optics package shall be designed to meet the lighting requirements as specified herein with a drive current no greater than 600ma but shall be designed and capable of continuous operation within allowable temperature limits to meet the application requirements.
   8. Operating temperature range: (-) 40 to (+) 50 c.
   9. Led driver efficiency shall be 90% or higher with power factor greater than 90% at any drive current.
11. Drivers shall include a “removable driver tray” or other system for east of driver replacement.

12. Drivers shall have quick-disconnects.

2.04 LAMPS

A. Fluorescent:

1. Low-mercury lamps: comply with EPA’s toxicity characteristic leaching procedure test; shall yield less that 0.2 mg of mercury per liter when tested according to NEMA IL1.

2. T8 program-start, low mercury lamps, rated 32w maximum, minimal length of 48 inches, 3100 initial lumens minimum, CRI 85 minimum, color temperature 3500K, and average rated life of 40,000 hours or better based on 3 hrs per start, unless otherwise indicated.

3. T8 instant-start lamps, rated 32w maximum, normal length of 48 inches. 3000 initial lumens minimum, CRI 85 minimum, color temperature 3500K, and average rated life of 40,000 hours or better based on 3 hrs per start, unless otherwise indicated.

4. T4 compact fluorescent amalgam, ecologic lamps, rated 42w maximum, 5.6” length, 2400 initial lumens, CRI 82 minimum, color temperature 3500K, 4-pin base, with average rated life of 12,000 hours, or better. With end of life protection.

B. LEDs:

1. Optics package: consisting of one or more led modules or “light bars” each comprised of multiple led’s. The number of led modules used shall be based on the required lumen output to achieve the project illumination design goals defined in field quality control. The optics package with the required number of light bars shall also be rated with the housing for 3g vibration. The optics package (light bars) shall be rated ip66.

2. Manufacturers of led’s shall have been in the business for +15 years, engaged in research, development and marketing of led wafers and shall have patents on these and related products.

3. Led’s used by the luminaire manufacturer shall be identified and direct-sourced from the manufacturer of the led and shall be certified by the luminaire manufacturer as being the led type and rating used in the manufacture and design of the photometric and thermal characteristics of the particular luminaire.

4. Led’s shall be color matched for all light bars on any given luminaire to a correlated color temperature (CCT) of 3500K minimum 5000K maximum with a cri of 70 or shall utilize remote phosphor technology.

5. Consisting of one or more led modules or “light bars” each comprised of multiple led’s connected such that individual led failures may occur without affecting any other led’s in the column and row where the failed led occurred.

6. Quality control checks, specifications and binning procedures used by the manufacturer of the luminaire shall be submitted along with the luminaire specification sheets and shop drawings.
7. Light loss factor: calculated at 15 years (minimum 11 hours of operation each day) combining light lumen depreciation (LLD) calculated at the maximum operating junction temperature, the luminaire dirt depreciation (LDD) and an efficiency factor related power supply degradation to light loss shall be greater than 22.5 percent.

8. Led maximum rated junction temperature: the overall design of the thermal package shall provide a temperature margin when operating at the maximum rated driver current in a 50 degree c ambient temperature not to exceed the maximum allowable led junction temperature.

2.05 LUMINAIRES

A. Tunnel Luminaire:

1. Manufacturer
   a. CREE/BETALED Series # STR-LWY-4M or approved equal. An approved equal luminaire shall meet the criteria listed in Sections above and as follows:

2. Housing
   a. Cast aluminum housing with passive heat sink
   b. Tool-less entry to light engine
   c. Designed to mount on a schedule 40, 2-inch nominal pipe size tenon
   d. Quick disconnect to allow separation and removal of driver and power door
   e. Door safety tether

3. Listings and Certifications
   a. UL 1598 listed wet location
   b. IP 66 per IEC 60529
   c. Certified to ANCI C136.31-2001 Bridge and Overpass Vibration Standards

4. Finish
   a. Epoxy primer with silver powder topcoat
   b. Tested to withstand 5,000 hours of elevated ambient salt fog conditions as defined in ASTM Standard B 117

5. Luminaire and Driver Performance
   a. 40 L.E.D.’s max
   b. Delivered Lumens – 3,600 Lumens minimum
   c. L70 Hours @ 25 degrees C – 150,000 hours minimum
   d. Lumen Depreciation – 94% based on 50K hours @ 15 degrees C
   e. System Watts – 45W max
f. Total Current @277V – 0.19A

g. Photometric Distribution – Type IV Medium with no backlight control

h. Backlight, Uplight, and Glare (BUG) – B1, U0, G1

i. Driver Output Current – 350 mA

j. Operating Temperature -20C to +50C

k. Correlated Color Temperature 4300K (+/- 300)

l. Color Rendering Index – 70 minimum

m. Transient Protection – 10kV minimum in accordance with IEEE/ANSI C62.41.2

n. Power Factor – 0.9 minimum

o. THD – Less than 20% at full load

6. Warranty

   a. 5 year minimum for luminaire and driver

B. Perimeter Lighting Luminaire:

1. Manufacturer

   a. CREE/BETALED Series # STR-LWY-3M or approved equal. An approved equal luminaire shall meet the criteria listed in Sections above and as follows:

2. Housing

   a. Cast aluminum housing with passive heat sink

   b. Tool-less entry to light engine

   c. Designed to mount on a schedule 40, 2-inch nominal pipe size tenon

   d. Quick disconnect to allow separation and removal of driver and power door

   e. Door safety tether

3. Listings and Certifications

   a. UL 1598 listed wet location

   b. Certified to ANCI C136.31-2001 Bridge and Overpass Vibration Standards

4. Finish

   a. Epoxy primer with silver powder topcoat

   b. Tested to withstand 5,000 hours of elevated ambient salt fog conditions as defined in ASTM Standard B 117

5. Luminaire and Driver Performance
a. 20 L.E.D.’s max
b. Delivered Lumens – 2,300 Lumens minimum
c. L70 Hours @ 25 degrees C – 140,000 hours minimum
d. Lumen Depreciation – 93% based on 50K hours @ 15 degrees C
e. System Watts – 37W max
f. Photometric Distribution – Type III Medium with no backlight control
g. Backlight, Uplight, and Glare (BUG) – B1, U1, G1
h. Driver Output Current – 525 mA
i. Operating Temperature -20C to +50C
j. Correlated Color Temperature 4300K (+/- 300)
k. Color Rendering Index – 70 minimum
l. Transient Protection – 10kV minimum in accordance with IEEE/ANSI C62.41.2
m. Power Factor – 0.9 minimum
n. THD – Less than 20% at full load

6. Warranty
   a. 5 year minimum for luminaire and driver

C. Tunnel Cross Passage Luminaire:
   1. Manufacturer
      a. Paramount Industries Craft Lite Series # C4-2-32 or approved equal. An approved equal luminaire shall meet the specification sections listed above and the following criteria.
   2. Housing
      a. 316 Stainless Steel for all metal components both interior and exterior.
      b. Double Channel construction, one welded inside the other with space between the channel sides to capture the diffuser. Threaded hubs continuously welded into the channel ends providing a sealed wireway access. Removable plugs seal the hubs when not utilized.
      c. External stainless steel mounting straps.
      d. Interior SS painted with a minimum reflectance of 88%
      e. EPDM gasketing
      f. 0.150” clear acrylic lens
   3. Listings and Certifications
      a. UL 1598 Listed wet location
b. IP 65 per IEC 60529

4. Luminaire and Ballast Performance
   a. 2 lamp 32W T8
   b. Internal fuse
   c. High efficiency instant start electronic ballast with high ballast factor (1.2)
   d. Total luminaire optical efficiency 88% minimum

5. Warranty
   a. 5 year minimum for luminaire and driver

D. Tunnel Sump Luminaire:
   1. Manufacturer
      a. Cooper Crouse-Hinds Series #CPMVF or approved equal. An approved equal luminaire shall meet the criteria listed in Sections above and as follows:

   2. Housing
      a. Copper free aluminum housing & door assembly with stainless steel external hardware
      b. Side hinged cover for quick access
      c. Stainless steel wire guard
      d. Silicone rubber gasketing
      e. Aluminum reflector
      f. Borosilicate Glass Lens, heat and impact resistant

   3. Listings and Certifications
      a. UL844 Class 1, Div 2
      b. IP 66 per IEC 60529
      c. NEMA 4X

   4. Finish
      a. Epoxy powder coat
      b. Tested to withstand 50,000 hours of elevated ambient salt fog conditions as defined in ASTM Standard B 117

   5. Luminaire and Driver Performance
      a. 2 lamp, 42W compact fluorescent
      b. High power factor +90% electronic ballast
      c. Internal fuse
6. Warranty
   a. 5 year minimum

E. Tunnel Combination Exit Sign:
   1. Manufacturer
      a. Emergi-lite Series # Survive-All SVX approved equal. An approved equal luminaire shall meet the criteria listed in Sections above and as follows:
   2. Housing
      a. PVC body, vandal resistant polycarbonate faceplate fastened with stainless steel screws
      b. Gray housing, aluminum face color
   3. Listings and Certifications
      a. UL 924
      b. IP 66 per IEC 60529
      c. NEMA 4X
   4. Luminaire and Driver Performance
      a. 4W white LED light source
      b. Nickel cadmium battery
      c. Audible diagnostics
   5. Warranty
      a. 5 year minimum

PART 3 - EXECUTION

3.01 GENERAL
   A. Coordinate installation of lighting systems with the requirements of Section 26 05 00, Common Work Results for Electrical; Section 26 05 25, Wire and Cable; Section 26 05 26, Grounding and Bonding for Electrical Systems; Section 26 05 33, Raceway and Boxes for Electrical Systems; Section 26 05 53, Identification for Electrical Systems; Section 26 08 00, Commissioning of Electrical Systems; Section 26 24 16, Panelboards; and Section 26 29 13, Enclosed Controllers and MCC.
   B. Test operation of all luminaires
   C. Clean surfaces in accordance with NECA 502.
   D. Protect installed luminaires from subsequent construction operations.
3.02 CONNECTIONS

A. Tighten electrical connectors and terminals according to manufacturer’s published torque-tightening values. If manufacturer’s torque values are not indicated, use those specified in UL 486A and UL 486B.

B. Use TRV-Loctite in all fasteners before installation.

3.03 FIELD QUALITY CONTROL

A. Inspect each installed fixture for damage. Replace damaged fixtures and components.

B. Test and Observations:
   1. The contractor is responsible to verify normal operation of lighting units after installing luminaires and energizing circuits with normal power source.
   2. The contractor is responsible to verify emergency operation of lighting units after installation is complete and energized.
   3. Contractor to provide all manpower and equipment to enable designer and engineers to aim and or focus any adjustable luminaires.
   4. Contractor to provide all manpower and equipment to demonstrate the installation complies with the contractor documents.

C. Photometric Performance of Installed Units shall meet or exceed those values noted above.

D. Deliver luminaires and lighting equipment to the Project Site complete with related items, completely wired and assembled.

E. Inspect luminaires, lamps, and associated hardware before and after installation to ensure that they are of the quality and type specified and indicated, and are free of defects and damage.

F. Whenever practicable, test lighting systems at the same time that the distribution panelboard or switchboard is tested.

G. Adjust aperture rings on recessed luminaires to be flush with the finished ceiling.

H. Replace luminaires and components with damaged finishes or repair them to the satisfaction of the Resident Engineer prior to project closeout.

I. Install new lamps in luminaires with failed lamps not earlier than 48 hours before the date of final inspection.

J. Replace lamps that fail within 90 days after final Acceptance without additional cost to Sound Transit.

K. After installation of the lighting systems, turn off the normal lighting system and measure the emergency lighting levels along the walkways and the cross passages. Lighting levels shall not be less than 0.25 ft-candles at the walking surface.

3.04 SPARES

A. Fixtures and Mounting Accessories: 5 spare for each type.

B. Lamps: 10 percent of quantity furnished, minimum of two of each size and type.
C. Lenses: 3 percent of quantity furnished, minimum of one of each size and type.
D. Ballasts/Drivers: 3 percent of quantity furnished, minimum of one of each size and type.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for designing, furnishing, and installing a fire alarm and smoke detection system.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. National Fire Protection Association
   a. NFPA 70 National Electrical Code

2. International Fire Code Institute
   a. Uniform Fire Code (UFC)
   b. International Association of Plumbing and Mechanical Officials (IAPMO)
   c. Uniform Mechanical Code (UMC)

3. Code of Federal Regulations
   a. 42 U.S.C. 12181 Americans with Disabilities Act of 1990 (Title III) (ADA)

4. Seattle Fire Department

5. Seattle Fire Code

6. Seattle Department of Design, Construction and Land Use

7. Seattle Electrical Code

8. Seattle Mechanical Code

1.03 SYSTEM DESCRIPTION

A. The system shall provide addressable alarm points including the following:

1. Tamper Switches
2. Dampers
B. An interface port shall be provided on the Fire Alarm Relay Panel (FARP) to report all alarms and fire system status through the station FACP to the Station Building Management System (BMS).

C. Fire system status provided by the FARP to the station FACP shall include all FARP status, alarm and control information including:
   1. Tamper switches
   2. FARP real time clock
   3. FARP system trouble

D. Provide documentation of all status items available. The intent is to fully identify each status item to other contractors for system interoperability and graphical display building.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Shop Drawings:
   1. Drawings shall be drawn on 24-inch by 36-inch erasable mylar or approved. Layout Plan Drawings, Interconnect Drawings, and Wiring Diagrams shall have AHJ approval prior to submitting to the Resident Engineer. Submitted Drawings shall have AHJ approval marked thereon
   2. Provide a general layout of the complete system including equipment arrangement. It shall be the responsibility of the Contractor to verify dimensions and ensure compatibility all other systems interfacing with the fire alarm system.
   3. Identify on the shop drawings; raceway and conductor sizes and types with number of conductors in each conduit. Provide each raceway and device with a unique alphanumeric identification.
   4. Indicate on the point to point wiring diagrams, interconnecting wiring within the panel between modules, and connecting wiring to the field device terminals.

C. Interconnect Drawings: Show only external connections between equipment and devices. All wires shall be identified with alphanumeric designators and all termination points shall show the correct terminal identification.

D. Wiring Diagrams: Show the general physical arrangement of the component parts of the equipment and the connection of all internal wiring. All components, wires, terminal strips, and terminals shall be identified with alphanumeric designators.

E. Equipment Mounting Details: Show the mounting location for all floor and wall mounted equipment including distance from floor and column lines, and fabrication details for all special mounting brackets. Details shall also provide any special installation instructions. These details may be included on the Layout Plan Drawings if space allows.

F. Layout Plan Drawings: Show every device provided under this Section in its relative spatial location. Sections and elevations shall be utilized as necessary to accurately describe the installed location of all devices.

G. System Calculations:
   1. Provide voltage drop calculations indicating the system ability to furnish power at a minimum of 90 percent of nameplate listing in a standby power condition with all devices in alarm utilizing the proposed wire type and size. Demonstrate that
no single wire run between a circuit and its most remote device exceeds the manufacturer’s recommendations for wire length, circuit resistance, or circuit wire to wire and wire to ground capacity.

H. Battery Calculations: Itemize battery loads under standby and alarm conditions. Auxiliary power supplies and transponder battery calculations shall demonstrate the ability of the batteries to supply the required secondary power for a period of 24 hours (or local code requirements) with no external power applied and furnish power for worst case alarm signaling for 5 minutes at the end of this period with all devices in alarm and all device LED’s lighted. Battery sizing shall be at a factor of 1.5 times the results of this mathematical requirement to account for battery aging between replacements and for system modifications and expansions. Complete the Fire Alarm Emergency Power Calculation form in NFPA 72 appendix.

I. Equipment Data Sheets:
1. Show the color, configuration and dimensions of the equipment or device described.
2. Provide technical specifications, such as operating voltage, operating temperature and humidity limitations, mounting and wiring information and a description of the function and operation of the device.

J. Recommended Spare Parts List:
1. Submit a listing of all devices and components recommended for Sound Transit purchase as spare parts to support the system. The list shall include recommended quantities for all items.
2. Provide unit price list valid for 90 days after submittal.
3. Scheduled Testing: The vendor shall include step-by-step procedures and allowances for performance testing every fire alarm device and system output to demonstrate functionality in accordance with specification requirements and AHJ requirements.

K. Operation and Maintenance Manuals: Refer to Section 01 78 23 Operation and Maintenance Manuals. Manuals shall contain the following minimum information for all equipment listed in Part 2, herein:
1. Complete Operating Instructions.
2. Preventative Maintenance Instructions.
3. Catalog Sheets on all Devices and Equipment.
4. Manufacturers Operation and Maintenance Instructions.

L. Record Drawings: At the completion of the installation, provide record drawings to reflect the accurate as-built condition. Working plans shall show actual, accurate locations of devices, and actual routing of conduit and location of end of line devices. Provide updated as-builts on CADD and two full-size prints of the Record Drawings.

M. Acceptance Test Procedure (ATP):
1. Submit for approval, prior to testing, an ATP meeting the requirements of this Section.
2. Submit, for system record, all required data as compiled during installation and testing upon completion of the ATP tests. These data shall be loose leaf bound and labeled as system acceptance testing information.

3. Submit, for system record, a completed "Fire Alarm System Certification and Description" as included in NFPA 72.

1.05 QUALITY ASSURANCE

A. Regulatory Requirements

1. "Component Listing: Fire detection and alarm components furnished under this Section shall be UL listed, listed in the Fire Equipment List or FM, approved for fire signaling or fire suppression use. Accessory equipment shall be manufactured with UL listed components.

2. Conform to the requirements of NFPA 101.

3. Conform to applicable local regulations. Design and installation shall meet the requirements of the Authority Having Jurisdiction (AHJ).

B. Qualifications

1. Manufacturer: Company specializing in smoke detection and fire alarm systems with 5 years experience.

2. Installer: Company specializing in smoke detection and fire alarm systems with 5 years documented experience and certified by the manufacturer as a fire alarm installing contractor.

   a. Evaluate and supplement the design shown in the Contract Drawings as required for proper detection and alarm annunciation consistent with the characteristics of the products he proposes to incorporate into the system.

   b. Prepare a design that, in addition to the minimum requirement shown, includes all additional design equipment and installation necessary to obtain AHJ acceptance.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Edwards Systems Technology

B. Simplex

C. Notifier

D. Honeywell

E. Approved Equal

2.02 MATERIALS

A. General Requirements

   1. Equipment shall be new and marketed by a single manufacturer. The system shall include equipment, software, firmware, raceways, and wiring as required to
provide a complete and operating system in full compliance with these Specifications, Contract Drawings and requirements of the AHJ.

B. FIRE ALARM RELAY PANEL (FARP)

1. Analog addressable FACP shall be comprised of but not limited to the hardware and software required to perform the following major system functions:

a. Surface-mounted steel cabinet with indicator lights, hinged door and cylinder lock, factory finished in baked enamel.

b. System power supplies, including necessary transformers, rectifiers, regulators, filters and surge protection as required for system operation, capable of powering the system in a worst case condition with all devices in an alarm condition and local alarm devices lighted without exceeding the listed ratings.

c. System processors capable of processing all incoming alarm signals and issuing output signals required as a result of the alarm reception in order to transmit all alarms to Fire Alarm Control Panel.

d. Emergency power supply batteries shall be sealed, gelled-electrolyte, designed for fire alarm service.

e. A completely automatic, solid state battery charger shall maintain the batteries in fully charged condition. The charger shall be capable of charging the batteries from 75 percent of full charge to 100 percent of full charge within 24 hours.

f. Real-time clock for time annotation of events on the event recorder and printer

g. Display. Display alarm supervisory and component status signals...

C. SYSTEM POWER Supply

1. Input Power: 120 volts ac. from UPS.

2. Secondary Power Supply:

a. Provide sealed gelled-electrolyte batteries as the secondary power supply for the fire alarm relay panel and each system transponder. The battery supply shall be sized to operate the system in a supervisory mode for a period of 24 hours with no primary power applied and at the end of that period operate its alarm mode for a period of five minutes. Batteries shall be sized at 30 percent above the calculated size to compensate for deterioration and aging during the battery life cycle. Batteries shall be housed in the control cabinet or a separate cabinet with adequate cell separation to prevent accidental discharge. If housed in a separate cabinet, a fuse block shall be provided within the battery cabinet.

b. Provide battery-charging circuitry for each standby battery bank in the system low voltage power supply or as a separate circuit. The charger shall be automatic in design, adjusting the charge rate to the condition of the batteries. Charger shall be housed in the main fire alarm control panel or the battery cabinet.

D. MONITOR MODULE
1. Addressable module shall be provided to monitor tamper switches on gate isolation valves and dampers in the tunnel.

E. WIRE AND CABLE

1. Wire shall be rated for the application and the environment it is installed.
2. Wire shall be RHW, #18 AWG minimum.
3. Cable intended for communication connection with the FACP shall be 6 fiber SMFO.

F. LABELS

1. Indicating lights and controls shall be permanently labeled as to their function.

PART 3 - EXECUTION

3.01 INSTALLATION

A. The installation of the system shall meet all requirements of NFPA 70.

B. Circuit breakers in the panels feeding the control panel shall be fitted with suitable guard, such that the breaker cannot be turned off, but fixed so the breaker can trip and requiring the removal of a screw to remove the guard. Separate breakers shall be provided for each control panel main power and trouble circuits.

C. Conductors shall be copper and shall be of the type and size specified herein or as required to meet the voltage drop requirements of the circuit.

D. DEVICES

1. Relays and other devices to be mounted in auxiliary panels are to be securely fastened to avoid false indications and failures due to shock or vibration.

E. WIRING

1. Within Sub-panels: Shall be arranged and routed to allow accessibility to equipment for adjustment and maintenance.
2. Terminals. Spade lugs with upset legs and insulation sleeves sized for the conductors.
3. Each conductor shall be identified as shown on the Contractor's drawings with wire markers at every splice and terminal point. Attach the wire markers within 2 inches of the wire termination. Mark both ends with alphanumeric wire markers.
4. The fire alarm system shall be wired to conform to NFPA 72 Class A requirements.
5. Provide conductors and power supplies of sufficient size to minimize voltage drop consistent with the proper operation of all devices.

3.02 CONSTRUCTION

A. SYSTEM OPERATION

1. Activation of supervisory condition causing device (tamper switch, valve supervision device, damper) shall initiate a supervisory alarm signal at the FARP.
The FARP shall be connected to the station main control panel, and through the BMS to the Central Control System in the future.

2. Any system trouble caused by wiring failure including open circuits, grounded circuits and shorted circuits on circuitry required to be supervised in this manner; communications loss, device removal, battery low voltage, power loss, charger failure or failure in any device shall have capability to cause the following actions and indications:

   a. Initiate a fire alarm system trouble signal at main control.

3. All signal circuits including trouble circuits and supervisory indicating circuits shall be silencable by means of a switch on the control panel front. Subsequent alarm receptions shall cause the alarm signals to resound indicating the reception of a new alarm condition.

3.03 FIELD QUALITY CONTROL

A. TEST EQUIPMENT

1. Provide all test equipment, instruments, tools and labor required to conduct the system tests.

2. Use test instruments that bear valid calibration stamp showing date of calibration and the expiration date of the stamp. Calibration and accuracy of test instruments shall be certified by an independent testing laboratory having standards traceable to the National Institute of Standards and Technology.

   a. All alarm and control functions.

   b. All trouble and supervisory functions.

   c. Transfer to battery power.

B. ACCEPTANCE TESTING

1. Contractor shall be responsible for acceptance testing in accordance with the ATP, demonstrating the functionality of the system and verifying the correct operation of all system components, circuits, and programming.

2. Prepare a program matrix, referencing each alarm input to every output function affected as a result of an alarm condition on that input. In the case of outputs programmed using more complex logic functions involving "any", "or", "not", "count", "time", and "timer" statements; the complete output equation shall be referenced in the matrix.

3. A complete listing of all device labels for alphanumeric annunciator displays and logging printers shall be prepared prior to the ATP.

4. Contractor acceptance inspector shall use the system record drawings, in combination with the documents specified herein, during the testing procedure to verify operation as programmed. In conducting the acceptance test, the acceptance inspector shall request demonstration of any or all input and/or output functions.

5. System wiring shall be tested to demonstrate correct system response and correct subsequent system operation in the event of:

   a. Open analog loop.
b. Shorted analog loop.
c. Grounded analog loop.
d. Open communication link.
e. Shorted communication link.
f. Grounded communication link.
g. Open zone wiring.
h. Grounded zone wiring.
i. Open signal circuit wiring.
j. Shorted signal circuit wiring.
k. Grounded signal circuit wiring.
l. Initiating device removal.
m. Battery disconnected.
n. Primary power disconnected.
o. System indications shall be demonstrated to have capability as follows:
p. Transmit correct message for each alarm input.
q. Energize correct alarm light for each alarm input.
r. System charging current shall be normal trickle charge for a fully charged battery bank.

6. Demonstrate satisfactory operation to the AHJ.

C. CERTIFICATION

1. Manufacturer's representative shall submit a letter stating he has tested the system and found it acceptable in all respects.

D. Fire Department Acceptance

1. In addition to the proof-testing specified, the installation shall be subject to test by the local AHJ.

E. TRAINING

1. Furnish training to a minimum of four Sound Transit employees as follows:
   a. Training in the receipt, handling and acknowledgment of alarms.
   b. Training in the system operation including manual control of output functions from the system control panel.
   c. Training in the testing of the system including response to common troubles.
d. Training in the programming of the system, including writing program logic modules, entering into the software and uploading and downloading the program to the system.

e. The total training requirement shall be a minimum of 4 hours but shall be sufficient to cover all items specified.

F. Project Closeout

1. System documentation shall be furnished to the Resident Engineer and shall include but not be limited to the following:

a. System record drawings and wiring details including one set of reproducible masters and drawings.

b. System operation, installation, maintenance and programming manuals.

c. System menu-driven instructions for the alteration, addition or deletion of zones, modification, addition or deletion of zone messages and the modification, deletion or addition of logic modules as required for system operation.

d. Documentation of system voltage, current and resistance readings taken during the installation, testing and ATP phases of the system installation.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing, maintaining, monitoring and decommissioning instrumentation which monitor earth and structure movements, groundwater drawdowns, and structural loads during Work.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 12 19, Contract Interface.
2. Section 01 31 19, Project Meetings.
3. Section 01 35 91, Historic Treatment Procedures.
4. Section 01 57 15, Temporary Construction Noise and Vibration Control.
5. Section 01 71 30, Protection and Maintenance of Property and Work.
6. Section 03 05 15, Portland Cement Concrete.
7. Section 31 09 13.50, Tunnel Instrumentation and Monitoring.
8. Section 31 23 19, Dewatering.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. Washington Administrative Codes (WAC)
   a. WAC 173-160 Minimum Standards for Construction and Maintenance of Wells
   b. WAC 173-162 Rules and Regulations Governing the Regulation and Licensing of Well Contractors and Operators

2. Revised Code of Washington (RCW)
   a. RCW 18.104 Water Well Construction Act


4. American Association of State Highway and Transportation Officials (AASHTO):

5. American Petroleum Institute (API):
a. RP 13A Drilling Fluid Materials.

6. American Society for Testing of Materials (ASTM)
   b. ASTM D480 Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), Sch 40 and Sch 80

1.03 DEFINITIONS

A. Instrument Well: A well in which pneumatic, electric, or hydrological instrumentation is permanently or periodically installed to measure or monitor subsurface strength and movement. Instrument Well includes bore hole extensometers, inclinometers, and pneumatic or electric pore pressure transducers.

B. Maximum Level: Maximum allowable value for a specific geotechnical instrument.

C. Replacement Level: Value at which utilities are required to be replaced between points of zero settlement.

D. Trigger Level: Intermediate value less than the Maximum Level for a specific geotechnical instrument that serves as a trigger for additional remedial measures and enhanced monitoring requirements to be implemented.

E. Well: Water wells, resources protection wells, Instrument Wells, dewatering wells, and geotechnical soil borings.

F. Instrument: Survey systems, including surface, structure, optical survey target, and utility settlement points, strain gages, Instrument Wells and geophones.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Instrumentation Installation, Monitoring and Transition Plan: Within 45 days of Notice to Proceed.

C. Work Plan for Instruments on UW Campus: 45 days prior to instrumentation installation on the UW Campus.

D. Corrective Action Plan: Within 45 days of Notice to Proceed.

E. Well Decommissioning Work Plan: Within 45 days of Notice to Proceed.

F. Manufacturers’ Product Data for all types of instruments to be installed, including calibration certificates.

G. Qualifications of Instrumentation Specialist, surveyor, and well driller for well decommissioning.

H. Copies of Start Cards and approved variances for all Instrument Wells.

I. Logs of borings of Instrument Wells, including sample data (depth, SPT N-Values) and Soil Descriptions of each sample.
J. Within five working days after approval of each instrument type, two sets of operating manuals for each type of instrument, including read-out devices and appurtenant equipment required for a complete installation.

K. Within five working days after completion of installation of each instrument, submit location data as required by the instrumentation schedule shown on the Contract Drawings.

L. Monitoring Data.

M. Provide post-decommissioning submittals to the Resident Engineer within 10 calendar days after completion of the work. These include, but are not limited to, well abandonment logs, waste characterization analytical test results, waste disposal certificates, and other completed forms and documents required by the Washington State Department of Ecology and other permitting agencies.

N. Monitoring Plan for Contractor Designed Temporary Shoring.
   1. Instrument types, locations, action levels, and monitoring frequencies in accordance with the requirements specified herein.

1.05 QUALITY ASSURANCE

A. Perform all instrumentation activities described in this Section, including procurement, under the direct supervision of an Instrumentation Specialist retained by the Contractor and approved by Sound Transit. The Instrumentation Specialist may be an independent individual or employee of an engineering firm, testing laboratory, or similar organization. The Instrumentation Specialist shall be licensed as a Professional Engineer registered in the State of Washington with a minimum of five years experience designing, installing, and monitoring instrumentation systems similar to those described in this Section. Demonstrate experience by resume and references.

B. Instrumentation Coordination and Data Review Meetings
   1. See Section 01 31 19, Project Meetings, for meeting requirements regarding instrumentation coordination and data review.

C. Perform all surveying activities under the direct supervision of a licensed Professional Land Surveyor registered in the State of Washington.

D. Calibration
   1. Calibrate all instruments prior to installation.
   2. Verify calibration results are within the tolerances for the particular instrument as listed on the manufacturer’s standard published data sheet for that instrument. Instruments with calibration results that do not fall within the specified tolerances will be rejected.
   3. Recalibrate inclinometers, survey instruments, readout units, and other equipment that is used for monitoring on an on-going basis at the manufacturer’s recommended intervals, or whenever, in the opinion of Sound Transit or the Contractor, there is reason to suspect that the associated data is being affected by calibration changes or errors.
   4. Perform all calibration in accordance with the instrument manufacturer’s recommended methods.
   5. Ensure calibration equipment and standards are traceable to National Institute of Standards and Technology standards and are themselves in current calibration.
Submit evidence of traceability and calibration of standards to the Resident Engineer upon request.

E. Sound Transit may observe instrumentation activities. Sound Transit may also conduct Quality Assurance monitoring of instrumentation. Make the site available and otherwise accommodate these activities.

F. Sound Transit will test instruments for proper function upon completion of installation. Provide assistance to Sound Transit in testing instrumentation. Information will be made available to the Contractor within five days after testing.

G. Complete well decommissioning using a well driller licensed in the State of Washington.

1.06 DELIVERY, STORAGE AND HANDLING

A. Store all instrumentation and related materials in a secured area on site. Provide access to be freely available to Sound Transit.

B. Store all instruments within temperature and humidity limits recommended by manufacturers.

C. Protect the instruments from damage during storage, handling, and other operations.

D. Avoid introducing dirt, dust, or other foreign material into instrument sensors, leads, or other components.

E. Comply with all other recommendations of manufacturers for storage and handling.

1.07 PROJECT CONDITIONS

A. Availability of Data

1. Monitoring data becomes the property of Sound Transit and are not to be disclosed to third parties or published without written permission of Sound Transit.

2. Submit all monitoring data to the Resident Engineer within 24 hours of being acquired, unless noted otherwise.

3. Data developed by Sound Transit will be available to the Contractor within 24 hours of being acquired.

B. Permits and Coordination

1. Sound Transit will acquire all permits, access agreements and other authorizations necessary to perform the instrumentation work described in this Section on private property. Sound Transit will provide copies of all documents to the Contractor at the Preconstruction Meeting.

2. Sound Transit will acquire a Project Construction Permit (PCP) to perform the instrumentation work described in this Section and shown on the Contract Drawings within the public right of way.

3. Coordinate activities affecting utilities with the appropriate utility company.

4. Pre-construction utility surveys: In accordance with Section 01 71 30, Protection and Maintenance of Property and Work.

5. Pre-construction building surveys: In accordance with Section 01 71 30, Protection and Maintenance of Property and Work.
C. Coordination of Instrumentation with Other Contracts

1. At Substantial Completion, coordinate with the follow-on Contractors to take over responsibilities for maintaining and monitoring instrumentation around the U District and Roosevelt Stations.

2. Reference Section 01 12 19, Contract Interface, and the Contract Drawings for additional information and requirements.

1.08 INSTRUMENTATION INSTALLATION, MONITORING AND TRANSITION PLAN

1. Schedule and outline of procedures and timing for installation of instrumentation:
   a. Summary table for all instrument installations by number and location showing timing of installation
   b. Initial monitoring readings schedule.

2. Manufacturer's descriptive literature, including technical specifications, for proposed instruments.

3. Manufacturer's literature on protective enclosures.

4. Detailed manufacturer's literature on installation procedures for each instrument, including cable and tubing locations, and methods for protecting instruments during construction.

5. Materials for grout backfill.

6. Calibration certificates for each instrument. Verify calibration sheets include at a minimum the zero correction value, the gauge factor, temperature correction factor, and calibration data at the time of manufacture.

7. Sample reports for each instrument type.
   a. Description of the instruments to be used.
   b. Description of installation procedures.
   c. Plan showing proposed instrumentation locations, locations of data loggers or computers, cable routing to data loggers or computers, communication systems (if used)

8. Instrument Monitoring
   a. Baseline Readings
   b. Routine Monitoring
   c. Action Level Monitoring
   d. Coordination with in-tunnel monitoring data at cross-passages, in accordance with Section 31 19 13.50, Tunnel Instrumentation and Monitoring.
   e. System Maintenance
   f. Instrument replacement procedures: If an instrument is repaired, replaced or moved subsequent to installation record, submit new instrumentation type, as built location, and calibration sheets. Report the
reason the original instrument was altered and the date the new instrument was operational.

g. Locations of contractor installed control points that will be used for the optical surveys of settlement instrumentation.

1) Contractor installed control points shall be located at least 100 feet horizontally from the centerline of the tunnels or edge of the excavations. Purpose of minimum offset is to lessen potential for construction induced displacements to affect control points.

9. Reporting of Monitoring Data

a. Description of Instrumentation Data Management System (IDMS)

b. How data is posted to IDMS.

c. How data is viewed in IDMS.

d. Reports generated in IDMS.

e. Alarms and notification through IDMS.

f. How access is controlled to IDMS and by whom.

10. Transition Plan – to turn over the system to the follow on Contractors.

a. As-built instrumentation locations

b. Instrument details, such as serial numbers, calibration factors, paper report of data collected during the course of this project, and summary of all repairs and/or replacements to instruments.

c. Report on action levels.

1.09 WORK PLAN FOR INSTRUMENTS ON UW CAMPUS.

1. Installation Procedures and Schedule.

2. Drilling equipment and anticipated work areas.

3. Protection measures to prevent impacts to:

a. Paved and un-paved surfaces from drilling equipment.

b. Air-intake structures near NL-407.3 and NL-407.7 from construction exhaust.

4. Monitoring procedures and frequency for each type of instrument.

1.10 CORRECTIVE ACTION PLAN

A. Details of actions to be taken in the case that settlement or lateral movement, strains, or groundwater drawdown exceed the Trigger or Maximum Levels indicated on the Contract Drawings.

B. Provide specific actions for the following buildings and utilities.

1. 72-inch Diameter North Trunk Sewer

2. 54-inch Diameter Water Main in Montlake Blvd
3. 42-inch Diameter Water Main in 12th Ave NE
   a. New section of pipe adjacent to the Roosevelt Station.
   b. Above ground improvement zone at Cross Passage 31.
   c. Above running tunnels.
4. 138-inch Diameter North Interceptor Sewer
5. NG-425 Manor Apartments
6. NG-433.1 Neptune Theatre
7. NG-433 UW Tower
8. NG-418
9. NG-420
10. NG-421
11. NG-611
12. NG-625

C. Include operational changes to reduce the rate of soil or structural movements, strains in bracing, and groundwater drawdown.

D. See Section 01 35 91, Historic Treatment Procedures, for protection and restoration requirements for historic buildings.

1.11 WELL DECOMMISSIONING WORK PLAN

A. Submit at least 60 Days prior to beginning the decommissioning work.

B. At a minimum, include the following in the work plan:
   1. Schedule of activities.
   2. Methods and procedures of decommissioning.
   3. Equipment to be used.
   4. Driller’s water well drilling license number and qualifications.
   5. Waste management procedures.
   6. Name, address, contact phone number for anticipated disposal facility.
   7. Health and Safety Plan and requirements. Include air monitoring, action levels, and decontamination procedures, in accordance with requirements of appropriate Specification Sections.
   8. Emergency and contingency procedures and measures.
   9. Copies of Notice of Intent to Decommission a Well.
   10. Variances, if any approved.
PART 2 - PRODUCTS

2.01 GENERAL

A. Verify all instruments and equipment are the manufacturer’s standard products without modifications except those that may be noted below.

B. For vibrating wire instruments, ensure the manufacturer submit test data demonstrating that the sensor has been stable, within the accuracy requirements of this Section, for a period of not less than 5 years under laboratory conditions, when thermal effects have been considered. Instruments for which such stability data cannot be submitted are not to be considered “or equal”.

C. Where model numbers are given in this Section, interpret them to represent models selected on the basis of past factory specifications and project experience demonstrating that the equipment will meet the specified performance objectives. Verify with the selected manufacturer that the designated model, or the updated version, or allowed equal, meets the design performance requirements described in this Section.

D. All instruments, except inclinometers and survey system instruments which cannot be readily automated shall be fully compatible with dataloggers and associated software described in this Section, without loss of accuracy or function.

E. Only use signal cables for instruments provided by the manufacturer of the associated instrument and suitable for the expected environment. Do not splice cables between the instruments and dataloggers.

F. All instruments and equipment shall be manufactured in the United States of America.

2.02 MATERIALS

A. Grout backfill mix for all instrumentation installations: Mixture of 94 pounds of portland cement, 25 pounds of bentonite, and 30 gallons of water.

B. Cement: Portland Cement, in accordance with Section 03 05 15, Portland Cement Concrete.

C. Concrete: Concrete Mix Design 3.A.1 in accordance with Table A, Section 03 05 15, Portland Cement Concrete.

D. Epoxy Mortar: Two-component, 100 percent solids, 100 percent reactive compound suitable for use on dry or damp surfaces. Use Sikadur 32 Hi-Mod produced by Sika Chemical Corp., or approved equal.

E. Bentonite:
   1. Premium grade Wyoming sodium montmorillonite manufactured in accordance with API RP 13A.
   2. Bentonite pellets: Compressed Wyoming bentonite of pellet size 3/8 inch to 1/2 inch, Baroid Industrial Drilling Products Company or approved equal.

F. Controlled Density Fill (CDF): In accordance with City of Seattle Standard Specifications for Road, Bridge and Municipal Construction.

G. Materials for Well Decommissioning:
   1. Obtain water from an approved, potable water source.
   2. Bentonite.
3. Use high early strength, Type III Portland cement.

2.03 INCLINOMETERS

A. Inclinometer Probe:
   1. Slope Indicator Co. (Sinco) Model 50302500, Geokon Model 6000 or approved equal.
   2. Measurement Requirements:
      a. Resolution: 0.0001 feet per 2 feet
      b. Accuracy: within 0.025 feet per 100 feet
      c. Range: within 35 degrees from vertical

B. Inclinometer Cable:
   1. Slope Indicator Co. Model 50601000, Geokon Model 6000-4 or approved equal.
   2. Steel core wire, Neoprene cable jacket, depth marks vulcanized to jacket every foot.
   3. Constructed to prevent slippage between jacket and core.
   4. Connectors as recommended by manufacturer.
   5. Minimum length: 200 feet.

C. Readout unit: Slope Indicator Co. Model 50310900, Geokon Model GK-603 or approved equal.

D. Inclinometer Software:
   1. Computer software for uploading casing information to readout device, downloading instrument readings to computer, data reduction, and plotting. Use software that is compatible with the specified probe and read-out device.
   2. Software capable of plotting:
      a. Multiple profiles of the same casing on the same plot calculated from the bottom up or the top down.
      b. Real-Time-Displacement at selected depths.

E. Ancillary equipment: provide pulley assemblies compatible with casing and probe, and other accessories for a complete and functional system.

F. Casing
   1. Slope Indicator Co. Models 51101100 or 51150210, Geokon 6400 or approved equal.
   2. Material: Acrylonitrile/butadiene/styrene (ABS) with internal grooves at 90 degree intervals.
   3. Diameter: 2.75-inch Outer Diameter, 2.32-inch Inner Diameter.
   4. Spiral / misalignment: no more than 0.033 degree per foot
5. Couplings: as provided by casing manufacturer.

6. Casing cement (if used): As recommended by manufacturer for temperature and humidity conditions at the site.

7. Top and bottom end caps: As provided by casing manufacturer.

8. Ancillary equipment: Pop rivets, rivet gun, joint tape, pipe clamps, and other equipment as recommended by casing manufacturer for a complete and functional system.

G. Tremie Tube

1. Continuous polyethylene or approved equal.


3. Wall thickness sufficient to withstand external hydrostatic pressure and internal grout pressure.

H. Backfill: Grout backfill mix specified herein.

I. Protective Enclosure: As specified herein.

2.04 SURVEY SYSTEM

A. Surface Settlement Points: As shown on the Contract Drawings.

B. Structure Settlement and Soldier Pile Shoring Monitoring Points: As shown on the Contract Drawings, or use adhesive-backed targets, Leica Models #635-317 (20mm square), #635-318 (40 mm square), or #635-319 (60 mm square), or approved equal.

C. Utility Settlement Points: As shown on the Contract Drawings.

1. Fiberglass bar: Fibergrate Dynaform®, Tencom P626, or approved equal.

2. Epoxy Mortar: Compatible with fiberglass and utility materials, service life minimum 5 years under wet conditions.

D. Optical Survey Points: Adhesive-backed targets, Leica Models #635-317 (20mm square), #635-318 (40 mm square), or #635-319 (60 mm square), or approved equal.

E. Protective Enclosures: As specified herein.

F. System Accuracy Requirements

1. The accuracy requirements established in this Section apply to the final data, including the composite effects of reflectors, readout instruments, measurement methods, temperature, operator variability, and other contributing factors.

2. All accuracies in this Section have an associated confidence level of 90 percent.

3. Survey points used for monitoring ground surface settlement:

   a. Within 0.01 foot vertical

   b. Within 0.01 foot horizontal

4. Reflectors installed on temporary or permanent structures:

   a. Within 0.01 foot vertical
b. Within 0.01 foot horizontal

5. Optical monitoring lines: 0.01 foot perpendicular to the line.

2.05 STRAIN GAGE SYSTEM

A. Furnish a strain gage system including weldable vibrating wire strain gages, thermistors, signal cables, read-out device, and surface mounted terminal enclosures, as manufactured by Slope Indicator Co., Geokon or approved equal.

B. Provide weldable vibrating wire strain gages with:

1. Maximum strain range of 3,000 microinches per inch.
2. Average sensitivity of one microinch per inch.
3. Temperature range of minus 40 to 150 degrees F.
4. Signal cable with four conductors, rubber insulated and shielded.
5. Service life minimum of five years under normal conditions.
6. Thermistors furnished integral to each strain gage.
7. Slope Indicator Co. Model 52602101 with strain gage sensor Model 52623000, or Geokon Model 4000, 4100 or 4150, or approved equal.

C. Provide waterproof signal cables and connectors in sufficient lengths and numbers for operation of the approved strain gages, as recommended by the manufacturer. Each signal cable shall be clearly labeled with a unique strain gage designation.

D. Provide protective conduit for the signal cables.

E. Provide steel protective covers over all strain gages. The protective covers shall be designed and mounted so as not to affect the operation of the gages, as recommended by the strain gage manufacturer.

F. Provide weatherproof enclosures for termination of signal cables with:

1. Hinged doors that provide rapid and convenient access, without unbolting and removing the entire enclosure.
2. Lockable and keyed alike, provide three sets of keys to Sound Transit.
3. Fitted with flanges, brackets, or other equipment appropriate for the associated type of mounting. Mounting equipment shall be welded or otherwise attached to the enclosure and shall not penetrate the protective enclosure via bolt holes or similar opening.
4. Standard fittings for conduit and cable entry.
5. Terminal board for individual cable connections.
6. Manual switch plates with connectors for the read-out device. Each strain gage designation shall be clearly marked at the switch position to which it was connected.
7. Model 57711600, as supplied by Slope Indicator Co., Model 4000-6 as supplied by Geokon for arc weldable strain gages, Model 4100-5 as supplied by Geokon for the 4100 strain gage, or approved equal.
2.06 PIEZOMETERS

A. Use piezometers of the vibrating wire type, Slope Indicator Co. Model 52611030, Geokon Model 4500S or approved equal.

B. Housing: stainless steel.

C. Use piezometers which include integral thermistors for temperature measurement.

D. Measurement requirements:
   1. Resolution: within 0.025 percent of Full Scale
   2. Accuracy: within 0.1 percent of Full Scale
   3. Range: 100 feet head

E. Protective Enclosures: As specified herein, except with at least 12 inches internal diameter.

2.07 MULTI-POINT BOREHOLE EXTENSOMETER

A. Provide three to five position multiple point borehole extensometers to measure subsurface settlement. Use a reference head with an electric sensor with a total system accuracy not less than 0.1 inch.

B. Anchors and Rods:
   1. Three to five mechanically or hydraulically operated anchors set at depths as indicated on the Contract Drawings. Use Slope Indicator Co. Model 51703952, Geokon Model A-5 or approved equal.
   2. Non-corrosive rods individually sheathed in protective tubing.
   3. Rod spacers to space and support rods.
   4. All necessary couplings, caps, fittings, installation tools and accessories.

C. Electrical Reference Head:
   1. Vibrating wire transducers, Slope Indicator Co. Model 52636325, Geokon Model 4450VW or approved equal. Provide thermistors for transducers.
   2. Connect reference head to datalogger devices for remote reading as specified herein.
   3. Capable of manual check on readings using a depth micrometer or similar device.
   4. Provide a minimum range of up to 2 inches of heave and 6 inches of settlement.
   5. Provide direct burial PVC jacketed-type cabling for remote readouts.

2.08 GEOPHONE

A. See Section 01 57 15, Temporary Construction Noise and Vibration Control, for Geophone requirements.
2.09 PORTABLE READOUT UNIT

A. Furnish one portable readout unit capable of reading all vibrating wire instruments described in this Section.

B. Slope Indicator Co. Model 52613500, Geokon Model GK-403 or approved equal.

C. Provide connector cables for all instruments to be read with the readout unit.

2.10 DATALOGGER

A. Capable of reading all vibrating wire instruments and other sensors associated with instruments described in this Section.

B. Slope Indicator Co. Model CR1000 Datalogger, Geokon Model 8002 LC-2/16 or approved equal, for monitoring multiple instruments at the Roosevelt and Brooklyn Stations.

C. Slope indicator Co. Models 52613310 or 5261400, Geokon Models 8002 LC-2 or 8002 LC-2/4, or approved equal, for single or four channel dataloggers, respectively, for borehole instrumentation.

D. Provide one single-channel datalogger for each piezometer installed.

E. Provide dataloggers for extensometer installations as follows:

1. Install dataloggers prior to the leading TBM advancing to within 500 feet of the piezometer and extensometer locations.

2. Do not remove dataloggers until the trailing TBM has moved at least 2500 feet past the piezometer and extensometer locations.

3. Dataloggers can be installed in a staggered fashion as the tunnels advance.

4. Install dataloggers one week prior to cross passage construction for extensometers located within 200 feet of a cross passage.

5. Do not remove dataloggers until 1 month after cross passage construction has been completed.

6. All other readings can be taken using a portable readout unit in lieu of using dataloggers.

F. Complete with input, output, signal conditioning, communications, and other hardware for a complete and functional system, including but not limited to:

1. Multiplexers

2. Local input/output connection for laptop computer

3. Telephone modem or wireless connection.

G. Software: Capable of comparing the output of each sensor, in engineering units, against user-selected alarm limits, and electronically relaying hourly logged readings to the Contractor’s and Sound Transit’s offices. The alarm systems shall also have 24 hour connection to two pagers, to be assigned to designated representatives of the Contractor and Sound Transit, respectively.

H. Mount the datalogger in a protective enclosure as specified herein that will accommodate each manufacturer’s enclosures for components of the system.
I. Provide a continuous, adequate power source for the data logger in accordance with the manufacturer’s recommendations.

2.11 INSTRUMENTATION DATA MANAGEMENT SYSTEM

A. Capable of storing and disseminating all vibrating wire instruments and other sensors associated with instruments described in this Section.

B. Automated processing of the instrumentation data to convert readings into meaningful engineering units.

C. Checks for action levels for each instrument and alerts the Resident Engineer and Contractor in the event an action level is reached.

D. Displays graphs of instrumentation data.

E. Generates reports of instrumentation data.

F. Access to the information is controlled.

G. Argus system provided by SINCO, or approved equal.

2.12 PROTECTIVE ENCLOSURES

A. Provide protective enclosures with the following features, and as indicated on the Contract Drawings:

1. Bolted lids.

2. Painted or otherwise protected from weather, and waterproof to prevent the ingress of water into the enclosure.

3. With flanges, brackets, or other equipment appropriate for the associated type of mounting. Weld or otherwise attach mounting equipment to the enclosure and do not penetrate the protective enclosure (i.e., no bolt holes).

4. A minimum of 3-inch clearance all around the enclosed instrument, or as indicated on the Contract Drawings, or as required by product manufacturers for specific instruments.

5. Materials: Steel or cast iron.

B. Ensure conduit for signal cable penetrates the wall of the enclosure using standard fittings to provide continuous protection for the cable.

C. Ensure signal cables not enclosed in conduit penetrate the wall of the enclosure through standard weather-proof flexible compression (grommet) fittings.

D. For enclosures subjected to vehicular traffic, mount the enclosure flush with the ground surface, and design for H-20 AASHTO loading.

2.13 IDENTIFICATION TAGS

A. Provide each instrument with a stainless steel indented name tag designating the instrument number, as shown on the Instrumentation Schedule on the Contract Drawings.

B. Indent character a minimum of 3/8 inch high, indented with the indenter marker press provided by name plate manufacturer.
C. Where possible without affecting instrument function, attach name tags directly to instrument using heavy black (UV-resistant) nylon tie-wrap.

D. For name tags that cannot be attached directly to the associated instrument, mount on the associated structure or enclosure as close as practicable to allow convenient, unambiguous reading. Mount using epoxy or other adhesive as recommended by name tag manufacturer. Use a mounting method that is approved by Sound Transit prior to use.

E. For each strain gage, provide an alpha-numeric identifier, approved by Sound Transit at each strain gage location. The identifier shall be stenciled characters two inches high using paint, and permanently marked near the end of the corresponding strain gage signal cable and at the final switch position to which it is connected.

PART 3 - EXECUTION

3.01 GENERAL

A. Be responsible for safety during all instrument installation and monitoring activities. Conduct all instrumentation activities in accordance with applicable Federal, State, and local regulations and all project-specific health and safety plans. Where conflicting requirements are encountered, the most stringent shall apply.

B. Characterize and dispose of all waste generated by work in accordance with applicable regulations and these Specifications.

C. Allow time for and include all instrumentation installation, monitoring, baseline readings, and associated work in the construction schedule.

D. Install all instrumentation complete and functional to the satisfaction of Sound Transit. Replace unsatisfactory instrumentation or associated equipment at own expense.

E. Be responsible for locating utilities before installing instruments that involve digging and drilling. Damage to utilities, structures, or other facilities shall be the Contractor’s sole responsibility.

F. Provide access to all instrument locations and facilitate occasional monitoring of other instrumentation by Sound Transit by temporarily stopping or interrupting certain portions of the work, as may be required as not to delay the work unnecessarily. Schedule and perform work in a manner so as not to delay monitoring by Sound Transit.

G. Upon direction from Sound Transit, remove and dispose of instruments. Do not remove instruments prior to receiving written direction from Sound Transit. Restore the surface to conditions to match the surrounding ground surface.

H. Leave instruments that are no longer accessible in place. Cut signal cables from such instruments flush with the structure or ground surface, remove protective enclosures and at least the upper six inches of casing, and backfill conduits with grout backfill mix as specified herein.

I. Fill holes drilled in concrete structures with epoxy mortar to match surrounding concrete.

J. Remove name tags attached to concrete structures and all associated adhesive.

K. Backfill holes from protective enclosure mountings and similar installations with CDF to prevent future settlement.
L. Prepare and submit the instrumentation borehole and well abandonment Start Cards, as well as a copy to the Washington State Department of Ecology. Submit a copy of approved variances.

M. Notify the Resident Engineer at least 7 Days prior to the start of work.

N. Prepare and submit well abandonment logs to the Resident Engineer.

O. Coordinate activities with other components of these Specifications.

3.02 INSTALLATION SCHEDULE

A. Install all instruments and make operational, with stable baseline readings, a minimum of four weeks prior to the start of shoring, excavating, tunneling, or other work requiring monitoring unless specified otherwise.

B. Obtain baseline readings prior to the start of associated construction activities, as specified herein. Notify Sound Transit when instruments are ready for baseline readings.

C. Verify baseline readings agree to within the accuracy of the instrument or as approved by Sound Transit.

D. Do not begin construction activities without written approval from Sound Transit.

E. For strain gages, install on the corresponding bracing member after lifting and placing, and prior to excavating more than three feet below centerline of struts. Take zero-load readings before excavating more than three feet below centerline of struts.

F. For optical survey targets and contractor designed temporary shoring monitoring points, install on the corresponding shoring element prior to excavating more than three feet below the instrument.

G. Portable readout units may be used for testing instrument function prior to connection with datalogger and at other times as necessary. However, implement fully automated (datalogger) reading function prior to the start of construction of the associated feature, or as specified herein.

H. Provide surveyed location of each instrument within five working days after installation has been completed.

3.03 PROTECTION

A. Provide protective enclosures, plates, conduits, and other equipment as required to protect the instrumentation system from damage during construction.

B. Be responsible at own expense for repairing or replacing instruments or associated components that are damaged during construction, as directed by Sound Transit.

C. Route all signal cables to the corresponding readout station inside of protective conduit.

3.04 INSTALLATION PROCEDURES

A. General

1. Unless otherwise specified, install all instruments in accordance with the manufacturer’s recommendations and requirements. Manufacturer’s recommendations are included as a part of these Specifications by reference, and are applicable, regardless of whether a particular recommendation is explicitly stated in this Section or not.
2. Adhere to manufacturer’s requirements for alignment of instruments.

3. Follow manufacturer’s precautions on handling. Many of these instruments are susceptible to damage if not handled properly.

4. For instruments installed in boreholes (with the exception of the EMI boreholes), perform the following:
   a. Obtain soil samples at 5-foot vertical intervals in conjunction with the Standard Penetration Test (SPT).
   b. Preserve soil samples in airtight jars or plastic bags and submit to the Resident Engineer. Include the following information on the sample container in permanent ink: instrument designation, date, sample number, sample depth and sample SPT value.
   c. Provide the following information on boring logs for each instrument installation: instrument designation, date, logger’s name, sample numbers, sample depths, SPT values, and descriptions of soil samples in accordance with the Unified Soil Classification System (USCS).

B. Inclinometers

1. Install inclinometer casings to the depths listed on the Contract Drawings.

2. Install inclinometer such that the bottom of casing is within 1 degree of vertical, referenced to the top of the casing at the ground surface or top of slurry wall.

3. For cemented casing, join casing using casing cement followed by installation of pipe rivets at 90-degree intervals around casing for each pipe section (total eight rivets). Join other types of casing as recommended by casing manufacturer.

4. Tape all joints and install bottom cap to prevent grout entry.

5. Attach tremie tube to outside of casing using wire or tape. Align end of the tube to be even with bottom of casing, to allow filling of borehole from the bottom up. Block bottom of the tremie tube, to force grout through side ports.

6. Orient inclinometer casing so that the orthogonal grooves are positioned parallel and perpendicular to the expected direction of movement, typically perpendicular to the long axis of the excavation, tunnel, or retaining wall, as approved by the Resident Engineer. Temporarily close top of casing to prevent entry of foreign material.

7. Fill casing with water and anchor casing as required to prevent it from floating out of the borehole during installation.

8. Fill the annular void between the drill hole and the inclinometer casing with backfill grout in one continuous stage, pumped through the tremie tube. Collect minimum 3-inch diameter jar sample of grout at time of installation to verify setting time.

9. Do not install protective cap or otherwise disturb inclinometer for a minimum of 24 hours after installation, or until backfill grout has set, as approved by the Resident Engineer.

10. Install protective enclosure concentric with inclinometer casing to a depth of at least 3-feet below ground surface. Center inclinometer casing inside the protective enclosure, and fill annulus with grout to 12-inches below top of
inclinometer casing. Backfill around outside of casing to ground surface with concrete of CDF to ensure that casing will remain in position.

C. Utility Settlement Points

1. Remove pavement over utility by coring or cutting. Minimize area of pavement removal.

2. Excavate to top of utility using vacuum truck, hand auger, or other suitable method. Do not damage utility.

3. Install temporary casing, trench box, or similar protective equipment as required to provide safe support and access for installation of settlement point.

4. Clean top surface of utility as recommended by epoxy manufacturer to ensure adequate bond with fiberglass bar.

5. Install bar and pipe riser as indicated on Contract Drawings. Maintain centralized alignment throughout installation. Do not allow bar to contact the inside of the riser pipe.

6. Install protective enclosure at pavement surface to accommodate traffic and prevent vandalism or other disturbance of measurement point.

D. Strain Gages

1. Install strain gages in accordance with the manufacturer’s printed installation instructions.

2. Install all strain gages on the corresponding bracing members with steel covers, and stenciled gage identification numbers next to the gages. Mark corresponding identification numbers on each signal cable.

3. Anchor protective conduit at five-foot maximum intervals.

4. Install terminal enclosures adjacent to each section of instrumented struts, in protected location, and with convenient access for Sound Transit.

5. Connections to datalogger shall be made in accordance with the strain gage manufacturer’s recommendations.

E. Piezometers

1. Support all downhole components during installation to prevent damage.

2. Measure the depth of the sensor by measuring the length of sensor and signal cable in the casing, to the nearest 0.1 foot.

3. Backfill around piezometer and boring with backfill grout mix as specified herein.

4. Provide protective enclosure as specified herein.

F. Multi-Point Borehole Extensometer:

1. Drill borings for the extensometer of a diameter as recommended by the instrument manufacturer, to provide a borehole in which to install the anchors and rods.

2. Bundle and install extensometer anchors in one installation at the depths indicated on the Contract Drawings.
3. Install electrical reference head, and hook up to datalogger.

4. Provide protective enclosure as specified herein.

G. Contractor Designed Temporary Shoring Monitoring:

1. For temporary soldier pile shoring systems: install a structure settlement point on the top of every other soldier pile.

2. For other temporary shoring systems, including soil nail walls, install structure settlement points on the top of the wall at intervals of no more than 25 feet.

H. Optical Survey Points:

1. For owner designed shoring: As indicated on the Contract Drawings.

I. Structure Settlement Points:

1. Install Structure Settlement Points: As indicated on the Contract Drawings.

2. Assign a unique name to each Structure Settlement Point.

3.05 MAINTENANCE

A. Maintain all instrumentation in accordance with manufacturer’s recommended procedures and schedule, or as directed by Sound Transit, including instrumentation installed during previous contracts.

B. Replace damaged installations which are the result of the Contractor's operations immediately, including instrumentation installed during previous contracts.

C. Report all damaged or non-functional instrumentation to the Resident Engineer immediately.

3.06 INSTRUMENT MONITORING

A. General

1. Perform monitoring activities for all instrumentation specified herein. Reference the Contract Drawings and requirements specified herein for monitoring frequency for each instrument.

2. Provide all necessary assistance in the form of labor and equipment to enable Sound Transit to access those instruments, which Sound Transit will occasionally monitor. These may include, but are not limited to, removing obstacles or obstructions and providing access to elevated instruments.

3. When instruments detect sudden changes in measured properties, values that exceed Trigger or Maximum Level values, or other notable conditions, take additional readings as required. Coordinate monitoring activities for extensometers at cross-passages with in-tunnel instrumentation in accordance with Section 31 09 13.50, Tunnel Instrumentation and Monitoring.

4. Monitor surface settlement and structure settlement points located within 200 feet of U District and Roosevelt Stations and the Maple Leaf Portal for both lateral and vertical movements. Monitor all other surface settlement and structure settlement points for vertical movement only.

B. Baseline Readings:
1. Obtain baseline readings from all instrumentation.

2. Provide baseline readings by conducting three separate and complete sets of readings on each instrument. Each baseline reading shall be taken at least one but not more than 3 days after the previous measurement. Baseline readings will be taken with sufficient accuracy to produce similar results in each of the three readings.

3. Baseline measurements shall be taken within four weeks of the first required reading of the instrument.

4. Submit electronic copies using files in the latest version of Microsoft Excel and/or specialized software specified herein associated with the instruments described in this Section and paper copies of the data from readings of monitoring instruments and settlement points taken as indicated herein, to Sound Transit within 12 hours after the readings are taken.

C. Action Levels:

1. Action levels are as defined herein, and values for each instrument are indicated on the Contract Drawings or specified herein. Levels indicated are the following, for each type of instrumentation:

   a. Optical survey targets and contractor designed temporary shoring monitoring points, wall survey points: Total movements.

   b. Surface and structure settlement points within 200 feet of the Maple Leaf Portal, U District Station, or Roosevelt Station: Total movements. All other surface and structure settlement points: Vertical movements.

   c. Extensometers, near surface settlement points, and utility settlement points: Vertical movements.

   d. Inclinometers: Horizontal movements.

   e. Piezometers and observations wells: Groundwater Elevation.

   f. Geophones: Velocity.

   g. Strain gages: Strain.

2. When instrumentation data indicates measurements that exceed the action levels, implement the following procedures specified herein.

3. Exceeding Action Levels:

   a. Trigger Level:

      1) Verify measurement and notify the Resident Engineer immediately after obtaining measurements that exceed the Trigger Level for that instrument.

      2) Double the frequency of future monitoring of that instrument and adjacent instruments until movements have stabilized.

      3) Implement procedures in order to limit further movements.

      4) For the following utilities, perform leak tests. Coordinate testing and leak repairs with Seattle Public Utilities (SPU).
a) 54-inch Diameter Water Main in Montlake Blvd.

b) 42-inch Diameter Water Main in 12th Ave NE.

c) All cast iron pipe water mains.

b. Maximum Level:

1) Verify measurements and notify the Resident Engineer immediately after obtaining measurements that exceed the Maximum Level for that instrument.

2) For all values exceeding those indicated, and depending on conditions, Sound Transit may suspend excavation and associated activities at that location, and require the Contractor to submit alternative proposals for minimizing further movements.

3) If work is suspended, obtain approval from Sound Transit prior to restarting excavation at that location, under approved procedures.

4. Monitor geotechnical instruments continuously until ground and/or the structure have been stabilized. The Resident Engineer has the discretion to reduce the frequency of monitoring if readings stabilize.

D. Replacement Levels

1. Replace utilities between points of zero settlement along the utilities if the following movement levels are exceeded:

   1) 54-inch Diameter Water Main in Montlake Blvd: 0.75 inch.

   2) 42-inch Diameter Water Main in 12th Ave NE:

      a) Above ground improvement zone at Cross Passage 31 and running tunnels: 0.75 inch.

      3) For cast iron mains: Maximum levels specified herein and shown on the Contract drawings.

      4) For ductile iron mains: 3.5 inches.

2. For sewer and storm drains: Replace any sagged sections and match existing slopes.

3. Coordinate work with the appropriate utility companies.

E. Contractor Designed Temporary Shoring and Optical Survey Point Monitoring

1. Conduct optical surveys for vertical and horizontal movements.

2. Take readings a minimum of twice weekly during mass excavation.

3. Take readings a minimum of once per week after completion of mass excavation and after wall movements have stabilized. Continue readings on this schedule until directed to modify or cease readings by Resident Engineer.

4. Action levels: Follow procedures specified herein for other instrumentation if the following levels are exceeded.
a. Trigger Level: 0.6 inch.

b. Maximum Level: 1.0 inch.

F. Strain Gage Monitoring

1. Perform monitoring as shown on the Contract Drawings. Monitor gages once per week during construction activities.

2. Action levels: Follow procedures specified herein for other instrumentation if the following levels are exceeded.
   a. Trigger Level: 500 microstrain.
   b. Maximum Level: 700 microstrain.

3.07 WELL DECOMMISSIONING

A. Decommission Wells in accordance with the regulatory requirements and/or approved variance. Do not decommission wells without approval from the Resident Engineer.

B. Decommission wells per the following schedules, as indicated on the Contract Drawings for each well:

1. Schedule A: Decommission well at least 14 Days prior to performing any construction within 250 feet of the well.

2. Schedule B: Decommission after construction, but prior to final Substantial Completion.

3. Schedule C: Do not decommission well. Well will be decommissioned as part of a subsequent contract.

4. Schedule D: Decommission well at any time.

C. Contain and containerize all ground water flowing out of the wells during decommissioning. Store ground water in 55-gallon drums or a temporary holding tank.

D. Restore the surface to conditions to match the surrounding ground surface.

3.08 WASTE MANAGEMENT

A. Collect and properly dispose of all waste generated during well abandonment.

B. Handle and dispose of groundwater collected in accordance with Section 31 23 19, Dewatering.

C. Handle and dispose of well material and soil generated from the abandonment procedure as solid waste.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 31 09 13.50
TUNNEL INSTRUMENTATION AND MONITORING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing, maintaining, protecting and removing of the geotechnical instrumentation required to observe deflections and pressures of the initial shotcrete lining during construction of all Sequential Excavation Method (SEM) tunnels and shafts. This Section also specifies the reading, collecting, reducing, processing, plotting, interpreting, and reporting of data from these instruments.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 45 00, Quality Control \ Quality Assurance
2. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.

1.02 DEFINITIONS

A. Subsurface Instrumentation: Instrumentation installed from within the tunnels during SEM tunneling operations.

B. Instrument Monitoring: The reading of installed instruments at defined time intervals, plotting and calculating data to include: vertical and horizontal displacements, and changes in the phreatic surface.

C. Survey Control: Precise field measurements as specified herein, taken by qualified personnel using approved methods and equipment capable of accurately determining elevations, distances and coordinates that are essential for the prosecution of this Specification Section’s work.

D. Monitoring Bolts: Devices used to measure deformations of the initial shotcrete lining. Measurements are made by optical survey methods.

E. Roof Leveling Points: Devices used to monitor the vertical displacement at the highest point of the initial shotcrete lining. Measurements are made by optical survey methods.

F. Monitoring Cross Section: Tunnel cross section defining installation location of monitoring bolts and roof leveling points as shown on Contract Drawings.


1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Shop Drawings:

1. Survey control layout: Show survey bench marks, and baselines.
2. Instrument layout and installation details.

3. Instrument layout and installation details: After instrumentation installation is complete, submit the following:

4. Instrument identification numbers and locations, including sketches, stations and offsets, coordinates, and date and time of installation, as applicable for each instruments.

5. As-built installation details of each instrument, including initial elevations, materials used, and dimensions of key elements.

6. A separate statement describing the procedure used for the installation of each.

7. Other data pertinent to instrument installation.

8. Proposed schedule and procedures for instrumentation installation in accordance with this section.

9. Installation report of instruments in accordance with this section.

10. Geologic and groundwater conditions relevant to installation and reading of instrument.

11. Thickness of initial shotcrete lining at instrument location.

C. Product Data: Manufacturer’s catalog cuts, drawings, material specifications, installation and maintenance instructions, and other data pertinent to manufactured items used in the work of this Section. Submit information minimum 30 Days prior to installation of instruments or commencement of tunnel excavation, whatever occurs first.

D. Qualifications: Documentation regarding the qualifications of supervisory personnel and technicians performing the instrumentation work have to be submitted in accordance with the requirements of this specifications. Submit information minimum 30 Days prior to installation of instruments or commencement of tunnel excavation, whatever occurs first.

E. Certification: Manufacturer’s certification that products, materials, and equipment furnished meet the specified requirements. Submit information minimum 30 Days prior to installation of instruments or commencement of tunnel excavation, whatever occurs first.

F. Structure and Instrumentation Damage Reports: Submit three copies of notes on approved forms to The Resident Engineer immediately after observations have been made. In addition, report immediately to The Resident Engineer all damaged or otherwise non-functioning instrumentation.

G. Daily Log: In addition to the requirements specified above submit daily, in an approved format, a log of construction events and observations to include the following:

1. Detailed progress of excavation operations each day, location, type and time of installation of excavation supports.

2. Construction loading in the vicinity of instrumentation.

3. Amount and description of water seepage observed in excavation.

4. Cause and duration of any interruptions or delays to excavation.

5. Location or elevation of significant soil strata boundaries contacts, discontinuities, and a brief soil description.
6. Temperature, rainfall, humidity in the tunnel, and other environmental factors that may affect readings or results.

1.04 PURPOSE OF GEOTECHNICAL INSTRUMENTATION PROGRAM

A. Provides early information on the interaction of the construction process and its effect on ground, Ground Water and structures.

B. Permits timely implementation of proper procedures, such as change in excavation sequence and additional SEM support measures, as and when required to prevent damage to structures and utilities.

C. Documents ground movement and structure movement that may occur as a result of construction operations.

D. SEM is a construction method, where the type and amount of tunnel and shaft support designed is based on the anticipated subsurface conditions. The assumptions are verified by monitoring and in-situ measurements. Information during tunneling about the interaction of ground and tunnel support help to foresee problems of lining and face stability and provide basis for adjustment of excavation and support if needed.

E. Displacement measurements and roof leveling provide kinematic observation of the initial shotcrete lining, and provide information about stability of the installed tunnel support.

F. When in the judgment of the Contractor and The Resident Engineer, the instrumentation data indicates potentially damaging ground or structure displacements and/or stresses, adjust the excavation and support procedures as approved by The Resident Engineer, to reduce future ground and structural displacements and/or pressures and stresses to stay below monitoring response values.

1.05 QUALITY ASSURANCE

A. General

1. In accordance with Section 01 45 00, Quality Assurance \ Quality Control.

2. The following describes the minimum inspection and testing required in the Contractor’s Quality Control (CQC) Plan and Program. The implementation of the CQC Plan and Program does not relieve the Contractor from the responsibility to provide the work in accordance with the Contract Documents, applicable codes, regulations and governing authorities. The CQC Plan and Program shall include, but not be limited to, the following testing and inspection elements.

B. Codes Regulations, Reference Standards and Specifications:

1. Codes and regulations of jurisdictional authorities.

2. Make a final quality control inspection for each instrument, at the manufacturer’s facility, prior to shipment. During inspection, complete a checklist to indicate each inspection and test detail. Supply a completed copy of the checklist with each instrument.

C. Survey Control:

1. Establish a secondary control system consisting of horizontal and vertical reference points for constructing the tunnels and placing the final lining. Install horizontal control points either as a brass disc or lead and tack. Install vertical control points either as a brass disc or 1/2 inch diameter by minimum 3-inch long anchor bolt with nut and washer.
2. Employ survey procedures and equipment that are in accordance with the Federal Geodetic Control Committee (FGCC) Standards and Specifications for Geodetic Control Networks using Second Order Class I specifications for horizontal and vertical control work.

3. Ensure all tunnel horizontal traverses are closed loops and adjusted by the least squares method. Ensure all tunnel vertical traverses are closed loops and adjusted by distributing the error of closure equally through the turning points. Provide The Resident Engineer with all traverse adjustments results within 24 hours.

4. Verify all underground tunnel control after completion of the TBM-driven tunnels, but prior to construction of Cross Passages.

5. Install vertical control points at each Cross Passage location throughout the TBM-driven tunnels.

6. Provide each platform mounting bracket with a forced centering hole.

D. Survey Data Collection:

1. Provide and maintain all equipment and software necessary to record all secondary survey control measurement observations.

2. Ensure all survey data provided to The Resident Engineer contains: a time and date stamp for each observation, original field measurements, and the correctly computed coordinates / elevations in addition to the survey data tags necessary to re-compute the data if required.

3. Preserve original unedited data and provide one copy of the data to The Resident Engineer.

E. Survey Equipment, Adjustment and Calibration:

1. Adjust instrument for culmination error every six months or whenever the difference between the direct and reverse readings of theodolite depart from 180 degrees by more than 15 seconds. Readjust cross hairs and level bubble whenever their misadjustments affect instrument reading by amount of least count.

2. The National Geodetic Survey (NGS) has established specific calibration baselines for the purpose of comparing survey equipment to known monumentation to verify correct instrument operation and verification of compliance with manufacturer's specifications. Service every six months and check frequently all electronic distance measuring instruments (EDMI's) and retroreflectors over lines of known distances at an approved NGS baseline. Recalibrate any EDMI if physical damage is incurred.

3. Compute calibration results using procedures in NOS NGS-10, Use of Calibration Base Lines. Record actual measurements, apply atmospheric corrections and then adjust by least squares to compute a constant, as well as, a relative correction factor (scale correction). Calibrate all prisms at the same facility.

4. Forward results of this calibration to The Resident Engineer. Post correction factors in Contractor's office for computing area and apply them as required to maintain specified accuracy.

5. Immediately remove and repair or replace instruments found to be in disrepair or misadjustment.
6. Provide a certification of adjustment to The Resident Engineer for all instruments to be utilized before commencement of any survey work.

7. Provide and maintain the ability in-house to check and adjust all tribrachs for eccentricity. Perform adjustment checks at least once a week. A record of adjustments to all tribrachs shall be kept current and made available to The Resident Engineer monthly or upon request. Number and tag each tribrach with date of last adjustment.

8. Provide one set of calibrated and ready to use back-up instruments.

F. Tolerances:

1. Displacement Measurement: Measure and record the absolute displacement of the respective monitoring bolts to 0.006 foot.

2. Roof Leveling: Measure and record the elevation of the bolt to 0.006 foot.

G. Responsibilities of Contractor

1. Reading of Instruments: Perform reading of all instruments specified herein.

2. Furnishing, installing, protecting and removing of instruments.

3. Monitoring Data:
   a. Submit monitoring data to The Resident Engineer in the form of files stored on compact disks (CDs) with a corresponding hard copy (print out) of the data. Supply data in a format approved by The Resident Engineer and compatible with The Resident Engineer's data analysis software. On each set of data, clearly indicate the instrument identification number and location, reference elevation and depth for readings as appropriate, directions of movement as appropriate, the date and time that the readings were taken, and names of individuals who performed the measurement.

4. Submit the monitoring data to The Resident Engineer within the following time limits:
   a. Submit data from roof leveling and displacement measurements immediately following reading and plotting, but at the latest:
      1) 4 hours after the readings are taken for instruments located in cross passages with ongoing excavation work, shotcrete linings less than 3 days old or cross passages with only partially completed shotcrete linings.
      2) 12 hours after the readings are taken for instruments located in cross passages with shotcrete linings more than 3 days old.
   b. Submit data from all other instruments within 24 hours after the readings are taken.
   c. Make interpretations of the instrument monitoring data, and provide these interpretations to The Resident Engineer within:
      1) 6 hours after the readings are taken for instruments located in cross passages with ongoing excavation work, shotcrete linings less than 3 days old or cross passages with only partially completed shotcrete linings.
2) 12 hours after the readings are taken for instruments located in cross passages with shotcrete linings more than 3 days old.

3) 24 hours after the readings for all other instrumentation.

d. Mining operations will be stopped when monitoring data is not available within the specified timeframes, and commenced once data becomes available.

5. Submit instrument reading data in mined tunnels along with any conversion procedure, if necessary and including an excavation progress graph showing:

a. Distance between the instrument and the excavation face at the time of the initial reading.

b. Distance between the instrument and the excavation face at subsequent readings.

c. Station of other headings which may influence the results including bench/invert heading and any other headings within the tunnel, as well as other construction activities in the vicinity which may influence the results.

d. Detailed list of reading results.

e. Names of the monitoring surveyor and the monitoring technician.

f. Weather conditions if applicable.

g. Include in the report, diagrams related to the above items and descriptive interpretation as necessary.

h. Calculate, record and plot the change in elevation, location or ground water table of each individual instrument with respect to the initial reading. Plots shall be cumulative change data, showing absolute changes versus time. Each plot shall be on an 8.5-inch by 11-inch sheet. Furnish hard copy plots as well as electronic files.

6. Scheduling: Except where otherwise specified, maintain access to all monitoring instruments and facilities. Temporary stoppage or interruption of certain portions of the work may be required to monitor and take readings. Minimum instrument monitoring schedule as specified.

7. Access to Instruments: Provide and facilitate access to instruments for The Resident Engineer.

H. Qualifications of Contractor’s Instrumentation Personnel

1. The Contractor shall engage qualified survey personnel with previous experience performing the type of survey control required. The Contractor shall assign a Registered Land Surveyor licensed in the State of Washington, with a minimum of three years experience in the supervision and direction of survey parties, to be responsible for survey control.

2. The Contractor shall engage qualified technicians with experience in the installation of the instruments specified herein.

3. The Contractor shall engage a licensed Professional Engineer or Land Surveyor registered in the State of Washington with a minimum of 3 years of experience in tunneling and installation of instruments of the type specified in this Section who
is not an employee of the Contractor to supervise and direct installation technicians and to be responsible for instrument installation.

4. The Contractor shall engage a licensed Professional Engineer registered in the State of Washington who is not an employee of the Contractor with a minimum of three years of experience in tunneling and in interpretation of instrument readings of this type, to interpret monitoring results with respect to structural stability of the shotcrete lining.

5. A single person can fill one or more of the personnel positions specified herein.

I. Quality Control Personnel

1. The Contractor shall engage personnel as specified herein to supervise the following instrumentation related activities:
   a. Submission of instruments for approval.
   b. Review of instrumentation layout and location in the field.
   c. Supervision of installation and calibration, if necessary, of instruments.
   d. Production of as-built drawings.
   e. Reading of instruments.
   f. Gathering and processing of data.
   g. Plotting of tables and graphs.
   h. Submission of data to the Resident Engineer.
   i. Maintenance of instruments and replacement of damaged instruments or damaged portions of instruments.
   j. Contact and coordination with the Resident Engineer after instrument reading above threshold value is received.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General

1. On any request for consideration of a substitution, clearly state the nature of the deviation from the product specified.

B. Monitoring Bolts

1. Monitoring Bolt with a fine threaded end (with cap for thread protection) for attachment to a tape survey target or prism as approved by the Resident Engineer.

C. Roof Leveling Points

1. Monitoring Bolt with a fine threaded end (with cap for thread protection) for attachment to a survey target or prism and a suspension plate for positioning of survey rod to allow backup roof deformation readings as approved by the Resident Engineer.
D. Vibrating Wire Piezometers

1. Use piezometers of the vibrating wire type, Slope Indicator Co. “Model 52611030”, Geokon “Model 4500” or approved equal.

2. Housing: Stainless steel.

3. Use piezometers which include integral thermistors for temperature measurement.

4. Measurement requirements:
   a. Resolution: within 0.025 percent of Full Scale.
   b. Accuracy: within 0.1 percent of Full Scale.
   c. Range: 1.5 times cross passage depth below ground water.

2.02 SOURCE QUALITY CONTROL

A. Factory Calibration

1. Conduct a factory calibration on all instruments at the manufacturer’s facility prior to shipment.

2. Provide certification to indicate that the test equipment used for this purpose is calibrated and maintained in accordance with the equipment manufacturer’s calibration requirements and that, where applicable, calibrations are traceable to the National Institute of Standards and Technology.

PART 3 - EXECUTION

3.01 PREPARATION

A. Survey Control

1. Prior to start of construction, install cased bench marks.

2. Establish the elevation of each cased bench mark by running level circuits started and closed at the specified existing bench mark.

3. Establish turning points during leveling so that foresight and backsight distances are approximately equal.

4. Do not exceed sight distances of 200 feet.

5. Establish an error of closure less than 0.003 foot for level circuit closures. If an error of closure greater than 0.003 foot is achieved for any level circuit, resurvey the circuit.

6. Prove the established elevations of cased bench marks by obtaining consistent results on at least three separate and complete level circuits. If an inconsistent elevation for any cased bench mark results, resurvey the level circuit until correct and repeatable elevations are obtained.

B. Protection and Maintenance
1. Protect from damage due to construction operations, weather, and traffic all survey reference and control points, instruments and appurtenant fixtures, instrument leads, connections, and other instrumentation system components.

2. Protect and maintain all instrument systems. Maintenance includes repairs or replacement of damaged or missing system components. Repair or replace damaged or missing instrumentation at no expense to the Resident Engineer using approved materials and procedures. Repair or replace damaged or missing instrumentation components or entire instruments for tunnel instrumentation as required and practicable within 24 hours.

3.02 INSTALLATION

A. Locations and Sequence of Installation

1. Install instruments in accordance with the following schedule:
   a. Install subsurface instrumentation during mining operations.
   b. Install monitoring bolts and roof leveling points as close as practicable to the excavation face at locations shown on the Contract Drawings such that initial reading can be taken no more than 3 hours following excavation.
   c. Install elements of the typical Monitoring Cross Section for the safety of structure, personnel and equipment as shown on the Contract Drawings and wherever indicated by subsurface conditions, or otherwise directed by the Resident Engineer.
   d. Obtain approval from the Resident Engineer if the actual point of instrument installations will be relocated more than three feet from the scaled location shown on the Contract Drawings or approved Working Drawings.

B. Installation of Monitoring Bolts and Roof Leveling Points

1. Install monitoring bolts in the initial shotcrete lining such that the bolts protrude perpendicularly to the initial shotcrete lining. Assure sufficient anchoring of the bolts into the shotcrete to avoid loosening of the bolts over the entire construction period. Install bolts in predrilled holes in the shotcrete bonded with epoxy resin.

C. Vibrating Wire Piezometers

1. Install all instruments in accordance with the manufacturer's recommendations and requirements. Manufacturer's recommendations are included as a part of these Specifications by reference, and are applicable, regardless of whether a particular recommendation is explicitly stated in this Section or not.

3.03 FIELD QUALITY CONTROL

A. Instrument Monitoring

1. General
   a. As a minimum, perform tunnel geotechnical instrumentation monitoring, and follow the minimum schedule as specified herein.
   b. When instruments detect sudden changes in deformation or changing groundwater levels, take additional readings in number and frequency as directed by the Resident Engineer.
2. Responsibility for Monitoring:
   a. Monitor all existing installed instrumentation specified herein during construction and dewatering operations. Instrument monitoring requirements are as specified herein.
   b. Provide all necessary assistance in the form of labor and equipment to also enable the Resident Engineer to access and monitor the instruments.

3. Initial Readings:
   a. Obtain initial readings from all instrumentation.
   b. Perform initial reading prior to commencement of the succeeding top heading or bench-invert excavations.
   c. Provide initial readings by conducting three separate and complete sets of readings on each instrument. Readings will be taken with sufficient accuracy to produce similar results in each of the three readings.

4. Reading Frequency:
   a. Monitoring Bolts and Roof Leveling Bolts:
      1) Obtain initial and subsequent readings of convergence bolts and roof leveling points by use of optical survey methods.
      2) Read instrument daily from installation to completion of SEM excavation and support activities.
      3) Continue daily readings after completion of SEM works until movements have stabilized. Continue reading weekly until the installation of the waterproofing system.
   b. Vibrating Wire Piezometers:
      1) Read instrument every 6 hours after start of dewatering system and continue until the start of Cross Passage excavation.

5. Instrumentation Monitoring Response Values:
   a. Instrumentation monitoring response values are defined in Table 1, herein.

   TABLE 1 - MONITORING RESPONSE VALUES

<table>
<thead>
<tr>
<th>INSTRUMENT TYPE</th>
<th>RESPONSE VALUES</th>
<th>LIMITING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>THRESHOLD</td>
<td>LIMITING</td>
</tr>
<tr>
<td>Monitoring Bolts</td>
<td>Absolute Displacement</td>
<td>Absolute Displacement</td>
</tr>
<tr>
<td></td>
<td>0.50 inch</td>
<td>0.75 inch</td>
</tr>
<tr>
<td>Roof Leveling Points</td>
<td>Vertical Displacement</td>
<td>Vertical Displacement</td>
</tr>
<tr>
<td></td>
<td>0.50 inch</td>
<td>0.75 inch</td>
</tr>
</tbody>
</table>

   b. Implement excavation and support sequence changes and/or additional support measures as specified in Section 31 71 23, Tunnel Excavation.
by Sequential Excavation Method, when instrumentation data indicates settlement of ground and/or movement of the initial shotcrete lining beyond the monitoring response values specified in Table 1.

6. Exceeding Monitoring Response Values:

a. Threshold Values

1) Verify measurement and notify the Resident Engineer immediately after obtaining any measurement that exceeds the Threshold Value for that instrument. Double the frequency of future monitoring of that instrument and adjacent instruments until movements have stabilized to the satisfaction of the Resident Engineer. Implement procedures (e.g. reduce advance rates and increase initial lining thickness or install additional support measures) in order to limit further movements.

b. Limiting Values

1) Verify measurement and notify the Resident Engineer immediately after obtaining any measurement that exceeds the Limiting Value for that instrument. For all Limiting Values exceeding those indicated, and depending on conditions, the Resident Engineer may suspend excavation and associated activities at that location, and require the Contractor to submit alternative proposals (i.e. change of excavation and support sequence, increase of initial lining thickness and/or installation of additional support measures items as specified in Section 31 71 23, Tunnel Excavation by Sequential Excavation Method, or any other measures) to stop further movements. If work is suspended, obtain approval from the Resident Engineer prior to restarting excavation at that location, under approved procedures.

c. Monitor geotechnical instruments continuously until the ground and/or the structure have been stabilized. Inform the Resident Engineer of the results of the implemented procedures.

END OF SECTION
SECTION 31 11 00
CLEARING AND GRUBBING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for clearing, grubbing, and disposing of vegetation, including bushes, brush, trees, stumps, roots, rubbish, refuse, trash, and debris within the indicated site limits.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 35 93, Archaeological Finds.
2. Section 01 56 39, Temporary Tree and Plant Protection.
3. Section 02 41 00, Demolition.
4. Section 31 20 00, Earth Moving.

PART 2 - PRODUCTS

2.01 MATERIALS AND EQUIPMENT

A. Furnish materials, tools, equipment, facilities, and services as required for performing site clearing and grubbing.

PART 3 - EXECUTION

3.01 PREPARATION

A. Prior to clearing and grubbing operations, notify the Resident Engineer at least one week in advance of planned activities and make work sites available to Sound Transit's Archaeologist for observation. Notify the Resident Engineer in the event artifacts are discovered during clearing and grubbing work. Comply with the requirements of Section 01 35 93, Archaeological Finds.

B. Dispose of cleared, grubbed, and removed material away from the site. Burying and burning of materials at the site is not permitted. Stockpile salvaged material in a secured location.

C. Clear and restore areas used for the Contractor's convenience; restore areas to original condition providing mulching, seeding, and planting as required.

D. Protect survey markers and monuments, existing improvements, existing observation wells and piezometers, and adjacent properties from removal and damage.
E. Protect all trees, lawns, and planted areas that are not in direct conflict with the work shown on the Contract Drawings. Restore all on-surface disturbed areas to a condition satisfactory to the Resident Engineer.

F. Review with the Resident Engineer the location, limits, and methods to be used before clearing work. Perform clearing and grubbing in compliance with all local, state, and federal laws and requirements pertaining to clearing and grubbing.

G. Care of Existing Trees: Protect trees and plants indicated in the Contract Documents to remain and to be preserved as specified in Section 01 56 39, Temporary Tree and Plant Protection.

H. Tree Salvage:
   1. Prior to tree removal, attend an on-site meeting with the Resident Engineer to review requirements for tree salvage for each tree.
   2. For tree salvage, de-limb all trees and cut into 14 ft sections with a minimum diameter of 12 inches.
   3. Clearly label each log with the tree tag number in weatherproof ink or paint.

3.02 CLEARING AND GRUBBING

A. Clear the site within the limits indicated on the Contract Drawings and remove cleared materials and debris from the site. Unless otherwise indicated, clearing and grubbing includes removal of all roots, grass and debris from the existing ground.

B. Remove stumps and roots completely in excavation areas and under embankments where the original ground level is within 3-1/2 feet of subgrade or slope of embankments. In embankment areas, where the original ground level is more than 3-1/2 feet below the subgrade or slope of embankment, cut off trees, stumps, and brush to within 6 inches of the ground.

C. Do not start earthwork operations in areas where clearing and grubbing are not complete. Stumps and large roots may be removed concurrently with excavation.
   1. Where the work includes requirements for wood chip mulch, acceptable material from clearing and grubbing activities may be used to produce such mulch.

D. Demolition/Removal
   1. Coordinate the work of this Section with the work of Section 02 41 00, Demolition, as required to remove existing pavements, curbs, structures, and site improvements which interfere with new construction and where demolition is not indicated.

E. Disposal of Cleared Vegetation, Grubbed Material and Waste
   1. Dispose of in a safe, acceptable manner, in accordance with applicable laws and ordinances.
      a. Do not bury or burn trash and debris on the site.
      b. Remove cleared vegetation, grubbed material and waste from the site at frequent intervals so that its presence will not delay the progress of the Work or cause hazardous conditions for workers and the public.
c. Removed materials, waste, trash, and debris shall become the property of the Contractor. Remove such materials from the Site and dispose of in a legal manner. It is the responsibility of the Contractor to locate disposal sites and determine length of haul route.

2. Backfill: Backfill excavations resulting from work under this Section in accordance with applicable requirements of Section 31 20 00, Earth Moving.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for earthwork including: excavation and placement of compacted fill, subgrade and foundation preparation; subsurface extraction of miscellaneous structures and facilities indicated or required to be removed; and finish grading.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 35 93, Archaeological Finds
2. Section 01 56 39, Temporary Tree and Plant Protection
3. Section 01 57 13, Temporary Erosion and Sediment Control
4. Section 01 57 19, Temporary Environmental Project Control
5. Section 01 71 23, Field Engineering
6. Section 01 74 00, Cleaning and Waste Management
7. Section 02 41 00, Demolition
8. Section 31 11 00, Clearing and Grubbing
9. Section 31 23 19, Dewatering
10. Section 31 23 33, Trenching and Backfilling
11. Section 31 50 00, Excavation Support and Protection
12. Section 32 11 23, Aggregate Base Courses
13. Section 32 90 00, Planting
14. Section 33 01 00, Operation and Maintenance of Utilities

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.


c. ASTM D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort

d. ASTM D2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

e. ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

f. ASTM D2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)

g. ASTM D2974 Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils

h. ASTM D3017 Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)

i. ASTM D4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

2. Washington Administrative Code (WAC)

a. WAC 296-155 Part N, Safety Standards for Construction Work, Excavation, Trenching and Shoring

3. Washington State Department of Transportation (WSDOT)

a. Standard Specifications for Road, Bridge, and Municipal Construction

4. City of Seattle (COS)

a. Standard Plans for Municipal Construction

b. Standard Specifications for Road, Bridge, and Municipal Construction

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Material source, and all tests and certifications necessary to approve material, including moisture/density relation test results. If on-site material is proposed for use as any of the materials specified in construction, provide test results certifying suitability of said material. Sampling and tests for on-site material suitability shall be performed at a minimum of every 200 cubic yards of material, and shall also be performed randomly at the request of the Resident Engineer.

1.04 QUALITY ASSURANCE

A. Quality Plan: Conform to Section 01 45 00.20, Quality Assurance / Quality Control, covering all earthwork operations and the field quality control to be performed.

B. Quality Control: Provide quality control to ensure compliance with specified requirements.
C. Tests: Engage the services of an approved independent soils testing laboratory to perform tests.

D. Tolerances:
1. Construct finished surfaces to plus or minus 1/2 inch of the elevations indicated.
2. Maintain the moisture content of fill material as it is being placed within 2 percent of the recommended moisture content of the material.

1.05 CLASSIFICATION OF EARTHWORK

A. For specification purposes, earthwork shall be classified as follows:
1. Excavation-Common: All excavation involved in grading and construction of the station structure, parking areas, landscaped areas, walkways, roads, driveways, and connections thereto; and all other excavation classified or indicated as common excavation.
2. Subsurface Extraction: Includes removal of abandoned utilities, tanks, walls, foundations, and other miscellaneous subsurface man-made structures that interfere with new construction and are designated to be removed, and the cleaning of such items if they are indicated to be salvaged. Removal of such obstructions at or above grade is specified in Section 02 41 00, Demolition.
3. Structure Backfill: Structure backfill includes furnishing structural fill material, and placing and compacting structural fill material around structures to the lines and grades indicated. Structural fill material includes borrow excavation and material when required.
4. Fill for Raising Grade: Includes raising of subgrade or grade to indicated elevation with structural fill, including moisture-conditioning and compaction of placed fill material. Structural fill material includes borrow excavation and material when required.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Fill and Backfill Materials – General Requirements
1. For material used for fill and backfill construction use inert, inorganic soil, free from deleterious substances and of such quality that it will compact thoroughly without the presence of voids when watered and rolled. (Inorganic soil is defined as soil containing less than two percent by weight of organic material when tested in accordance with ASTM D2974.) Excavated on-site material will be considered suitable for fill, backfill, and embankment construction if it is free from organic matter and other deleterious substances and conforms to the requirements specified herein.
2. When excavated material is suitable for fill, backfill, and embankment construction, condition material for reuse and properly stockpile for later filling and backfilling operations. Conditioning includes spreading material in layers not to exceed 8 inches and raking free of debris and rubble. Remove rocks exceeding 6 inches in largest dimension and deleterious material from the site and disposed of as specified herein under Disposal of Surplus Material.
3. Where conditions require the importing of fill or backfill material, use an inert soil or soil-rock material free of organic matter and meeting or exceeding the minimum requirements specified herein for the location.

4. All material to be used for filling and backfilling construction requires written approval of the Resident Engineer.

B. Structural Fill

1. Select from suitable on-site excavated material meeting the requirements of Section 9-03.14(1), Gravel Borrow of the WSDOT Standard Specifications; otherwise, import material conforming to Section 9-03.14(1), Gravel Borrow of the WSDOT Standard Specifications.

2. Material containing peat, muck, swampland, buried logs or stumps, or other contamination making the material not fit for embankment base is deemed unsuitable.

C. Non-structural Fill

1. Select from suitable on-site excavated material as determined by the Resident Engineer; otherwise, the Contractor shall import material conforming to Section 9-03.14(3), Common Borrow of the WSDOT Standard Specifications. Material containing wood, organic waste, coal, charcoal, or any other extraneous or objectionable material is deemed unsuitable.

D. Backfill where not otherwise indicated: Gravel Borrow, Mineral Aggregate Type 17 in accordance with COS Standard Specifications Section 9-03.14.

E. Structural backfill Controlled Density Fill (CDF) in accordance with WSDOT Standard Specification Section 2-09.3(1)E.

F. Materials for Trenching, Bedding, and Backfilling of utilities in accordance with Section 31 23 33, Trenching and Backfilling.

G. Aggregates for pavement bases: Section 32 11 23, Aggregate Base Courses.

H. Aggregates including but not limited to the following categories are to comply with the City of Seattle Standard Specifications Section 9-03:

   a. Roadway Ballast
   b. Crushed Surfacing
   c. Gravel Backfill for Walls
   d. Pit Run Sand, Washed Sand
   e. Pea Gravel: Mineral Aggregate Type 9

2.02 SOURCE QUALITY CONTROL

A. Verify that fill, and backfill, materials proposed to be used in the work are tested in the Independent Testing Laboratory for compliance with WSDOT Standard Specification Section 9-03.20, COS Standard Specification Section 9-03.15 and as follows:


5. Percentage of Wear: ASTM C131 or C535 as applicable.

B. Where classification of soils is necessary to meet specified requirements, perform laboratory tests in accordance with ASTM D2487.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Staking and Grading
   1. Lay out the work, establish all necessary markers, bench marks, grading stakes, and other stakes as required, in accordance with the requirements specified in section 01 71 23, Field Engineering.

B. Existing Utilities
   1. Verify on site the location and depth (elevation) of all existing utilities and services before performing excavation work. Refer to Section 33 01 00, Operation and Maintenance of Utilities, for additional requirements. When excavating within 3 feet of an active utility line, perform excavation by hand.
   2. Remove abandoned utilities or utilities indicated to be abandoned or removed encountered in the progress of excavating and plug ends.
   3. Immediately report the discovery of active utility lines which are not indicated in the Contract Documents to the Resident Engineer and utility owners involved. Allow the Resident Engineer and utility owners free access to determine the measures deemed necessary to repair, relocate, or remove the utility.

3.02 PREPARATION

A. Erosion Protection: Refer to Section 01 57 13, Temporary Erosion and Sediment Control.

B. Clear and Grub areas indicated on the Contract Drawings prior to earth moving operations in those areas. Refer to Section 31 11 00, Clearing and Grubbing.

C. Perform demolition in accordance with Section 02 41 00, Demolition, prior to earth moving operations in those areas.

D. See Section 01 56 39, Temporary Tree and Plant Protection, for Temporary Tree and Plant Protection requirements.

E. Comply with the requirements of Section 01 35 93, Archaeological Finds.

3.03 CONSTRUCTION

A. Earthwork General Requirements
   1. Dust Control: Refer to Section 01 57 19, Temporary Environmental Controls.
   2. Erosion Protection: Prevent erosion of the site at all times. Refer to Section 01 57 13, Temporary Erosion and Sediment Control.
3. Construction Traffic: Disperse travel paths of traffic and construction equipment over entire width of compacted surfaces so as to aid in obtaining uniform compaction. Protect exposed soil layers with high moisture content from excessive wheel loads.

4. On-Site Excavation or Borrow Pits: Do not excavate or remove any material from the project site or right-of-way which is not within the designated excavation, as indicated by the slope and grade lines, without written authorization from the Resident Engineer.

5. Stockpiling of Fill and Backfill Material:
   a. Excavate and separately stockpile suitable fill and backfill material, segregated by type, during the progress of the excavation work. Save sufficient suitable excavated material, if available, for later filling, backfilling, and embankment construction.
   b. Establish excavated material stockpiles on site only in locations where they will not interfere with the progress of the work. It is the responsibility of the Contractor to establish stockpiling offsite, if necessary.

6. Disposal of Surplus Material:
   a. Excess earth materials, unsuitable materials, and debris shall become the property of the Contractor. Remove material from the site and dispose it in accordance with Section 01 74 00, Cleaning and Waste Management.
   b. Comply with the WSDOT Standard Specification Section 2-03.3(7) and its referenced sections.
   c. The Contractor is responsible for locating an approved disposal site and haul route.

7. Maintenance of Excavations, Slopes, and Embankments:
   a. Excavate and remove material outside the limits of the excavation that is unstable and constitutes potential slides and material that comes into excavations for any reason including from the driving of piles.
   b. Maintain slopes and embankments until substantial completion and acceptance of the work. Promptly repair slides, slipouts, washouts, settlements, and subsidences that occur for any reason, and refinish the slope or embankment to the indicated lines and grades.
   c. Refer also to Section 31 50 00, Excavation and Support Protection, for requirements.

B. Subsurface Extraction
   1. Remove subsurface facilities and obstructions to the extent indicated.
   2. When subsurface facilities are encountered during excavation that interfere with new construction, and such facilities are not indicated, notify the Resident Engineer promptly for corrective determination.

C. Dewatering
   1. Dewater excavation as specified in Section 31 23 19, Dewatering.
2. Prevent surface water and subsurface or ground water from flowing into excavations and from flooding project site and surrounding areas.

3. Provide and maintain pumps, sumps, suction and discharge lines, and other dewatering system components necessary to convey water away from excavations.

4. Establish and maintain temporary drainage ditches and other diversions outside excavation to convey water. Do not use trench excavations as temporary drainage ditches.

D. Moisture Control

1. Initiate stormwater runoff control measures to intercept and convey stormwater away from the site. Initiate dewatering measures to eliminate any standing water.

2. Where subgrade or layer of soil material must be moisture conditioned before compaction because it is too dry, uniformly apply water to surface.

3. Remove and replace, or scarify and air dry soil material that is too wet to permit compaction to specified density.

4. Soil material removed because it is too wet to permit compaction may be stockpiled or spread and allowed to dry. Assist drying by discing, harrowing, or pulverizing until moisture content is reduced to a satisfactory value.

E. Excavation

1. General Excavation Requirements:
   a. Perform excavation as indicated and required for concrete footings, foundations, retaining walls, exterior paving, floor slabs, concrete walks, and for site levels and grading, and provide shoring, bracing, underpinning, cribbing, pumping, and planking as required.
   b. Comply with applicable requirements of WAC 296-155 Part N.
   c. Trenching for utilities: Section 31 23 33, Trenching and Backfilling.
   d. Excavate the bottoms of excavations to be level, firm, undisturbed earth, clean and free from loose material, debris, and foreign matter.
   e. Excavate to the lines and grades indicated on the Contract Drawings.
   f. Support and maintain excavations by providing structural support of earth walls as specified in Section 31 50 00, Excavation Support and Protection, so that sides are stable and will not move. Excavations may be maintained by sloping cut faces where space permits, if calculations sealed and signed by a civil or structural engineer currently registered in the State of Washington, show that the slopes are safe. Ensure calculations consider all existing conditions, including adjacent traffic, construction loading, and other local effects.
   g. Keep trenching widths to a minimum. Allow for adequate working space for installing forms and as required for safety systems for within the limits of excavations.
h. Remove unstable bottom material. Remove large stones, debris, and compressible soils from excavation bottoms to a minimum depth of 12 inches.

i. Except as otherwise indicated, preserve the material below and beyond the lines of excavations. Where an excavation is carried below the indicated grade, backfill with structural fill to the indicated grades. Compact as described in Article 3.03.1, herein.

j. Place excavated material at a sufficient distance from edge of excavation so as not to cause cave-ins or bank slides, but in no case closer than 3 feet from the edge of excavations.

k. Payment will not be given for over-excavation caused by the Contractor’s negligence or convenience.

F. Backfilling

1. Backfill for utility trenches as specified in Section 31 23 33, Trenching and Backfilling.

2. Use materials removed from site excavations if such material meets specified requirements.

3. Backfilling is required around all substructures. Fill holes, pits, and other voids with structural fill and provide compaction in accordance with Article 3.03.1.

4. Allowable thickness of fill lifts depends on the material type and compaction equipment used. Place backfill in layers not to exceed eight inches of loose material for materials to be compacted by heavy equipment, and not more than four inches of loose depth for material compacted by hand-operated tampers.

5. Place backfill material in such manner that unbalanced horizontal loads will not be applied to a newly-placed structure or portion of structure, utility, or pipeline. Do not backfill around portions of structures requiring backfill on only one side or on less than all sides, until the concrete has reached the specified 28-day strength to withstand the earth pressures on structures.

G. Subgrade Preparation and Protection

1. Prepare and protect the subgrade for roadway surfacing and pavements in accordance with COS Standard Specification Section 2-09.3.

H. Finish Grading

1. Finish grade all areas to elevations and grades indicated within the specified tolerance.

2. In landscape areas where utility trenching or grading activities occurred, grade to the depth required below finished grade to allow placement of topsoil and/or mulch up to finished grade indicated in the Contract Drawings.

I. Compaction

1. Before compaction, moisten or aerate each layer as necessary to provide the optimum moisture content.

2. Compaction Density: Compact each layer of embankment, fill, and backfill material to not less than the indicated or specified compaction. Required compactions are defined as Class I and Class II, as follows:
3.03 REQUIRED COMPACTIONS

a. Class I Compaction: 90 percent relative compaction as determined by ASTM D1557.

b. Class II Compaction: 95 percent relative compaction as determined by ASTM D1557.

3. Required Compactions:

a. Embankment or Fill where the Surface will be Bearing Foundation: Class II for full depth. Where embankment construction exceeds 5 feet in depth, provide minimum Class I compaction below the top 2.5 feet.

4. Fill Below Pavements: Class II for full depth. Where fill exceeds 3 feet in depth, provide minimum Class I compaction below the top 3 feet.

5. Backfill around Structures: Class I under top 12 inches; Class II for top 12 inches.

6. Cut-and-Cover Backfill: Class I to 36 inches above utility; Class II for balance, with a minimum of Class II for top 12 inches.

7. Original Ground or Cut Subgrade: Except where original ground or cut subgrade, or fill less than 1 foot thick, will be subgrade or bearing foundation, scarify the surfaces and provide Class II compaction for at least 8 inches in depth. Include the following additional requirements:

a. Provide Class II compaction for original ground when such original ground is within 2.5 feet of finished pavement grade, for full width of pavement plus 3 feet on each side thereof.

b. Provide Class II compaction for top 6 inches of undisturbed original ground upon which embankments are to be constructed.

c. Where not otherwise indicated or specified and where structures are not involved, provide Class I compaction to minimize settlement.

3.04 FIELD QUALITY CONTROL

A. Density Tests: Test compacted fill, backfill, and embankment to verify compliance with specified requirements in accordance with ASTM D2922. Conduct test frequently enough to be in accordance with the Contractor's Quality Plan, but not less than the following:

1. Expansive Horizontal Areas: One test per 100 cubic yards, or fraction thereof, of fill or backfill placed.

2. Confined Areas and Embankments: One test per every second lift of fill, backfill, or embankment placed.

B. Compaction Tests: Perform tests for compaction in accordance with test procedures specified in ASTM D1557, Method D, as applicable. Perform field testing of soils or compacted fill in place in accordance with applicable requirements of ASTM D2922. Perform field tests at the same frequency described for density tests.

C. Moisture Content Tests: Test the compacted fill, backfill, and embankment to verify compliance with specified requirements in accordance with ASTM D3017. Test for moisture content with the same frequency as that specified above for density test.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies requirements for excavation spoils and muck management and disposal.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections not referenced below may also be related to the proper performance of this work.

1. Section 01 12 16, Work Sequence.
2. Section 01 35 43.15, Unknown Hazardous and Contaminated Substances.
3. Section 01 57 13, Temporary Erosion and Sediment Control.
4. Section 01 57 15, Temporary Construction Noise and Vibration Control.
5. Section 31 20 00, Earth Moving.
6. Section 31 23 33, Trenching and Backfilling
8. Section 31 51 00, Anchor Tiebacks.
10. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.
11. Section 31 73 23, Tail Void Grouting.
12. Section 31 74 19.05, Shotcrete for SEM Tunnels.

1.02 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Excavation Spoils and Muck Management and Disposal Plan: Within 90 Days after the effective date of the Notice to Proceed.

1. Include proposed detailed methods for handling, stockpiling, treating (if necessary), testing, transporting, and disposing of all waste materials generated by the activities referenced in Article 1.01 B.

2. Include details of hauling waste materials by material type, including sub-contractor for hauling, hauling equipment, hours of hauling waste materials, and disposal site for each type of generated waste material.
3. Include descriptions of each anticipated waste material, after handling and stockpiling, with anticipated water content, pH, and waste material contents.

4. Include signed letters from each disposal site operators certifying that they are licensed to receive the waste materials with the anticipated physical and chemical characteristics of the waste materials. Include copies of all permits the receiving facility is required to maintain in order to accept the waste material anticipated to be treated (if necessary), handled or disposed of at the facility. Include statements from each proposed disposal site of how many tons of each type of waste material they can receive on a daily basis, and the physical characteristics of each type.

5. Provide a contact name, address, e-mail address, phone numbers and hours and days of operation for each disposal facility. Indicate any special arrangements made by the Contractor to deliver and dispose of waste material between the hours of 10:00 p.m. and 7:00 a.m. Note contractual constraints on hauling waste material from the project site.

6. Include round trip haul distances to each site, and methods for weighing quantities of waste material.

7. Provide detailed methods of sampling and testing all muck and excavation spoils prior to leaving the site, including water content, and pH. In the event the Contractor blends different waste materials in a common stockpile the waste material shall be sampled and tested from the blended waste material. Muck going directly to disposal shall be sampled per Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine and Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.

8. Provide detailed methods for adjusting pH, soil stabilization, or chemically treating muck and excavation spoils, if necessary, prior to disposal.

9. Provide disposal fees for each type of waste material at each proposed disposal site.

10. Provide a copy of the contract(s) with the proposed disposal site(s) and the acceptability criteria of each waste material to be disposed of at each proposed site.

C. Muck and Excavation Spoil Report

1. Submit on a monthly basis a cumulative running total report to the Resident Engineer with the following information:
   a. A record of the type, quantity (by weight), physical characteristics of each waste material (including pH), disposal site for each waste material disposed, total transportation costs, and all daily tipping fees for each type of waste material at each site.
   b. Copy of all receipts, weight tickets, manifests, truck tickets, and fees issued by the disposal facility for each waste material, or co-mingled waste material.
   c. Certification from each receiving facility owner that his/her operating permit conditions were met for waste materials being disposed.
   d. Report format shall be spreadsheet acceptable to the Resident Engineer.
1.03 DEFINITIONS

A. See definitions in technical specifications referenced in Article 1.01B.

B. Contaminated Soil: Refer Section 01 35 43.15, Unknown Hazardous and Contaminated Substances.

C. Muck: Refer Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

D. Excavation Spoils: All spoils generated by the work of all Sections of Division 31 – Earthwork, with the exception of muck created by the work of Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

E. Adulterated: Describes adding a non-native material, chemical or substance to a native soil.

F. Waste Materials: All excavated spoils, soils and muck generated by the site construction activities.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 MEANS AND METHODS

A. Means and method of handling, stockpiling, blending, stabilizing, treating (if necessary), transporting and disposal of all waste materials are exclusively determined and controlled by the Contractor.

B. The Contractor's means and methods determine the final physical and chemical characteristics of the waste material prior to disposal including its contents, water content and pH.

C. Design means and methods of executing the work to minimize cost of waste materials disposal, including means and method of controlling water content of waste materials, preventing the co-mingling/cross contamination of waste materials, and controlling the pH of the waste materials.

D. The Geotechnical Baseline Report describes the physical and chemical characteristics of the undisturbed in-situ materials only, and in no way characterizes the waste material after it is disturbed by the Contractor.

E. All cost impacts associated with the management of the site waste materials due to the means and methods of construction are the responsibility of the Contractor.

F. Control all stockpile runoff, refer Section 01 57 13, Temporary Erosion and Sediment Control.

3.02 PERMITS, REGULATIONS, AND LAW

A. Comply with all city, county, state and federal permits, regulations and laws controlling the handling, transporting and disposal of waste materials.

B. Comply with Section 01 12 16, Work Sequence, for hourly restrictions imposed on hauling muck and excavation spoils.
C. Confirm that all disposal sites that are to receive high pH waste materials are permitted and licensed to receive high pH waste materials, and are licensed to contain and treat runoff from high pH (> 8.5) waste materials.

D. In the event excavation and/or muck waste material disposal is suspended at any time the Contractor shall submit within 24 hours the reasons for the suspension in writing to the Resident Engineer.

### 3.03 HAULING EQUIPMENT

A. Use hauling equipment appropriate for containing, and hauling waste materials with high water content (30 percent by volume), and high pH (>8.5).

B. Comply with Section 01 57 15, Temporary Construction Noise and Vibration Control, for noise restrictions, and modify equipment and methods accordingly.

### 3.04 DISPOSAL SITE TYPES AND SPOIL TYPES

A. The following types of permitted landfills may be licensed to receive spoil as provided in the table below:

<table>
<thead>
<tr>
<th>Waste Material Type</th>
<th>Dangerous Waste Landfill</th>
<th>Muni Landfill</th>
<th>Clean Fill Dumpsite</th>
<th>Inert Waste Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pH (&gt;12.5, untreated)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High pH (8.5&lt;pH&lt;12.5, Untreated)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unadulterated Excavation Spoil</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>High pH &quot;Adulterated&quot; Spoil (treated to&lt;8.5)</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X*</td>
</tr>
<tr>
<td>Contaminated Spoil/Soil</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B. * Provided that the leachability tests determine that treated spoil will not produce leachate with pH > 8.5SU.

C. The data provided above is provided for information only. The Contractor shall make its own arrangements for the legal disposal of all muck and excavation spoils.

### 3.05 PARTIAL LIST OF LOCAL DISPOSAL SITES (NOTE TO REVIEWER: DISPOSAL SITE LIST TO BE RESEARCHED AND UPDATED FOR 100%)

A. The information provided in the following table is for Contractor information only, and to assist Contractors not familiar with local conditions. Sound Transit does not warrant or guaranty the completeness or accuracy of the information provided. The list only includes some of the sites in the region.
### PARTIAL LIST OF LOCAL DISPOSAL SITES

<table>
<thead>
<tr>
<th>NAME</th>
<th>COMPANY</th>
<th>ADDRESS1</th>
<th>ADDRESS2</th>
<th>CITY, STATE</th>
<th>ZIP CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steve Whitesgarber</td>
<td>Cadman, Inc (Sky River)</td>
<td>PO Box 97038</td>
<td></td>
<td>Redmond, WA</td>
<td>98073</td>
</tr>
<tr>
<td>Dave Enders</td>
<td>Concrete Northwest</td>
<td>PO Box 280</td>
<td></td>
<td>Mt Vernon, WA</td>
<td>98273</td>
</tr>
<tr>
<td>Craig Patton</td>
<td>Corliss</td>
<td>PO Box 487</td>
<td></td>
<td>Sumner, WA</td>
<td>98390</td>
</tr>
<tr>
<td>Zack Fiorito</td>
<td>AAA &amp; Monroe Rock Quarries</td>
<td>15421 166th St SE</td>
<td>Snohomish, WA</td>
<td>98290-6716</td>
<td></td>
</tr>
<tr>
<td>Larry Baker</td>
<td>Rinker Materials</td>
<td>6300 Glenwood Ave</td>
<td>Everett, WA</td>
<td>98203-4247</td>
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</tr>
<tr>
<td>Tad Forenon</td>
<td>Pacific Topsoils</td>
<td>805 80th St SW</td>
<td>Everett, WA</td>
<td>98203</td>
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</tr>
<tr>
<td>Zack Fiorito</td>
<td>Fiorito Brothers</td>
<td>15421 166th St SE</td>
<td>Snohomish, WA</td>
<td>98290-6716</td>
<td></td>
</tr>
<tr>
<td>Jeff Paulson</td>
<td>Hos Brothers Construction</td>
<td>7733 W Bostian Rd</td>
<td>PO Box 1788</td>
<td>Woodinville, WA</td>
<td>98072-1788</td>
</tr>
<tr>
<td>William Melfi</td>
<td>Reserve Silica Corp</td>
<td>PO Box 95</td>
<td>Ravensdale, WA</td>
<td>98051</td>
<td></td>
</tr>
<tr>
<td>Barry O'Young</td>
<td>OMA Construction</td>
<td>PO Box 3705</td>
<td>Seattle, WA</td>
<td>98124</td>
<td></td>
</tr>
<tr>
<td>Tom Mason</td>
<td>Glacier Northwest/Mats Mats</td>
<td>5975 E Marginal Way S</td>
<td>Seattle, WA</td>
<td>98134</td>
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</tr>
<tr>
<td>Bill Kombol</td>
<td>Palmer Coking Coal Company</td>
<td>PO Box 10</td>
<td>Black Diamond, WA</td>
<td>98010</td>
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</tr>
<tr>
<td>Lee Langley</td>
<td>Iron Mountain Quarry</td>
<td>20800 Wayside Mine Rd</td>
<td>Granite Falls, WA</td>
<td>98252</td>
<td></td>
</tr>
<tr>
<td>Budd Totten</td>
<td>Mt. Si Quarry, Inc</td>
<td>39801 SE 101st St</td>
<td>Snoqualmie, WA</td>
<td>98065-9230</td>
<td></td>
</tr>
<tr>
<td>Troy Njos</td>
<td>Quality Rock Products</td>
<td>10201 Little Rock Rd SW</td>
<td>Olympia, WA</td>
<td>98512</td>
<td></td>
</tr>
<tr>
<td>Rob Hild</td>
<td>Menzel Lake Gravel</td>
<td>PO Box 1494</td>
<td>Marysville, WA</td>
<td>98270</td>
<td></td>
</tr>
</tbody>
</table>

**END OF SECTION**
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for the dewatering systems required to control water levels and hydrostatic pressures during Station, Portal and Cross Passage construction.
B. Separate dewatering systems are required at the U District Station, Roosevelt Station, Maple Leaf Portal, and at each of the 17 Cross Passages in the Ground Support Category 2.
C. Dewatering for the 17 Cross Passage sites can be performed from either inside the tunnel using a wellpoint system or from the surface using deep, pumped wells or a combination thereof. Detailed design submittals are required and approval must be obtained prior to installation of the associated dewatering systems.
D. Dewatering includes intercepting seepage into the excavations; increasing the stability of cross passage excavations; increasing the stability of the station box excavation bottom; preventing loss of material from bottoms of excavations; decreasing hydrostatic pressures during tieback installation at Roosevelt Station; pumping; disposing of pumped water; and monitoring of water quality.
E. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 01 12 19, Contract Interface.
   2. Section 01 31 19, Project Meetings.
   3. Section 01 45 00.20, Quality Assurance / Quality Control.
   4. Section 01 57 24, Temporary Site Water Discharge.
   5. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

1.02 DEFINITIONS
A. Aquifer - Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit water to pumped wells, wellpoints, eductors and sumps.
B. Aquitard – Rock or sediment in a formation, group of formations or part of a formation may or may not be saturated but of sufficiently low permeability to retard the flow of water or provide perching layer for water in an overlying aquifer.
C. Artesian Groundwater - Groundwater under sufficient pressure to flow out at the ground surface when encountered by a well or excavation.
D. Confined Groundwater - Groundwater under sufficient pressure to rise above the level of the overlying confining layer at which it is encountered by a well or excavation.
E. Confining Layer - A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. It may lie above or below the aquifer and has a permeability or hydraulic conductivity lower than the adjacent aquifer.

F. Dewatering Specialist - Professional civil engineer or licensed hydrogeologist employed by the dewatering subcontractor who is responsible for overall design and performance of the dewatering system.

G. Dewatering System – A system that will lower the water table, piezometric level, or potentiometric surface adequately to permit safe and dry construction

H. Dewatering Well – A drilled or jetted hole in the ground with casing, well screen, and filter material that allows extraction of groundwater.

I. Eductor – A dewatering well with a water jet pump which creates a vacuum (negative pressure) by circulating clean water at high pressure through a nozzle and venturi arrangement located in a well. Can also be called an Ejector and may consist of a single pipe installation with a short well screen at the bottom or a two pipe installation with a fully penetrating screen across several aquifers.

J. Eductor System – A number of eductors connected to a common header(s) and operated by a common pump(s),

K. Flowing Artesian Well – A well that intercepts confined groundwater with sufficient pressure to flow at ground surface.

L. Groundwater – Water that is found in fully saturated soils, sediments and rocks below the surface of the ground and which flows primarily in response to gravitational forces

M. Groundwater (Unconfined) - Water in an aquifer that has a water table that is at atmospheric pressure.

N. Groundwater Table - A particular potentiometric surface for an unconfined aquifer.

O. Impermeable/Low Permeability Materials – Materials that don't allow water to flow freely through them (e.g., clay, silt, etc.).

P. Incidental Sump Pumping – Sump pumping of perched or pocketed groundwater in an excavation where the static groundwater table has already been lowered below subgrade using eductors/ejectors, wells or wellpoints.

Q. Observation Well - A non-pumping well used to observe the elevation of the water table or the potentiometric surface/piezometric head.

R. Perched – Groundwater separated from an underlying body of groundwater by unsaturated or relatively low permeability soil.

S. Permeability - The property of sediments and rocks that allows the movement of water through them (also known as hydraulic conductivity).

T. Permeable Materials – Materials that allow water to move quickly through them (e.g., gravel and/or sand, etc.).

U. Piezometric Level/Head – The level representing the total hydraulic head of groundwater in a confined aquifer.

V. Piezometric Pressure – Pore water pressure at a specific point.

W. Pore Water Pressure – The pressure of groundwater in a soil, measured relative to atmospheric pressure.
X. Potentiometric Surface/Piezometric Level - Theoretical (imaginary) surface of the static head of groundwater in an aquifer. The water table is a particular potentiometric surface for an unconfined aquifer.

Y. Pumping Level - The level of water in a well casing or screen when pumping is in progress.

Z. Pumping Test – A test performed through controlled groundwater pumping from a well. The measured and recorded flow rate from the pumped well and groundwater changes in observation wells and the pumped well are used to determine aquifer characteristics and the hydraulic properties of the wells.

AA. Pumped Well – A hole in the ground with a casing, screen and filter pack that includes its own motorized pump in the casing or screen to lift water to the surface. Also called Deep Wells.

BB. Sand/Gravel (Filter) Pack - A sand or gravel material which is placed in the annular space between a drilled hole and the well casing and/or well screen and whose purpose is to retain and prevent the movement of formation.

CC. Saturated Zone – The part of unconfined aquifer below the water table where the soil pores are completely filled with water.

DD. Screen (Well Screen) – A cylinder of steel or plastic material used to allow water to enter a well while preventing sediment or rock particles from entering the well.

EE. Specific Capacity – The volume in gallons per minute of a pumped well’s discharge divided by the concurrent drawdown of the pumped well’s water level in feet during pumping.

FF. Subgrade – The finished grade level of an excavation as shown on the drawings, below any structure or slab including excavation for foundation materials.

GG. Sump – Shallow hole in the ground with a slotted or perforated casing containing a pump and surrounded by filter sand or gravel to prevent the pumping of formation material.

HH. Test Well - A well used to assess and/or test the geologic and hydraulic properties of an aquifer.

II. Vibrating Wire Piezometer (VWP) – A sensor designed for measurements of the pore water pressure in soil. A VWP utilizes a stainless steel diaphragm to which a vibrating wire element is connected.

JJ. Well Development – The method of using swabbing, surging, jetting, resonance and/or pumping techniques to:

1. Clean drilling debris from the well and the surrounding formation.
2. Repair damage done by drilling to the formation.
3. Remove biological or chemical encrustation from the well screen.
4. Improve the efficiency.
5. Enhance the hydraulic connection between the well screen and the formation by bringing a percentage of the fines in the aquifer formation into the properly sized well screen so that a more open filter pack is obtained around the well screen. A technique to move water or air out through the screen and then back into the well quickly is common. Also a means to remove or control the fines is required.
KK. Wellpoint - A short slotted or perforated screen (usually steel or plastic and generally less than 4 inches in diameter and less than 5 feet long) attached to a riser pipe. A wellpoint is typically jetted, driven, or installed in a drilled hole.

LL. Wellpoint System – The system that consist of a number of well points placed at close intervals and attached to a common header and vacuum pump.

1.03 SYSTEM DESCRIPTION

A. Dewatering consists of designing, furnishing, installing, operating, maintaining, monitoring, and removing dewatering systems to facilitate completion of the associated excavations as well as all associated reporting requirements.

B. Provide and construct observation wells and instrumentation to monitor groundwater levels and quality during construction and gauge the performance of the dewatering system(s), as described in:

1. Table 1: U District Station
2. Table 2: Roosevelt Station,
3. Table 3: Maple Leaf Portal
4. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method

C. Design, provide, install, operate, and remove dewatering sumps and trenches as necessary to control perched or undrained pockets of groundwater not collected by pumped wells, wellpoints, or eductors.

D. Design Guidelines

1. Be responsible for the design and adequacy of the methods and systems to accomplish the following:
   a. Within plan limits of excavation, lower the groundwater level to 2 feet below base of final excavation as shown on the drawings.
   b. Keep excavation in a hydrostatically-controlled condition during construction (i.e., no boils, quick conditions, etc.).
   c. Prevent damage to adjacent buildings, structures, utilities, and other work that may result from settlement or other groundwater-related effects. Have dewatering design reviewed and approved by any impacted utility authorities before the start of dewatering work.
   d. Dewater and dispose of the water so as not to cause injury to public or private property.
   e. Have available, at all times, competent workers and spare equipment for the continuous and successful operation of the dewatering systems, 24 hours per day, 7 days per week.
   f. Dewatering systems shall be designed and operated so as to prevent removal of the natural soils post well development.
   g. Keep open excavations free of water, and control surface runoff so as to prevent entry or collection of water in excavations.
2. Design the dewatering systems using accepted and professional methods of design and engineering as specified and incorporating the information obtained from the contractor installed monitoring wells.

3. Methods of dewatering may include sump pumps, single or multiple stage wellpoint systems, eductor type systems, pumped wells, and combinations thereof.

4. Operate the dewatering system at the U District Station continuously from start of mass excavation through to Substantial Completion. The N140 will assume control of the system at this time and will continue dewatering operations until Station construction is complete. Operate all other dewatering systems as long as necessary to complete the associated excavations.

5. Locate dewatering systems where they will not interfere with utilities. Conduct groundwater discharge, conveyance, treatment, and transmission to offsite locations in a manner that meets with the approval of the City of Seattle and other governmental authorities having jurisdiction, and in accordance with Section 01 57 24, Temporary Site Water Discharge and the requirements herein.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Qualifications of Contractor’s specialty dewatering system subcontractor at least 90 days prior to installation of the associated dewatering system, including:

1. Project descriptions, dates, and owner contacts for 5 dewatering projects completed by the specialty subcontractor(s) in similar soils and groundwater conditions.

2. Qualifications of the Dewatering Specialist.

C. Qualifications and 24-hour contact information of Contractor’s On-Site Supervisor overseeing day to day operation, maintenance and monitoring of the dewatering system, including:

1. A list of associated project experience and a summary for each project of the Supervisor’s experience related to dewatering system installation, operation and maintenance.

D. Ground Water Control Plan at least 30 days prior to installation of each dewatering system, indicating the following:

1. The type of dewatering system proposed.

2. Design drawings indicating the proposed location, size and depth of eductors, wellpoints, pumped wells, sumps, treatment facilities, and associated piping as well as as-built locations of observation wells and VWPs.

3. Design calculations including:

   a. Anticipated flows and drawdown with distance from the dewatering system.

   b. Selection of appropriate filter material and screen size for dewatering wells.

   c. Analyses/calculations supporting the capacities of pumped wells, eductors and wellpoints
d. All assumptions used to develop the dewatering plan.

4. Schedule for installation, sequencing of dewatering operations, maintenance, and, with the exception of the U District Station, abandonment of the dewatering system.

5. Drilling and development techniques.

6. Specifications and manufacturers’ literature for the materials and methods proposed for the eductors, pumped wells, wellpoints, sumps, pumps, prime movers, standby equipment, discharge pipes, filters/gravel packs, screens, observation wells, VWPs, and water treatment facilities elements.

7. Logs from observation wells and VWPs installed as part of dewatering monitoring program.

E. Copies of all permits required for performing the work of this Section obtained by the Contractor, including Well Tag Identification Numbers.

F. Installation logs of eductors, wellpoints, pumped wells based on as-built survey locations. Logs shall include observed soil conditions, development information and well efficiency analyses. A unique designation shall be assigned to each installation. Installations logs shall be submitted at least 30 days prior to the start of excavation.

G. Records as specified herein.

H. Quality Plan conforming to the requirements of Section 01 45 00.20, Quality Assurance / Quality Control, covering all dewatering operations and the field quality control to be performed.

I. Flow meter calibration reports prior to installation.

J. Certificate of filter pack material quality and gradation prior to delivery.

1.05 QUALITY ASSURANCE

A. Employ a licensed professional civil engineer or hydrogeologist, registered in the State of Washington and specialized in hydrogeology or geotechnical engineering, with at least 5 years’ experience in the design, operation and maintenance of similar dewatering systems to design and direct operation of dewatering system as the Dewatering Specialist.

B. Contractor’s On Site Supervisor shall have a minimum of two years of experience supervising operation and maintenance of construction dewatering projects.

C. Provide water quality and quantity monitoring and maintain records as required by the applicable permits.

D. Groundwater discharge, conveyance and transmission are to be in accordance with Section 01 57 24, Temporary Site Water Discharge.

1.06 PROJECT CONDITIONS

A. Permits

1. ST will provide discharge permits for the U District and Roosevelt Stations and Maple Leaf Portal sites. Obtain all other permits and licensing for dewatering and disposal of pumped water as required to construct and complete the Work.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Furnish all materials, tools, equipment, facilities, and services required for the dewatering system. Make available equipment, machinery and piping, including standby power and pumps in good working order and of adequate capacity to continue dewatering operations in an emergency.

B. Provide observation wells and piezometers as required herein for monitoring groundwater conditions in accordance with Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

2.02 FILTER MATERIAL FOR DEWATERING WELLS, WELLPOINTS, AND EDUCTORS

A. Gravel / Sand pack filter material shall be clean, rounded, washed select gravel or sand free from silt, clay and other deleterious material.

2.03 FLOW METERS

A. Flow meter shall be capable of reporting current flow in gallons per minute and total flow volumes in gallons or cubic feet.

B. Flow meters shall be capable of accurately measuring the flow from an eductor, pumped well, or wellpoint system within 10% of the anticipated flow.

C. Flow meters shall be McCrometer, Flow Technology, or approved equal.

PART 3 - EXECUTION

3.01 GENERAL

A. Provide all equipment necessary for dewatering. Have onsite, at all times, sufficient pumping equipment and machinery in good working condition and shall have available, at all times, competent workmen for the operation of the pumping equipment. Adequate standby equipment shall be kept available at all times to insure efficient dewatering and maintenance of dewatering operations during power failure.

B. Commence dewatering for excavations prior to when groundwater is first encountered, and continue until such times as water can be allowed to rise in accordance with the provisions of this Section or other requirements.

C. Surface runoff shall be collected or diverted from entering the excavation to maintain an excavation subgrade free from standing water.

D. Conduct dewatering at all times in such a manner as to preserve the undisturbed bearing capacity of the subgrade soils at the bottom of excavation.

E. If foundation soils are disturbed or loosened by the upward seepage of water or an uncontrolled flow of water, the affected areas shall be excavated and replaced with an appropriately engineered backfill dictated by the Resident Engineer.

F. Dispose of water from the work in a suitable manner without damage to adjacent property and in accordance with all permits. No water shall be drained into excavations without prior consent of the Resident Engineer. Filter water using an approved method to remove sand and fine-sized soil particles before disposal.
G. Control release of groundwater to its static level in such a manner as to maintain the undisturbed state of the natural foundation soils, prevent disturbance of compacted backfill and prevent flotation or movement of structures, pipelines, and sewers.

H. Provide continuous system monitoring and adjustment 24 hours per day, 7 days per week to maintain optimum performance and maximum drawdown from the wellpoint system. Monitoring and adjustment shall be performed by someone experienced in the operation of vacuum wellpoint systems.

I. Decommission all pumped wells, educators, wellpoints and observation wells in accordance with Section 31 09 00.

J. Use drilling or jetting equipment that is capable of penetrating boulder formations and over-consolidated glacial sediments. The occurrence of shallow saturated soils, confined aquifers, heaving sands, very dense soils and/or boulders as an impediment to the installation of eductors, wellpoints, pumped wells or observation wells will not constitute a basis for change of conditions.

3.02 CONSTRUCTION

A. Dewatering System

1. Perform dewatering in accordance with working drawings and design data. Keep the Resident Engineer advised of changes made to accommodate field conditions and, on completion of the dewatering system installation, revise and resubmit Groundwater Control Plan as necessary to indicate the installed configuration of the system.

2. Dispose of pumped water from excavation, and drainage from areas used or occupied for construction and other purposes. Construct pipelines, including underground portions in streets or elevated portions over streets, as are necessary. Provide water to flush storm sewer and drains. If using water from the Seattle water system, obtain and pay for a fire hydrant use permit as needed. A backflow prevention device will be required and will be inspected by Seattle Public Utilities (SPU) at time of permit purchase. Arrange discharge line to facilitate taking samples by a regulatory authority.

3. Organize dewatering operations to maintain the groundwater level within excavations as required for execution of the work, and to provide a stable, dry subgrade for the execution of construction operations.

4. Meet quantity and quality discharge permit requirements as specified under Section 01 57 24, Temporary Site Water Discharge, for pumped water before discharging to approved points of connection to the storm or sanitary sewer. In addition to these requirements, dewatering discharge shall have less than 20 ppm suspended solids (silt/sand content) as determined by a Rossum SAND TESTER (Journal AWWA, 46:123, February 1954) or equivalent.

5. Provide back-up power for all dewatering systems.

6. Develop all wells by surging, swabbing or both, or other approved method to ensure maximum efficiency of each well in the system. Remove at least 3 well volumes of water from the well. Measure and record water quality parameters during development, such as temperature, pH, and conductivity.

B. Filter Material for Dewatering Wells, Well Points, and Ejectors / Eductors
1. Furnish sufficient gravel/sand filter pack material for initial filter packing of the pumped wells, eductors, or wellpoints and such additional filter material as the wells may take during development.

2. Design gravel/sand filter packs to maximize the flow of water into the eductors, wellpoints, and pumped wells and to minimize the amount of fine-grained material removed from the formation.

3. Adjust selection of the gravel/sand filter pack material for each installation as necessary in accordance with the grain size distribution of the materials encountered during the installation.

C. Well and Wellpoint Screen and Casing

1. Screens, casings, and riser pipes for eductors, wellpoints, and wells shall be capable of performing their intended function throughout the duration of the dewatering system.

2. For all pumped wells, design well screens to minimize entrance velocity, maximize flow to the well, and prevent post-well development entry of the filter pack into the well casing.

3. Use screens that are factory slotted and sized appropriately for the filter to prevent the removal of fines from the gravel pack or formation during post-development operation.

D. Eductor and Wellpoint Construction

1. Use hydraulic jetting, sonic or air rotary drilling techniques to install eductors and well points. Mud rotary, continuous flight augers, hollow stem augers, drive and drill or other technologies which might result in the smearing of fines from silty materials to sandy materials shall not be used.

2. Provide a minimum 8-inch diameter hole for eductors and for drilled wellpoints

3. Use two-pipe eductors.

4. Vacuum pumps for wellpoint systems shall provide a minimum of 25 inches of Hg and the system must be able to deliver to each vacuum wellhead at least 20 inches of Hg. The Contractor must be able to test the vacuum at each wellhead if requested by the Resident Engineer. The system will be considered non-compliant unless it can meet these minimum requirements of delivering a proper vacuum to all of the wellheads.

E. Pumped Well Drilling

1. Use bucket auger, cable tool drill and drive, or air rotary drilling techniques to install dewatering wells. Mud rotary, continuous flight augers, hollow stem augers, drive and drill or other technologies which might result in the smearing of fines from silty materials to sandy materials shall not be used.

F. Pumps, Supply and Discharge Pipe

1. Use pumps for dewatering wells and wellpoint systems that are industry standard for the applications specified herein with sufficient capacity, head, horsepower, wiring, fittings, and switching facilities to maintain continuous operation throughout the duration of the dewatering system.

2. Design system piping with allowances for friction losses and lift sufficient to convey extracted groundwater to the treatment system and discharge point. The
return flow and discharge pipes shall be sized to minimize back-pressure on the system and include air pressure relief valves to eliminate entrained air.

3. Design wellpoint vacuum header with allowances for friction losses and lift sufficient to convey extracted groundwater from the wellpoint to the vacuum pump.

G. Flow Meters
1. Use flow meters to measure water leaving each eductor pump and return flow to the reservoir.

2. Use flow meters to monitor flows at each discharge point.

H. Sumps and Drains
1. Furnish, install, reinstall, operate, maintain, and remove sump pumps and discharge pipe/hose to transport groundwater and storm water inflows into the excavation to the water quality treatment facility.

2. At a minimum, each sump shall include a perforated or slotted pipe surrounded by appropriately-sized filter material and pumps that have sufficient head and volume capacity to transport water to the water quality treatment facility.

I. Observation Wells and Vibrating Wire Piezometers
1. In accordance with Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork except as modified herein.

2. Drill all observation well and VWP boreholes using a sonic drill. A Washington State licensed geologist shall log all boreholes. The geologist will collect the sonic core in sealed plastic sleeves to retain soil moisture. The geologist shall label the sonic core with borehole number, date, depth, and top direction and shall place the sealed core in wooden boxes constructed for core storage. Store core samples until the excavation for the associated dewatering system is complete.

3. Develop each observation well sufficiently to ensure hydraulic connectivity with the aquifer. An observation well will be considered in hydraulic connectivity with the aquifer if (1) the screen and casing are free of sediment, and (2) on three separate occasions, after filling the 2-inch-diameter casing with water and maintaining the water at the top of the casing for 1 hour, the water returns to static level (+/- 1 foot) within 72 hours. Alternatively, if the well drains quickly, the Contractor may, on 3 different occasions, add to the well a volume of water equal to at least 3 well casing volumes, followed by monitoring of the recovery of the well water level to static level within 72 hours. Replace any observation well that does not exhibit hydraulic connectivity with the aquifer at no cost to Sound Transit.

4. Decommission all observation wells within excavations after the excavations have reached final subgrade.

5. Protect observation wells and VWP during excavation. Observation wells and VWPs shall be cut-off after each excavation lift. Each instrument so altered shall be clearly labeled with its identification and with the current elevation of the top of the casing.

J. Water Supply for System Installation and Electrical Service
1. Provide water supply and electrical service needed for the installation and operation of the dewatering systems.

2. Provide separate meters for dewatering systems’ electrical service. Electrical service for dewatering system shall not be used for any other construction power supply.

K. Standby Equipment

1. Maintain sufficient equipment and materials on site for repairs, necessary modification, and to ensure continuous and successful operation of the dewatering and monitoring systems for all ordinary emergencies, including power outage and flooding.

2. Provide one hundred percent standby electrical generating capacity with automatic switching from line to generator, including all safety features to prevent back-feeding the electrical supply system

L. Formation Protection and Well Development

1. Design, construct, operate, and maintain all eductors/ejectors, wellpoints, pumped wells, and sumps such that foundation soils fines will not be removed upon pumping.

2. Develop all eductor and pumped wells to remove fines resulting from drilling and construction and to increase the yield and hydraulic connection with the aquifer. Discharge all development water to sediment settling tanks. Do not discharge any development water directly to a surface water body, directly to ground surface or to the designated discharge point without prior treatment.

3. Develop all eductors, wellpoints and pumped wells until the sand content of the discharge water during surging is less than 20 parts per million (ppm) as determined by a centrifugal, separating meter such as a Rossum SAND TESTER or equivalent.

4. Replace any eductor, wellpoint or pumped well that produces more than 20 ppm sand/silt unless otherwise authorized by Sound Transit.

5. Conduct a minimum 4 step pumping step-test for all eductor and pumped wells.


\[ E_w = 100BQ/BQ + CQ^2 \]

Where:  
- \( E_w \) = Well Efficiency
- \( B \) = Aquifer Loss
- \( Q \) = Flow
- \( C \) = Well Loss

And

\[ E_w = \text{Well Efficiency} = \frac{Q}{s} \text{ (actual)}/\frac{Q}{s} \text{ (theoretical)} \]

Where \( s \) = Drawdown after 1 hour of pumping

7. Re-develop, re-habilitate, or replace any eductor or pumped well that does not exhibit and maintain an efficiency of 85%.
8. If any eductor or pumped well does not exhibit and maintain an efficiency of 85%, conduct a test pumping on the well for 2 hours with a pumping level no more than 10 feet above the pump intake and measure the flow.

9. If operational pumping indicates a 20% or greater decrease in specific capacity, retest and reanalyze the well’s efficiency.

10. If the Contractor disputes the level of development or efficiency of a well, provide access to the well for the Resident Engineer to evaluate and/or conduct additional well development.

M. Dewatering System Removal and Abandonment

1. Upon written authorization of the Resident Engineer, remove all dewatering system facilities and abandon all eductors, wellpoints, pumped and observation wells using a Washington State-licensed water well Contractor in accordance with the State of Washington WAC 173-160.

2. Do not abandon or remove any eductor, wellpoint, or pumped well without prior written authorization of the Resident Engineer.

3. Submit written documentation of abandonment of all eductors, wellpoints, wells, or other penetrations below the excavation subgrade including unique identification number, location coordinates, date and time of abandonment, the names of the Contractor’s personnel performing the abandonment and the Resident Engineer representative observing the abandonment.

4. Notify the Resident Engineer 24 hours prior to abandonment of any wells, sumps, gravel drains, or other penetrations below the excavation subgrade.

5. Abandonment of any eductors, wellpoints, wells, or other penetrations below the excavation subgrade not observed by the Resident Engineer will be over drilled to the original depth of the installation and re-abandoned at the Contractor’s own expense.

3.03 MAINTENANCE

A. Dewatering System

1. Maintain dewatering systems in accordance with working drawings and design data.

2. Immediately replace materials, equipment, facilities that are damaged or cease to operate properly. Notify the Resident Engineer of replacements made to the dewatering system.

3.04 FIELD QUALITY CONTROL

A. Records

1. Observe and record the average flow rate and time of operation of each pump used in the dewatering system. Provide flow meters for measuring the flow rates. Submit flow-rate data during the period that the dewatering system is in operation.

2. Observe and record the elevation of the groundwater during the period that the dewatering system is in operation. Submit observation records to the Resident Engineer within 24 hours of reading, on a regular basis.
3. During initial period of the dewatering, make required observations on a daily basis. If, after a period, dewatering operations have stabilized, reduce observations to longer intervals approved by Resident Engineer.

4. For drilled wells observe and record soil conditions, prepare field log of well installations, prepare record of well development data.

END OF SECTION
**TABLE 1A. SUMMARY OF U DISTRICT STATION GROUNDWATER LEVEL MONITORING LOCATIONS**

<table>
<thead>
<tr>
<th>Existing Groundwater Instrumentation Point (CONTRACTOR to Monitor)</th>
<th>Instrument Type</th>
<th>VWP Serial No.</th>
<th>Approximate Screened Interval or VWP Tip Elevation (feet NAVD 88)</th>
<th>Primary ESUs</th>
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</thead>
<tbody>
<tr>
<td>NB-258</td>
<td>OW</td>
<td></td>
<td>87.5-82.8</td>
<td>CSG</td>
</tr>
<tr>
<td>NB-259</td>
<td>OW</td>
<td></td>
<td>135.8-126.4</td>
<td>TLD</td>
</tr>
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<td>OW</td>
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<td>112.5-102.8</td>
<td>CSG</td>
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<td>NB-515</td>
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<td>127.5</td>
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<td>69.7</td>
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<tr>
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<td>78.4-69.0</td>
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<td>157.4-142.4</td>
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<tr>
<th>New Groundwater Instrumentation Approximate Station* (CONTRACTOR to Install &amp; Monitor)</th>
<th>Instrumentation Type</th>
<th>Approximate Location*</th>
<th>Approximate Target Elevation for Screened Interval or VWP Tip*&lt;sup&gt;a,c&lt;/sup&gt; (feet NAVD 88)</th>
<th>Target ESUs&lt;sup&gt;c&lt;/sup&gt;</th>
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<tbody>
<tr>
<td>1258+14</td>
<td>VWP</td>
<td>Centerline between tunnels, in temporary sump footprint</td>
<td>Saturated zone above 120</td>
<td>TLD/CSG</td>
</tr>
<tr>
<td>1258+14</td>
<td>OW</td>
<td>Centerline between tunnels, in temporary sump footprint</td>
<td>100-80</td>
<td>CSG/TLD/CSF</td>
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<tr>
<td>1259+00</td>
<td>VWP</td>
<td>Outside &amp; within 10 feet of station east wall</td>
<td>Saturated zone above 130</td>
<td>TLD/CSG</td>
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<tr>
<td>1259+00</td>
<td>VWP</td>
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<td>CSG</td>
</tr>
<tr>
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<td>CSG/TLD</td>
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<td>Station centerline</td>
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<td>CSG/TLD</td>
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<td>CSG</td>
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<td>Centerline between tunnels &amp; within 10 feet of north wall</td>
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</table>
Notes:

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<table>
<thead>
<tr>
<th>Existing Groundwater Instrumentation Point (CONTRACTOR to Monitor)</th>
<th>Instrument Type</th>
<th>VWP Serial No.</th>
<th>Approximate Screened Interval or VWP Tip Elevation (feet NAVD 88)</th>
<th>Primary ESUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB-111</td>
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<td></td>
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<td>CSG</td>
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<tr>
<td>NB-111</td>
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<table>
<thead>
<tr>
<th>New Groundwater Instrumentation Approximate Station (CONTRACTOR to Install &amp; Monitor)</th>
<th>Instrumentation Type</th>
<th>Approximate Location</th>
<th>Approximate Target Elevation for Screened Interval or VWP Tip (feet NAVD 88)</th>
<th>Target ESUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1316+65</td>
<td>VWP</td>
<td>Centerline between tunnels, south of ground improvement zone</td>
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<td>CSG/TLD</td>
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<td>VWP</td>
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<td>1317+50</td>
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<td>Station centerline</td>
<td>Saturated zone above 180</td>
<td>ENF/RGD/TLD/CSG/CSF</td>
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<td>1317+50</td>
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<td>VWP</td>
<td>Outside &amp; within 10 feet of station east wall</td>
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<tr>
<td>1318+30</td>
<td>VWP</td>
<td>Outside &amp; within 10 feet of station east wall</td>
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<td>CSF</td>
</tr>
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<td>1318+30</td>
<td>OW</td>
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<td>New Groundwater Instrumentation</td>
<td>Instrumentation Type(^b)</td>
<td>Approximate Location(^a)</td>
<td>Approximate Target Elevation for Screened Interval or VWP Tip(^c) (feet NAVD 88)</td>
<td>Target ESUs(^c)</td>
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<td>---------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>1318+60</td>
<td>VWP</td>
<td>Station centerline</td>
<td>Saturated zone above 180</td>
<td>ENF/RGD/TLD/CSG/CSF</td>
</tr>
<tr>
<td>1318+60</td>
<td>VWP</td>
<td>Station centerline</td>
<td>160</td>
<td>CSF</td>
</tr>
<tr>
<td>1318+60</td>
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<td>Station centerline</td>
<td>140-120</td>
<td>CSG</td>
</tr>
<tr>
<td>1320+30</td>
<td>VWP</td>
<td>Outside &amp; within 10 feet of station east wall</td>
<td>Saturated zone above 180</td>
<td>ENF/RGD/TLD/CSG/CSF</td>
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<tr>
<td>1320+30</td>
<td>VWP</td>
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<td>CSG</td>
</tr>
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<td>1320+30</td>
<td>OW</td>
<td>Outside &amp; within 10 feet of station east wall</td>
<td>140-120</td>
<td>CSG</td>
</tr>
<tr>
<td>1320+80</td>
<td>VWP</td>
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<td>Saturated zone above 180</td>
<td>ENF/RGD/TLD/CSG/CSF</td>
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<tr>
<td>1320+80</td>
<td>VWP</td>
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<td>CSG</td>
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<td>1320+80</td>
<td>OW</td>
<td>Station centerline</td>
<td>140-120</td>
<td>CSG</td>
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<tr>
<td>1321+60</td>
<td>VWP</td>
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<td>Outside &amp; within 10 feet of station west wall</td>
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<td>1321+60</td>
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<td>CSG</td>
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<td>ENF/RGD/TLD/CSG/CSF</td>
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<td>1321+90</td>
<td>VWP</td>
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<tr>
<td>1322+90</td>
<td>OW</td>
<td>Station centerline</td>
<td>140-120</td>
<td>CSG</td>
</tr>
</tbody>
</table>

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### TABLE 1C. SUMMARY OF MAPLE LEAF PORTAL GROUNDWATER LEVEL MONITORING LOCATIONS

<table>
<thead>
<tr>
<th>Existing Groundwater Instrumentation Point (CONTRACTOR to Monitor)</th>
<th>Instrument Type</th>
<th>VWP Serial No.</th>
<th>Approximate Screened Interval or VWP Tip Elevation (feet NAVD 88)</th>
<th>Primary ESUs</th>
</tr>
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<tbody>
<tr>
<td>Nb-275</td>
<td>VWP</td>
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<td>Nb-563</td>
<td>VWP</td>
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<td>298.8</td>
<td>RGD</td>
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<td>Nb-564</td>
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<td>TLD/CSG</td>
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<td>289.3-279.6</td>
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<td>Nb-594</td>
<td>OW</td>
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<th>Target ESUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1403+20</td>
<td>VWP</td>
<td>Centerline between tunnels</td>
<td>292</td>
<td>RGD</td>
</tr>
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<td>1403+20</td>
<td>OW</td>
<td>Centerline between tunnels</td>
<td>275-255</td>
<td>CSF</td>
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<tr>
<td>1403+80</td>
<td>VWP</td>
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<td>291</td>
<td>RGD</td>
</tr>
<tr>
<td>1403+80</td>
<td>OW</td>
<td>Outside &amp; within 5 feet of portal east wall</td>
<td>280-260</td>
<td>CSF</td>
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<td>1403+80</td>
<td>VWP</td>
<td>Outside &amp; within 5 feet of portal west wall</td>
<td>291</td>
<td>RGD</td>
</tr>
<tr>
<td>1403+80</td>
<td>OW</td>
<td>Outside &amp; within 5 feet of portal west wall</td>
<td>280-260</td>
<td>CSF</td>
</tr>
<tr>
<td>1406+20</td>
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<td>Outside &amp; within 5 feet of portal east wall</td>
<td>278-268</td>
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<td>1406+20</td>
<td>OW</td>
<td>Outside &amp; within 5 feet of portal west wall</td>
<td>278-268</td>
<td>RGD</td>
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</tbody>
</table>

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PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for excavating, trenching, and backfilling for utilities and related structures, as indicated, including underground piping for water supply, sanitary sewerage, storm sewerage, underground electrical conduits and duct banks, and utility boxes, catch basins, manholes, and vaults.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 71 23, Field Engineering
2. Section 03 05 15, Portland Cement Concrete
3. Section 31 20 00, Earth Moving
4. Section 31 23 19, Dewatering
5. Section 33 01 00, Operation and Maintenance of Utilities

C. When specified in the Contract Drawings or when approved by the Resident Engineer the Contractor shall supply controlled density fill (CDF) as backfill material.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge, and Municipal Construction
   b. Standard Plans for Municipal Construction

2. Seattle City Light Material Standards

3. Seattle Department of Transportation:
   a. SDOT Director’s Rule 5-2009, Street and Sidewalk Pavement Opening and Restoration.

   a. WAC 296-155 Part N: Safety Standards for Construction Work, Excavation, Trenching and Shoring

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Material source, and all tests and certifications necessary to approve material, including moisture/density relation test results. If on-site material is proposed for use as any of the materials specified in construction, provide test results certifying suitability of said material.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Bedding and Backfilling Materials:

1. Ductile Iron Pipe Water Main bedding: Class B bedding in accordance with COS Standard Plan 350. Mineral Aggregate Type 9 in accordance with COS Specification Section 9-03.


5. PVC Sanitary Sewer pipe bedding: Class B bedding in accordance with COS Standard Plan 285. Mineral Aggregate Type 22 in accordance with COS Specification Section 9-03.


7. Bedding for underground electrical conduits and duct banks shall conform to the Seattle City Light Material Standards 7150.0.

8. Trench Backfill: Imported Mineral Aggregate Type 17 conforming to COS Specification 9-03.16 or a similar material approved by the Resident Engineer.

9. CDF bedding and backfill conforming to Section 03 05 15, Portland Cement Concrete.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Prior to digging see Section 33 01 00, Operation and Maintenance of Utilities, for additional requirements.

B. Staking and Grades:

1. Refer to Section 01 71 23, Field Engineering, for requirements.

C. Existing Utilities:

1. Refer to Section 31 20 00, Earth Moving, Article 3.01B, for requirements.
D. Protection of Persons and Property:
   1. Erect and maintain temporary bracing, shoring, lights, barricades, signs, and other measures as necessary to protect the public, workers, and adjoining improvements from damage during trenching work in accordance with applicable codes and regulations.
   2. Protect utilities, pavements, and facilities from damage caused by settlement, lateral movement, undermining, washout, and other hazards created by the trenching operations.
   3. Protect open trenches outside of secured fence areas with steel plates with non-slip surfaces or water filled barriers during non-working hours. Provide barriers to block pedestrians or vehicles from entering the work area and approaching trenches during working hours.

E. Dewatering
   1. Prevent surface water and subsurface or ground water from flowing into excavations and from flooding project site and surrounding area.
   2. Where water is encountered in the trench, dewater as specified in Section 31 23 19, Dewatering.
   3. Provide and maintain pumps, sumps, suction and discharge lines, and other dewatering system components necessary to convey water away from excavations.
   4. Establish and maintain temporary drainage ditches and other diversions outside excavation to convey water. Do not use trench excavations as temporary drainage ditches.

F. Trenching and Excavating:
   1. Perform work in accordance with the requirements of WAC 296-155, Part N, Excavation, Trenching and Shoring.
   2. Do not undermine or disturb sidewalks, pavements, appurtenant structures, adjacent improvements or underground installations adjacent to and beyond the trench.
   3. Excavate to the depth, line, and grade indicated on the Contract Drawings.
   4. Excavate using open cut methods.
   5. Keep the length of trench excavation in advance of pipe installation operations to a minimum and do not exceed 200 feet.
   6. The maximum trench width in the Right of Way shall not exceed the neat line trench width as shown or indicated in the Contract Drawings.
   7. Outside the Right of Way and in unimproved areas, trench width above the top of pipe may at the Contractor’s option exceed the neat line trench width indicated on the Contract Drawings by sloping or benching. All requirements for excavating, handling and disposing of excavated material, and placing and compacting additional suitable backfill, outside of the neat line trench limits shall be at the sole expense of the Contractor.
   8. Excavate to the inverts indicated on the drawings plus any additional excavation as necessary to accommodate the Contract specified class of bedding. Provide
over-excavation for the pipe bells such that pipe barrels and bells along the pipe are uniformly supported full length.

9. Grade surrounding areas or utilize alternative controls to prevent surface water from flowing in to the excavations.

10. Maintain at least 3 feet of separation from the toe of the slope of any stockpiled excavated material from the trench edge.

11. For utility structures, provide a minimum of 12 inches between the exterior surfaces of utility structures and the sides of the excavation.

12. All ledgerock, boulders, stones, and any object larger than 3 inch in any dimension shall be removed within 6 inches in any direction from the pipe.

13. Remove trench protective systems in such a manner as to not disturb bedding or backfill. Where bedding or backfill is disturbed, reconsolidate the material as specified.

14. Ensure excavations for structures conform to the applicable requirements of Section 31 20 00, Earth Moving.

G. Bedding:

1. For Water Mains:
   a. Place bedding in accordance with the dimensions indicated on the Contract Drawings or as referenced in a COS Standard Plan.
   b. Provide uniform support along the entire pipe barrel, without load concentration at joint collars or bells. Provide over-excavation for the pipe bells such that pipe barrels and bells along the pipe are uniformly supported full length.
   c. Do not use blocking to adjust pipe to grade.
   d. Reconsolidate bedding disturbed by pipe movement or by removal of trench protection prior to backfill.
   e. Take special care to provide adequate bedding support at wye or tee connections and adjacent manholes or other structures to avoid bending or shearing stresses at these critical points.

2. Pipe Bedding for Storm Drains and Sanitary Sewers as specified in the City of Seattle Specifications Section 7-17.3(1)B and in accordance with COS Standard Plan 284 and 285.

3. Bed duct banks on 2 inches of compacted washed sand as indicated.


H. Backfilling: Backfill with material indicated. Take all necessary precautions to protect the pipe, duct bank or vault from any damage or shifting.

1. Pipe and duct bank Backfilling: Backfill from the side of the trench to a uniform depth of 1 foot above ductile iron pipe before starting compaction, and to a uniform depth of 2 feet above concrete pipe and duct banks before starting compaction.
2. Electrical Vault backfill in accordance with Seattle City Light Construction Guideline U2-15.1.

I. Compaction: Refer to Section 31 20 00, Earth Moving. The requirement for compaction is Class II Compaction in improved areas such as parking lots or sidewalks. The compaction requirement in unimproved areas or landscaped areas is Class I Compaction.

J. Restoration:

1. Comply with surface restoration requirements as indicated in the Contract Drawings, Contract Specifications, or as referenced in a COS Standard Plan.

2. In City of Seattle Right-Of-Way, comply with City of Seattle’s Director’s Rule for Street and Sidewalk Pavement Opening and Restoration.

3.02 FIELD QUALITY CONTROL:

A. Refer to Section 31 20 00, Earth Moving, for requirements.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for ground treatment utilizing Jet Grouting methods. The location and extent of the required jet grouting near the Roosevelt Station are shown on the Contract Drawings. Jet grouting may also be used at cross passages that require ground improvement.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 12 19, Contract Interface.
2. Section 01 57 19, Temporary Environmental Controls.
3. Section 01 74 00 Cleaning and Waste Management
4. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Society for Testing and Materials (ASTM)
   a. ASTM C94 Standard Specification for Ready-Mixed Concrete
   b. ASTM C150 Standard Specification for Portland Cement
   c. ASTM C494 Standard Specification for Chemical Admixtures for Concrete
   d. ASTM C618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
   e. ASTM C989 Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
   f. ASTM D1633 Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders
   g. ASTM D4044 Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
   h. ASTM D4050 Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems

2. American Petroleum Institute (API)
1.03 DEFINITIONS

A. Jet Grouting: The process of injecting cement grout to create an in-situ soil-cement column to allow excavation with minimal water ingress and to provide a stable crown and face for excavation. The cement grout is injected and mixed with the soil under high pressure through nozzles at the end of a monitor inserted in a borehole. The monitor is rotated and lifted at slow, smooth, constant speed to achieve a continuous geometry and quality of soil-cement.

B. Column Spacing: The theoretical designed offset between the axes of adjacent jet grout columns in any direction required to provide the design Column Overlap.

C. Column Overlap: The distance by which one column periphery is designed to overlap an adjacent column periphery such that a homogeneous block of treated ground is created.

D. Drilling deviation: The deviation of the drill hole from a theoretical straight line.

E. Spoil Returns: Excess jet grouting materials, including grout and soil that return through the drill hole and drill collar to the ground surface.

F. Single System: A jet grouting system where a high pressure jet of cementitious grout is used to disaggregate the ground.

G. Double System: A jet grouting system where a high pressure jet of cementitious grout surrounded by an annulus of air is used to disaggregate the ground.

H. Triple System: A jet grouting system where a high pressure jet of water surrounded by an annulus of air is used to disaggregate the ground with separate injection of cementitious grout.

I. Closure Column: An additional column installed to maintain column overlap in the event of excessive drilling deviation.

J. Contingency Procedure: The procedure to implement additional measures as required by ground conditions.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Qualifications:
   2. Jet Grouting Engineer.
   4. Independent Testing Laboratory.

C. Results of calibrations.

D. Shop Drawings: Design, specifications, method of operation, supporting calculations, and other data pertaining to but not limited to the following:

2. Production control.

3. Quality Control by laboratory testing.


5. Permeability test methods

E. Jet Grouting Work Plan.

F. Documentation:

1. Daily: Signed by the Jet Grouting Engineer and submitted within two working days. Record and show:
   a. Day, month, year, time of the beginning and end of the work shift; all workers’ names associated with each jet grouting rig; and a summary of equipment used during the shift.
   b. Time of beginning and completion of each soil-cement installed during the work shift. Location and reference number of each completed column.
   c. Water-cement ratios, cement type, brand and compound composition; cement grout injection pressures and rates, other pertinent cement grout mix data, mixing rotational speeds, penetration and withdrawal rates of the jet grouting equipment, and installation sequence for every soil-cement element including detail of jet nozzles.
   d. Other pertinent observations including, but not limited to: spoil returns, cement grout escapes, ground settlement or heave, collapses of the soil-cement element, advancement rates of the jet grouting equipment, and any unusual behavior of any equipment during the jet grouting process and other noteworthy events.
   e. Date, time, plan location, sample designation and elevation, and other details of soil-cement sampling and other quality control and field testing.
   f. Summary of any unproductive time, including start and end time, duration, and reason.
   g. Produce a graphical record of the jet grouting operation. Include the following:
      1) Graph of rotation speed, rate of withdrawal, grout pressure, grout flow, air pressure and air flow plotted against depth.
      2) Graph of drill hole deviation in two orthogonal directions.
      3) Plan showing as-built and design position of the jet grout columns at the top and bottom of the jet grout block.
      4) Plan showing any proposed setting out of required closure columns.
   h. Have the daily records checked for correctness and signed by the jet grouting Superintendent.
2. **Weekly:** Calculated elevations of ground level, top and base of all jet grout columns.

3. **Results of all quality control tests completed during the previous week.**

G. **As-Built Plan of Ground Treatment:** Prepare the as-built plan to a scale acceptable to Resident Engineer. Show all treatment points (and their reference numbers) and locations and types of tests carried out.

H. **Survey Control:**
   1. Type and location of horizontal and vertical control monuments to be set.
   2. Survey procedures, including equipment and software.

1.05 **QUALITY ASSURANCE**

A. **Qualifications:**
   1. **Jet Grouting Subcontractor:** Demonstrate the following relevant experience:
      Three projects completed successfully within the last seven years, each demonstrating the following characteristics:
      a. Jet grout columns installed to 100 feet below surface, achieving adequate interlock and average minimum soil mass compressive strengths of over 200 psi.
      b. Inclined jet grouting at angles of up to 20 degrees from vertical at depths of over 100 feet.

2. **Jet Grouting Engineer:**
   a. A graduate engineer from an ABET-accredited college, university or foreign equivalent.
   b. A minimum of 5 years combined field and design experience in jet grouting as specified herein.

3. **Jet Grouting Superintendent:**
   a. A minimum of 5 years experience installing jet grouting of similar scope and complexity.
   b. Present on site full time during jet grouting.

4. **Independent Testing Laboratory:** Minimum of 3 years experience with testing specified herein, and in accordance with Section 01 45 00.20, Quality Assurance/Quality Control.

B. **Survey Control:** Provide qualified survey personnel in accordance with Section 01 71 23, Field Engineering.

C. **Calibration:** Performed on a quarterly basis by an approved testing agency, for all gages, scales and meters used to perform the work.

1.06 **JET GROUTING WORK PLAN**

A. Detailed descriptions, data and calculations of proposed materials, facilities, and equipment to be used, including but not limited to the following:
a. Drilling equipment.
b. Drill alignment measuring equipment.
c. Drilling deviation control and monitoring equipment.
d. Drilling depth control and monitoring equipment.
e. Batching and mixing plant for grout production.
f. Grout quality assurance equipment.
g. High-pressure grout pumps.
h. High-pressure air compressors.
i. Jetting nozzle diameter measurement equipment.
j. Jet grouting column production monitoring equipment.
k. Other equipment.

2. Materials:
   a. Grout Mix Designs.
   b. Portland Cement.
   c. Ground Granulated Blast Furnace Slag.
   d. Fly Ash.
   e. Bentonite.
   f. Cement additives.

   B. The following information for methods of construction:

   1. Description of system proposed, whether Single, Double or Triple system, as well as anticipated nozzle pressure, rotation speed, and extraction rate, appropriate for anticipated subsurface conditions.

   2. Details of any trials proposed to confirm column diameter, drilling tolerances and column strength.

   3. Key installation plan showing column placement including proposed column spacing and design overlap, depths of placement, angles of inclination, drill hole deviation allowance and provision for closure columns.

   4. Proposed jet grout column diameter and methods for determining diameter in situ.

   5. Sequence of jet grouting including jetting parameters and contingency methods where drill holes exceed design drill hole deviation.


   7. Drilling method including setup alignment measurement and control, drilling deviation measurement and control, and directional accuracy.
8. Complete environmental control plan detailing methods for controlling, containing and disposing of all byproducts of the jet grouting operation, in accordance with Section 01 57 19, Temporary Environmental Controls.

9. Quality assurance procedures for grout production.

10. Monitoring and recording of jet grouting parameters.

11. Coordinate requirements for monitoring settlements and heave with Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.


C. The following information for the performance requirements:

1. Drilling method to retrieve core samples.

2. Location of planned coring.

3. Operational plan to determine in-situ permeability and strength within specified requirements.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Have adequate supply of required materials for jet grouting present at site at all times.

B. Deliver, store, and handle materials to prevent contamination, segregation, corrosion, or damage.

C. Store cement materials in a dry place and in accordance with Suppliers’ specification. Maintain materials in a clean and undamaged condition. Be responsible for replacing damaged or destroyed materials at no cost to Sound Transit.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Cement Grout

1. Portland Cement: ASTM C150, Type II.

2. Provide bulk cement with methods of measurement, handling, transporting and storing that conform to the manufacturer’s recommendations. Should cement be furnished in cloth or paper bags, package within plastic or rubber vapor barriers.

3. Grout Mix Properties: Proportioned to provide the required strength when mixed with soil as specified herein, and of mixing consistency as required to perform the work.

B. Water

1. Clean and potable.

2. Meets requirements of ASTM C94.

C. Alternative Cementitious Materials

1. Fly ash:

D. Admixtures
2. Do not use admixtures that have exceeded the manufacturer’s recommended shelf life.
3. Deliver, store and handle admixtures in accordance with the manufacturer’s recommendations.

E. Bentonite: API Recommended Practice 13A. Protect bentonite from moisture and contamination both in transit and during storage at the site.

2.02 EQUIPMENT

A. Drilling Equipment: Proven performance for use in performing jet grouting work.

B. Mixers, Holding Tanks and Associated Equipment: Type and capacity for producing uniform grout mixtures at all times and in the quantities required for the timely execution of the work.

C. Jet Pumps: High pressure pumps capable of delivering the grout at the flow rates and pressure required.

D. Recording Equipment:
   1. Automatic recording equipment with a meter to determine the volume of grout injected.
   2. Calibrated in gallons to the nearest quarter-gallon (1/4 gallon).

E. Grout Plant: Consisting of a mixer, agitated sump, grout pumps, gages, valves, pressure lines, and all other equipment necessary to mix and perform grouting as required.

2.03 MIXES

A. Strength
   1. 28-day Unconfined Compressive Strength shall be at least 300 psi for jet grout columns, tested in accordance with ASTM D1633.
   2. Obtain 4-inch minimum diameter cylinders for determination of strength for mix design testing, or as specified herein for wet grab sampling cylinders.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Environmental and Safety Requirements

   a. ASTM C618, Class F, with weight loss on ignition limited to three percent.
   b. Limit fly ash to a maximum of 20 percent by weight of total cementitious materials.
1. Maintain site in a clean and orderly state to the satisfaction of the Resident Engineer. Provide, install and maintain environmental controls to contain and dispose of surface runoff water, grout and drilling fluid overflows including, but not limited to:
   a. Containment walls and dikes with membrane barriers
   b. Sumps and cleanouts
   c. Silt traps
   d. Liquid storage tanks
2. Perform work in a manner that minimizes safety hazards and exposure of personnel and equipment to hazardous and potentially hazardous conditions in accordance with specified safety requirements.
3. Assess all ground and groundwater conditions, and working platform construction at all times during the construction period and react prudently and swiftly to all indicators and conditions.
4. Provide safe work areas and temporary platforms and stands at all times.
5. In case of emergency or work stoppage likely to endanger excavation or adjacent structures, continuously maintain full work force 24 hours per day including weekends and holidays until emergency or hazardous conditions no longer jeopardize stability and safety of the structures.
6. Dispose of Spoil Returns in accordance with Section 01 74 00, Cleaning and Waste Management.

B. Surveying and Setting Out
1. All drill holes to be set out to within 0.25 foot of the design position and elevation.
2. Initial drill inclination and azimuth to be set up to within 0.5 degree of design values.
3. Locate the top of jet-grout holes for the ground improvement zone at the north end the Roosevelt Station site within the construction limits shown on the drawings.

C. Drilling for Jet Grouting
1. Provide suitable drilling equipment capable of drilling to the depths and inclinations required.
2. Fit each drill rig with instrumentation to monitor drilling inclination and bearing to the required tolerances.
3. Check drill rig at set up and at a depth increment of 25 feet for positional accuracy, bearing and drilling inclination. Note any deviations outside of the specification and redrill the hole in accordance with the operation procedure plan.
4. Following review of the drill hole deviation measurements, adjust column size and grouting procedures as necessary to provide required ground treatment coverage.

D. Jet grouting
1. Use equipment that can be controlled to the desired design rate of withdrawal, rotation, grout flow and pressure, airflow and pressure. As a minimum maintain all designated parameters within a tolerance of five percent.

2. Use equipment that records the parameters set out herein with real time display to allow the jet grout operator to control the column construction to the required tolerances.

3. Maintain equipment in fully functional state; in particular provide an operational procedure for checking jet grout nozzle(s) for efficiency and diameter.

4. Where the jetting of a column is interrupted for any reason including the addition or removal of drill rods, then reintroduce the jet grout stem into the column by a minimum distance of 12 inches.

5. Commence jetting from the bottom and withdraw towards the upper limit of ground treatment.

6. Coordinate jet grouting operations with other aspects of the work. Install jet grouting in a manner so as to not create obstructions or other hindrances to subsequent aspects of the work.

7. Perform construction in a manner that limits subsidence or heave of surface in vicinity of the works to 1/2 inch. Movements will be monitored in accordance with Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

8. React diligently to drill hole blockages to prevent ground movements.

9. Complete jet grouting for the entire area as shown on the Contract Drawings.

3.02 FIELD QUALITY CONTROL

A. Quality Assurance of Grout

1. Produce grout such that jet grouting will not be interrupted due to insufficient grout being available.


3. Provide a series of agitating tanks to allow acceptance or rejection of grout to be carried out. Screen material from the mixers prior to entering the agitating tanks.
   a. Capacity of the holding tanks shall be adequate to sustain continuous operations.
   b. Fit the tanks with a graduated dip-stick capable of recording the volume of grout in the tank.

4. Perform the following testing once per shift or operation and record separately:
   a. Unconfined Compressive Strength of set grout and soil mixture at 28 days.

B. Quality Assurance Of Jet Grouting

1. Maintain all column setting out data, positional data, grouting parameters, and performance testing on a computer database for ease of assessment of jet grouting overall performance. Coordinate software and format for the database to be consistent with other requirements for record keeping specified herein.
C. Performance requirements:

1. Wet Grab Sampling
   a. Perform a minimum of one in situ sampling round, defined as a test suite, at a frequency of once per every 100 installed jet grout columns, at locations selected by the Resident Engineer. Obtain the entire suite of jet grout samples at the same element, consisting of a non-cured jet grout sample obtained at three depths selected by the Resident Engineer.
   
   b. Retrieve separate jet grout samples within 30 minutes of the withdrawal of the mixing equipment at a specific location. Use a device to retrieve the wet grab jet grout samples that is capable of obtaining a discrete fluid sample of jet grout at a pre-determined depth and is capable of accepting particles not thoroughly mixed that are up to 4 inches in dimension. Lower the sampler empty, air only, to the required depth in the jet grout column and then open. Close the sampler once filled with the jet grout to exclude entry or loss of jet grout and expeditiously raise to the ground surface.
   
   c. Retrieve jet grout samples of sufficient volume to produce a minimum of four full cylinders, 2-inch diameter by 4-inch height. Form cylinders of material passing through a 3/4-inch sieve.
   
   d. Store samples and test all jet grout cylinders by the Independent Testing Laboratory for unconfined compressive strength in accordance with ASTM D1633.

2. Coring
   a. Perform vertical coring from ground level.
   
   b. Obtain five cores for ground treatment zone, spaced across the ground improvement zone, excluding the field test program, at locations approved by the Resident Engineer.
   
   c. Take each core over a vertical distance within 5 feet of the base of the ground treatment zone. Log each core hole for quality of grouting and other observations.
   
   d. Take 8-inch long samples and preserve for UCS determination. Take a minimum of three samples from each core hole.
   
   e. Fully backfill hole with cement grout after completion of all sampling and ground water inflow measurements.

3. Field Test Program:
   a. Conduct test programs to evaluate the proposed grouting methods and the ability of the proposed grout mix to produce grout columns meeting the diameter, overlap and material property requirements.
   
   b. Perform one test program at a location approved by the Resident Engineer.
   
   c. Locate each test program in a portion of the ground treatment zones that can be incorporated into the finished work. Locate to avoid impacts on
adjacent roadways, utilities, and other surface features to the extent possible.

d. Install six jet grout columns for each test program, consisting of two rows of three columns each, for the full depth of ground treatment.

e. Collect and submit daily records in the same fashion as production jet grouting.

f. Core inspection for each test program:
   1) After the jet grout columns have set up sufficiently, obtain continuous core samples from the center of two of the columns. Also obtain continuous cores from the overlapping edges at two locations, as selected by the Resident Engineer.
   2) Inspect and log the cores and check for segregation.
   3) Confirm design column overlap.
   4) Select three samples from each of the two cores taken at the center of the columns and test in accordance with ASTM D1633 for 28-day strength.
   5) Complete core inspection prior to installation of additional jet grout columns.

g. Depending on the results of the test program, modify the jet grout parameters to meet design criteria if necessary.

h. Where the test program and results fail to achieve the design criteria, modify the jet grouting approach and install additional test columns, per direction of the Resident Engineer.

4. Non-Compliance

a. Criteria for Wet Grab Sampling:
   1) Unconfined Compressive Strength: As specified herein.

b. Criteria for Vertical Coring and Field Test Program Coring:
   1) Ungrouted sections of column exceed 10 inches in length.
   2) More than five percent of the cored length is ungrouted.
   3) Unconfined Compressive Strength: As specified herein.

c. Where test results indicate non-conformance with the specification, propose remedial works to rectify the situation to the approval of the Resident Engineer. Submit this proposal in a timely manner so as to prevent delay to the operations.

5. Permeability

a. Observe and record inflows for each core hole once per day for a minimum of three days prior to backfilling hole. Perform permeability testing in the presence of the Resident Engineer.
b. Limit permeability of core hole: $3.8 \times 10^{-8}$ feet per second, per hole, averaged over the three-day period.

c. Where test results indicate non-conformance with the specification, propose remedial works to rectify the situation without delay to the approval of the Resident Engineer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specification for minimum requirements for design and implementation of Ground Treatment using Permeation Grouting. Permeation grouting may be used at cross passage locations that require ground improvement.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 25 00, Substitution Procedures
2. Section 01 57 13, Temporary Erosion and Sediment Control.
3. Section 01 57 24, Temporary Site Water Discharge.
4. Section 01 74 00, Cleaning and Waste Management.
5. Section 01 78 39, Project Record Documents

1.02 REFERENCES

A. This Section incorporates by reference the latest revision of the following documents.

1. American Petroleum Institute (API)
   a. API 13A Drilling Fluid Materials

   a. ASTM D422 Gradation Testing of Soils
   b. ASTM C150 Portland Cement
   c. ASTM C494 Chemical Admixtures for Concrete
   d. ASTM C136 Sieve Analysis of Fine and Coarse Aggregates
   e. ASTM D1633 Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders
   f. ASTM D2834 Standard Test Method for Permeability of Granular Soils (Constant Head)
   h. ASTM D4832 Standard Test Method for Preparation and Testing of Soil-Cement Slurry Test Cylinders


B. Qualifications:

1. Grouting contractor: No less than three projects completed within the last five years, each including the planning and execution of a Ground Treatment program with permeation grouting that was similar in scope and type to that planned for this Contract.

2. Ground Treatment Manager: Full-time, on-site individual in responsible charge for all Ground Treatment operations, with a minimum of five years of experience in the design and field application of the methods utilized to perform the work planned for this Contract.

3. Grout Design Engineer: A minimum of five years' experience in the design and application of grouting systems and is currently licensed as a Professional Engineer registered in the State of Washington.

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Design Data for Permeation Grouting.

C. Design and Plans: Volumes for ground treatment, design assumptions, and calculations.

D. Quality Control Plans.

E. Mix Designs.

F. Daily Shift Reports: Within eight hours of the end of the shift.

G. Record document drawings indicating area and components of ground treatment.

H. Erosion and Sediment Control Plan, coordinated with requirements of Section 01 57 13, Temporary Erosion and Sediment Control.

1.04 DEFINITIONS

A. Ground Treatment: A general term referring to the use of Permeation Grouting to permanently modify the existing in-situ soil and groundwater conditions to enable stable excavation of adjacent soil and provide groundwater control.

B. Grouting: General term referring to the injection of cement, water, bentonite, sodium silicate, or other materials designed to perform Ground Treatment.

C. Permeation Grouting: Process of injecting a solution or particulates into the soil to fill void spaces.

1.05 DESIGN CRITERIA

A. Permeation Grouting shall be used for Ground Treatment at locations as indicated on the Contract Drawings.

B. Design to improve the soil conditions present to meet the criteria indicated herein.

C. Permeation Grouting:

1. Cement grout composed of water, bentonite, cement and fluidifier.
a. Grout mix shall be such that, when injected into either Coarse-grained Sand and Gravel (CSG) or Cohesionless Silt and Fine Sand (CSF) Engineering Soil Units, the confined compressive strength of the grouted soil shall average at least 200 psi.

2. Alternate grout materials may be submitted for possible substitution in accordance with Section 01 25 00, Substitution Procedures.

1.06 QUALITY CONTROL PLANS

A. Methods and plans for demonstrating that Ground Treatment meets design criteria.

B. Inspection, testing, monitoring, and sampling methods, where not otherwise indicated, for determining compliance with design criteria.

C. Methods for controlling and verifying the vertical limits of the Ground Treatment.

D. Criteria, equipment, and procedures for abandoning or remedying grouting occasioned by equipment failure, inadequacy of grout mix or delivery systems, or other cause.

1.07 DESIGN AND PLANS

A. Design calculations stating all design assumptions for the Permeation Grouting based on anticipated subsurface conditions.

B. Shop Drawings:
   1. The arrangement, spacing, and diameter of boreholes relative to the methods and mixes used. Include extent and depth of the grouted mass.
   2. Stamped, dated, and signed by the Grout Design Engineer.
   3. Profile views of Ground Treatment zones, showing relationship with adjacent shaft.

C. Equipment, methods, and details of Grouting operation. Include:
   1. Arrangement of grout mixing and injection equipment.
   2. Clearances from adjacent facilities.
   3. Sequence and details of drill-hole placement.
   4. Minimum set time and strengths.

D. Details for identifying, protecting, and maintaining utilities in working service.

E. Means and methods for handling, treating, and disposing of excess and spilled materials generated during the Grouting operation including changes to the erosion and sediment control system.

1.08 MIX DESIGNS

A. Submit proportions of materials proposed for each grout mix design.

1.09 EROSION AND SEDIMENT CONTROL PLAN

A. See Section 01 57 13, Temporary Erosion and Sediment Control.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Cement Grout:
   1. Portland cement
      a. ASTM C150, Type I, II, or III.
   2. Fluidifier: Compound to increase flowability of mixture, assist in dispersal of cement grains, neutralize setting shrinkage of grout.

B. Bentonite:
   1. Premium grade Wyoming sodium montmorillonite manufactured in accordance with API 13A.
      a. Grout mix: Contain no more than two percent bentonite by dry weight of cement.

C. Water: Fresh and potable water.

D. Admixtures:
   1. Contractor’s option as necessary to improve pumpability, to control set time, and to prevent segregation and bleeding.
   2. Admixtures shall be non-toxic and biodegradable and conform to ASTM C494.

2.02 EQUIPMENT

A. General:
   1. Drilling Equipment: Equipment used for drilling boreholes; lowering, raising, and rotating grout tubes; mixing grout; and injecting grout, shall have proven performance for use in performing Permeation Grouting.
   2. Drill bits shall be capable of advancing through ground conditions indicated.
   3. Spare parts and equipment shall be available on Site to maintain the grouting equipment in satisfactorily operating condition at all times during execution of the Ground Treatment work.

B. Permeation Grouting:
   1. Grout Mixer:
      a. The grout mixer shall be mechanically driven, capable of effectively mixing and stirring grout mixes with water-cement ratios between 0.6:1 and 6.0:1 measured by volume,
      b. Mixing shall be achieved by constant rapid circulation of grout. Low-speed paddle-type of mixers will not be permitted.
      c. The mixer shall be equipped with a suitable water-measuring device calibrated to read in cubic feet and tenths, and so designed that after each delivery the hands can be conveniently set back to zero.
   2. Agitated Sump:
a. The agitated sump shall be mechanically driven and so designed as to be capable of effectively stirring and holding in suspension all solid matter in the grout.

b. The agitated sump shall have a minimum capacity of 10 cubic feet of grout.

c. The agitated sump shall be equipped with a device for accurately measuring the volume of grout at any given time, to an accuracy of 0.1 cubic foot.

3. Grout Pump(s):

   a. Grout pump(s) shall be capable of pumping at minimum rates and pressures required to perform the work. Distribution of grout, under pressure, to the grouting location shall be monitored by separate, automatic recording flow rate indicators, totalizers, and pressure gauges.

4. Other Equipment:

   a. Grout lines used between the grout pump and the header and back to the agitator sump shall not be less than 1-1/2 inch inside diameter and capable of withstanding the maximum grouting pressure with ample margin of safety.

   b. Pressure gages shall be calibrated with not greater than 2 psi divisions on the dial.

   c. A “mud balance” calibrated to read in pounds per cubic foot shall be furnished and maintained at each batching and agitation setup.

PART 3 - EXECUTION

3.01 GENERAL

   A. Ground Treatment shall be completed at least 30 days prior to excavating in designated areas.

   B. Contain excess grout and soil from Ground Treatment operations in mud tanks or by other approved methods to facilitate rapid cleanup at the end of each shift at a minimum.

   C. Place equipment for mixing, holding, and pumping grout in a secure location and prevent spillage of material.

   D. Do not discharge water, waste, grout, or soil outside the confines of the work site including into any surface water or storm drain system.

   E. Thoroughly clean site and contain and dispose of all debris, water, waste grout, and spilled material at the completion of daily grouting operations.

   F. Dispose of waste per Section 01 74 00, Cleaning and Waste Management.

   G. Environmental Management:

      1. Meet all water discharge requirements per Section 01 57 13, Temporary Erosion and Sediment Control, and Section 01 57 24, Temporary Site Water Discharge.
3.02 GROUTING REQUIREMENTS

A. General:
   1. Drilling/grouting rods shall be of sufficient stiffness to ensure that the deviation of drilling locations from the theoretical axis is no greater than one foot.
   2. Grout injection rate shall be monitored by counting the strokes of the piston pump in a fixed period of time if piston displacement calibration is available or by using a flow meter.
   3. Grout injection pressures shall be monitored with calibrated pressure gauges mounted on the injection lines. Prior to the start of each injection, check to verify that there is no blockage in the grout injection equipment.

B. Grout Mixing:
   1. The method of injection for cement grouting shall be continuous mixing method, with the proper amounts of cement, sand, water, and additives automatically proportioned and continuously supplied at proper flow rates and pressures.
   2. A sampling cock, to allow frequent set time checks, shall be placed after the baffling chamber.
   3. Suitable check valves shall be placed in the grout lines at the proper locations to prevent backflow.

C. Injection Procedures:
   1. Using double packers, cement grout shall be injected into the design zones through grout ports in the sleeve pipes.
   2. The grouting pressure for any one pipe shall not be more than 2 psi per foot of overburden.
   3. Temporary, very high injection pressures will be permitted to crack open sleeve-ports, but these pressures will not be permitted for longer than one minute duration.
   4. The rate of injection into any port shall not exceed three gallons per minute.
   5. Adjust injection procedures as needed to prevent surface heave or prevent overstress of adjacent structures.
   6. Grouting shall be considered complete at any hole when theoretical target volumes have been reached for each hole.

D. Set Times:
   1. All grouts shall have a set time between 5 minutes and 50 minutes, with most grout having set times in the range of 20 minutes to 40 minutes.
   2. Samples shall be obtained for set time checks at least four times per hour of pumping or for every 1,000 gallons of grout, whichever is more.

E. Post Grouting Procedures:
   1. After the grout has set, cut off grout pipes a minimum of 18 inches below ground surface, backfill with grout and repair ground surfaces to pre-existing conditions or better.
3.03 GROUT MIXING
A. Mixing plant (Plant) shall be used for the preparation of the grout.
B. Plant shall consist of high-speed grout mixer, grout agitator, grout pumps and control unit, as required.
C. Plant shall be capable of supplying a uniform grout mixture in the quantities required for timely execution of the work.
D. If bentonite is used, add bentonite to water and mix thoroughly to hydrate prior to adding cement.

3.04 CLEANUP AND DECOMMISSIONING
A. Complete cleanup of the work area daily upon completion of grouting operations.
B. Dispose of grout in accordance with all required state and federal environmental regulations.

3.05 DAILY SHIFT REPORTS
A. Grouting:
   1. Include all the following information daily for each injection grout hole:
      a. Number and classification of labor and equipment used.
      b. Quality control sampling and measurements for grouting operations.
      c. Nature, causes, duration, and impacts from interruptions and delays during the shift.
      d. Start and finish times.
      e. Limits, including depth and width, of grout injection.
      f. Grout mix data.
      g. Grout injection rate and volumes injected.
      h. Injection pressures.
      i. Grout leakage.
      j. Ground heave.
      k. Grout hole geometry including location, spacing, depth, and casing details.
      l. Inclination.
      m. Test samples taken.

3.06 RECORD DOCUMENT DRAWINGS
A. See Section 01 78 39, Project Record Documents.
B. Identify coordinates (x, y, z) of Ground Treatment areas.
C. Submit mark-up drawings within 30 days of completion of work at each Ground Treatment location.

3.07 FIELD QUALITY CONTROL

A. Check condition of completed Ground Treatment.

1. Drill a minimum of two core holes from the ground surface or from the tunnel. Obtain continuous core samples from within the grouted zone.

2. If horizontal holes are used, drill core holes through the excavated face to a maximum length equal to two thirds the distance of the Ground Treatment beyond the shaft wall surface.

3. For horizontal holes, groundwater inflow rates for each core hole shall be measured and recorded. Where inflows exceed 0.25 gallons per minute the ground treatment zone does not conform to design criteria. Perform additional measures to decrease the permeability of the Ground Treatment.

4. Observe the recovered cores. If ungrouted zones in excess of 6 inches are observed, perform additional measures to provide a uniform grouted zone.

5. All core holes shall be fully grouted on completion.

B. Where a condition develops that is likely to endanger the stability of the cross passage excavation or overlying structure, a full crew shall operate 24 hours a day, including weekends and holidays, until those conditions no longer jeopardize the stability of the work.

END OF SECTION
SECTION 31 32 36
SOIL NAILING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies the material and construction requirements for the soil nail wall systems indicated on the Contract Drawings. This section also specifies requirements for any design modifications to be made to the wall systems.

B. Unless otherwise directed, the Contractor shall select the soil nail assembly materials, drilling method, grouting method, grouting pressures, anchor diameter, and corrosion protection systems associated with the soil nail installation. The Contractor shall be responsible for designing and installing soil nail assemblies that will develop the minimum ultimate tensile strength indicated on the Contract Drawings.

C. The work of this Section includes the following:

1. Design, furnish, and install temporary and permanent soil nails as required as excavation proceeds.

D. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections not referenced below may also be related to the proper performance of this work.

1. Section 01 45 00.20, Quality Assurance/Quality Control.
2. Section 03 05 15, Portland Cement Concrete.
3. Section 03 20 00, Concrete Reinforcing
4. Section 03 37 13, Shotcrete for Excavation Wall Facings.
5. Section 06 82 00, Glass-Fiber-Reinforced-Plastic.
6. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Association of State Highway and Transportation Officials (AASHTO):
   a. AASHTO M111 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
   c. AASHTO M291 Carbon and Alloy Steel Nuts
   d. AASHTO Construction Specifications Section 11.3.3.1.
2. American Concrete Institute (ACI):
   a. ACI 318 Building Code Requirements for Reinforced Concrete.

   a. ASTM A36 Standard Specification for Carbon Structural Steel
   d. ASTM A615 Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
   e. ASTM A722 Standard Specification for Uncoated High-Strength Steel Bar for Pre-stressing Concrete
   f. ASTM D1785 - 06 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
   g. ASTM C33 Standard Specification for Concrete Aggregates
   h. ASTM C109 Standard Test Method for Compressive Strength of Hydraulic Cement Mortars Using 2-in. or 50-mm Cube Specimens
   i. ASTM C150 Standard Specification for Portland Cement
   j. ASTM D1248 Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
   k. ASTM D3350 Standard Specification for Polyethylene Plastics Pipe and Fitting Materials
   l. ASTM D 4716 Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head

4. Washington State Department of Transportation (WSDOT)
   a. Standard Specifications for Road, Bridge and Municipal Construction (WSDOTSS

5. FHWA IF-03-017 Geotechnical Circular No. 7, Soil Nail Walls.

1.03 DEFINITIONS

A. Closure Time: The duration of time between excavation to the neat line and the application of the initial shotcrete facing.

B. Drill Bench: Temporary bench created for purposes of installing soil nails.

C. Neat Line: Excavated surface corresponding to final wall excavation face limits as indicated on the Contract Drawings.

D. Soil Nail System: Excavation support system that occurs in staged lifts, consisting of soil nails and shotcrete lagging. The excavation in the vicinity of the wall requires special care and effort compared with general earthwork excavation.
1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit calculations for design of the steel or FRP nail reinforcing elements, bearing plates, couplers, connections, and corrosion protection encapsulation system elements. Calculations shall show that the completed soil nail assembly meets the required minimum ultimate tensile strength as indicated in the Contract Drawings. Calculations shall be prepared, sealed, and signed by a professional engineer registered in the State of Washington. Design package shall include soil nail design engineer’s qualifications.

C. Submit at least 30 days prior to commencement of soil nail wall construction, Shop Drawings consistent with layout indicated on the Contract Drawings indicating soil nail system and installation procedures. Include:

1. Indicate for each soil nail: Horizontal and vertical position, soil nail number, length, diameter, declination angle, planar angle, tendon type, tendon size and material, and splay angle.

2. Details for spacers, centralizers, anchorage, bearing plates, and corrosion protection encapsulation system.

3. Show location of pre-installed shoring elements and adjacent utilities, based on field surveys.

4. Indicate locations of sheet drains, drain grates, and other appurtenances.

5. Indicate shotcrete thicknesses and reinforcement.

6. A detailed construction procedure which includes the proposed methods of excavation of the soil, a proposed plan for removal of groundwater encountered during excavation and drilling, proposed drilling methods and equipment, proposed hole diameter(s), and the proposed method of soil nail installation.

D. Submit at least 30 days prior to commencement of soil nail wall construction the proposed product data, including nail grout mix designs and representative cylinder test results from previous projects demonstrating strengths developed by the proposed grout mix.

E. Submit at least 30 days prior to testing, all necessary drawings and details to clearly describe the proposed system of jacking support, framing, and bracing to be used during testing, and calibration data for each test jack, pressure gauge and load cell.

F. Submit at least 30 days prior to commencement of soil nail wall construction qualifications for the Contractor, the proposed drilling operators and foreman, and shotcrete nozzleman.

G. Submit upon delivery to the project site certifications for nail tendons (steel and FRP), nail couplers and tendon centralizers.

H. Submit within 24 hours of testing the soil nail verification and/or proof test results.

I. Submit as-built drawings of the work no later than 60 days after completion of the work.
1.05 QUALITY ASSURANCE

A. If modifications are made to the soil nail system indicated on the Contract Drawings, provide calculations and drawings signed and sealed by a registered Structural Engineer licensed in the State of Washington.

B. Qualifications:

1. Contractor: Demonstrate completion of at least 4 soil nail retaining wall projects of similar size and scope on which the Contractor has designed and/or installed soil nails and shotcrete walls in the past 5 years.

2. Drilling Operators: Demonstrate completion of at least 3 similar soil nail walls of comparable size and type in the past 3 years.


4. Independent Geotechnical Engineer: Select a licensed independent geotechnical engineer currently registered in the State of Washington, with a minimum of five years of experience in monitoring and testing programs of soil nail excavation support systems.

C. Certifications:

1. Certified mill test for steel nail tendons including chemical composition, ultimate strength, yield strength and elongation for each heat unit.

2. Certified tests for FRP nail tendons including chemical composition, ultimate strength, and creep potential for each unit, including coupling and anchor system elements.

3. Certified calibration records from an Independent Testing Laboratory for each test jack and pressure gage pair and load cell to be used. Include the following items on calibration records: device identification numbers, date tested, and calibration test results to be certified for accuracy within percent of the applied loads.

4. Manufacturer certification for nail couplers and tendon centralizers.

1.06 SOIL NAIL CONSTRUCTION WORK PLAN

A. The contractor shall develop and submit a Soil Nail Construction Work Plan to be reviewed and approved by the Resident Engineer. The Work Plan shall include the items outlined in this section.

B. Design Calculations: If modifications are made to the soil nail system indicated on the Contract Drawings, provide calculations in accordance with design criteria specified herein.

C. Shop Drawings: As outlined in Section 1.04C.

D. Site Drainage Plan: Address all elements necessary to divert, control, and dispose of surface and subsurface water during construction of the soil nail wall, coordinated with other requirements indicated. Control of surface water behind retaining walls may be accomplished by sloping to promote runoff away from the excavation, trenches and sumps, or shotcrete gutters. Grade the excavation to promote drainage away from the toe of the retaining walls.
E. Proposed Drilling Methods and Equipment: Including drill rig type, use of cased or open-hole methods, proposed drill hole diameter, and method of cuttings and removal to achieve the specified pull-out resistance presented on approved submittals.

F. Methods for removing protrusions and backfilling voids, if required.

G. Soil Nail Installation Details:
   1. Nail grout mix design including: brand and type of portland cement and admixtures, quality and gradation of aggregates, proportion of mix by weight, and compressive strength test result verifying the specified minimum 3 day and 28 day grout strength.
   2. Nail grout placement procedures and equipment.
   3. Nail testing methods and equipment including: details of jacking frame and appurtenant bracing, methods of isolating test soil nails during shotcrete application, and methods of grouting the unbonded length of test nails after testing.
   4. Identification of independent testing laboratory for soil nail testing.
   5. Bearing plates and nuts used.
   8. Shotcrete installation procedures, in accordance with Section 03 37 13, Shotcrete for Temporary Support of Excavation Wall Facings.

1.07 SOIL NAIL INSTALLATION AND TEST RECORDS

A. Installation records shall include:
   1. Date and time of installation.
   2. Drill hole diameter.
   3. Head location.
   4. Length of installed nail.
   5. Inclination of installed nail.
   6. Tendon type.
   7. Soil conditions encountered during installation.
   8. Grout mix, pressure, and volume.

B. Test records shall include:
   1. Testing procedures.
   2. Testing results.

C. Installation and Test records shall be prepared by the independent Geotechnical Engineer and submitted to the Resident Engineer for approval.
1.08 DESIGN CRITERIA

A. If modifications are made to the soil nail system indicated on the Contract Drawings, revise design in accordance with the requirements herein.

B. Soil Nail System:
   1. Design in accordance with Publication No. FHWA IF-03-017 Geotechnical Circular No. 7, Soil Nail Walls.
   2. Be responsible for the stability of the interim temporary face cuts that exist prior to installation of the wall facing.

C. Applicable Design Methods:
   1. SNAILZ
   2. GOLDNAIL
   3. Other approved methods.

D. Soil Parameters:
   1. For soil properties see the Geotechnical Baseline Report.
   2. For jet grout improved soil areas see Section 31 32 13.36, Jet Grouting Soil Stabilization.

E. Minimum Utility Clearance:
   1. 1 foot below and 5 feet above all utilities and pre-installed shoring elements.

F. Facing:
   1. For shotcrete facing:
      a. Design in accordance with Section 03 37 13, Shotcrete for Temporary Support of Excavation Wall Facings, FHWA IF-03-017 Geotechnical Circular No. 7, Soil Nail Walls, and ACI 318.
      b. Minimum thickness requirements: As indicated on the Contract Drawings.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Use construction materials for the soil nail walls that are new and without defect.

B. Shotcrete: Refer to Section 03 37 13, Shotcrete for Temporary Support of Excavation Wall Facings.

C. Nail Grout: Neat or sand/cement mixture with:
   1. Cement: ASTM C150, Type II, Low Alkali.
   2. Aggregates: ASTM C33 and Section 03 05 15, Portland Cement Concrete.
   3. Minimum 3 day compressive strength of 1500 pounds per square inch (psi).
4. Minimum 28 day compressive strength of 3000 pounds per square inch (psi).

5. Slump of 8 inches plus or minus 1 inch.

D. Nail Tendons:

1. Steel: Conform to ASTM A615, Grade 75 or ASTM A722, Grade 150 continuous threadbar.

2. FRP: See requirements for FRP soil nail elements in section 06 82 00, Glass-Fiber-Reinforced-Plastic.

3. Couplers: Provide 100 percent of the specified minimum ultimate tensile strength of the threadbar as certified by the manufacturer. No splices are allowed with FRP soil nail elements.


5. Bearing Plates: Conform to ASTM A36.

6. Nuts and Washers: Conform to AASHTO M291, grade B, hexagonal-fitted, with beveled washer or spherical seat to provide uniform bearing.

7. Corrosion Protection for Bars and Accessories: Provide corrosion protection for all steel soil nail tendons and accessories.
   a. Epoxy Coating: Conform to ASTM A755, with a thickness of 10 mils plus or minus 2 mils.
   b. Double Corrosion Protection (Encapsulated) System: PVC or PE system for corrosion protection. Manufacturer system to be per approved shop drawings.

8. Centralizers:
   a. Schedule 40 polyvinyl chloride (PVC) material securely attached to the soil nail tendon.
   b. Size centralizers to position the soil nail tendon within 1 inch of center of the drill hole, to allow tremie pipe insertion to the bottom of the drill hole, and to allow the grout to flow freely up the drill hole.

E. Wall Drainage Network

1. Geocomposite Drain Strips:
   a. Preformed grid of embossed plastic or a system of plastic pillars and interconnections forming a semirigid mat.
   b. Manufactured with a drainage core not less than 0.25 inches thick or more than 0.50 inches thick.
   c. Drainage core with a minimum compressive strength of 15,000 pounds per square foot (psf) covered with filter fabric capable of maintaining drainage void.
   d. Maintain full flow through drain strip splices.

2. PVC Connector and Drain Pipes
a. Pipe: ASTM D1785 Schedule 40 PVC, solid and perforated wall, cell classification 12454-B or 12354-C, wall thickness SDR 35.
b. Drain Backfill: ASTM C33 No. 67 with no more than 2 percent passing the No. 200 sieve.

2.02 EQUIPMENT

A. Drilling:
   1. Select drilling equipment and method suitable for anticipated ground conditions.
   2. In caving ground, use cased or augercast drilling methods to support the sides of the drill hole.

B. Grouting:
   1. Use a continuously agitating type mixer capable of producing a uniformly mixed grout, free of lumpy and undispersed cement. Select the size of the grout mixer to allow the full length of the soil nail to be grouted in one continuous operation.
   2. Use positive displacement grout pumps. Equip grout pump with a pressure gage that can measure at least twice, but no more than three times, the intended grout pressure.

C. Soil Nail Testing:
   1. Dial gages:
      a. A minimum of two dial gages capable of measuring to 0.001 inch available at the site to measure the soil nail movement.
      b. Minimum travel sufficient to allow the test to be performed without resetting the gages.
      c. Align the dial gages within 5 degrees of the axis of the soil nail and support independent of the jacking set-up and the wall.
   2. Jack with pressure gage:
      a. Calibrated as a unit by an Independent Testing Laboratory within the last 12 months.
      b. Pressure gage graduated in 100 pounds per square inch increments or smaller.
      c. Range for the pressure gage not more than twice the maximum anticipated pressure during the testing.
      d. Ram travel for the jack is sufficient to enable the test to be performed without resetting the jack.
      e. Capable of applying each increment load in less than one minute.
   3. Load cell:
      a. In accordance with Section 31 09 00, Geotechnical Instrumentation Monitoring of Earthwork.
b. Calibrated by an Independent Testing Laboratory within the last 12 months.

4. Reaction frame:
   a. Sufficiently rigid and of adequate dimensions such that excessive deformation of the test apparatus requiring repositioning of any component does not occur during testing.
   b. Where the reaction frame bears directly on the shotcrete facing, design the reaction frame to prevent cracking of the shotcrete.

2.03 HANDLING AND STORAGE

A. Store cement to prevent moisture degradation and partial hydration. Discard cement that has become caked or lumpy.

B. Soil Nail Tendons:
   1. Handle all soil nail tendons and elements in accordance with manufacturer instructions.
   2. Keep soil nail tendons free of dirt, rust, and other deleterious material prior to installation.
   3. Keep FRP soil nail tendons from prolonged exposure to sunlight or other sources of UV light.
   4. Handle soil nail tendons in such a manner so as not to overstress the tendon.
   5. Damage to the soil nail tendon because of overstressing, abrasion, cuts, nicks, welds, and weld splatter shall be cause for rejection by the Resident Engineer.
   6. Grounding of welding leads to the soil nail steel is not allowed.
   7. Heavy corrosion or pitting of soil nails shall be cause for rejection. Light rust that has not resulted in pitting is acceptable, subject to approval by the Resident Engineer.

PART 3 - EXECUTION

3.01 GENERAL

A. Sequence construction in accordance with the approved Soil Nail Construction Work Plan. Make no excavation steeper or higher than those specified on the approved Soil Nail Construction Work Plan above or below the soil nail wall without written authorization of the Resident Engineer.

B. Visit the site prior to starting construction activities for the purpose of observing and documenting the preconstruction condition of existing structures, sidewalks, roadways, and the other infrastructure within or adjacent to the work area.

C. Monitor the areas behind all the shoring walls as required in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork. Notify Resident Engineer if new cracks develop in the existing structures. Limit vertical and horizontal movements as specified in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork, and as indicated on the Contract Drawings. If the Resident Engineer determines that
movements exceed Action Levels, take all necessary corrective actions to stop the movement, and perform repairs to the impacted structures.

3.02 PREPARATION

A. Hold a readiness review meeting prior to the start of work to clarify the construction requirements for the work and to coordinate construction activities in accordance with 01 45 00.20, Quality Assurance / Quality Control. Meeting shall be attended by: Sound Transit, the Resident Engineer, the Contractor, the approved Subcontractors for the excavation, soil nailing, and shotcreting and the Independent Geotechnical Engineer who will be observing the construction activities.

3.03 EXCAVATION

A. Excavation:

1. Do not excavate beneath a preceding shotcrete lift closer than 5 feet (horizontal) until:
   a. Nail grout and shotcrete on the preceding lift has reached 50 percent of their respective 28-day compressive strengths.
   b. Installation of connection hardware and soil nail testing for the preceding lift are complete and have been approved by the Resident Engineer.

B. Perform any excavation closer than 5 feet (horizontal) to the shotcrete face in accordance with the drill bench requirements described below and as shown on the approved Soil Nail Construction Work Plan.

1. During excavation of the drill bench for the next row of nails, maintain a bench to serve as a platform for the drilling equipment. Use the bench as a stabilizing berm against the final wall excavation face neat line.

2. Establish drill bench not more than 3 feet below the row of nails to be installed. Extend the bench out from the wall face a minimum distance to provide a safe working width for equipment and workers.

3.04 WALL EXCAVATION

A. Excavate to the neat line using procedures that:

1. Prevent ground loss.
2. Prevent swelling, air slaking or loosening of the soil face.
3. Minimize degradation of soil bearing support below the overlying portions of the soil nail wall and below the soil nails currently being installed.
5. Prevent ground freezing.

B. Do not excavate the ground beyond the neat line. Restore inadvertent over-excavation beyond the neat line using shotcrete as approved by the Resident Engineer.

C. Closure time:

1. First lift wall face: Less than 8 hours or as approved by the Resident Engineer.
2. Subsequent lifts: Less than 16 hours, unless ground conditions are suitable for longer duration closure times, as approved by the Resident Engineer.

D. For extensions of the closure time for approval, construct a test cut and demonstrate for each anticipated soil type that the unsupported final excavation face wall is stable throughout the proposed closure time.

E. Boulders, cobbles or other intrusions that are encountered at the soil face are the responsibility of the Contractor. Construct shotcrete facing to the minimum specified thickness, and to the line and grade as shown on the Contract Drawings, regardless of such intrusions.

3.05 TEMPORARY END OF WALL CONDITIONS

A. Where the construction sequence results in discontinuous lifts along any soil nail row, extend the ends of the lifts beyond the end of next lower lift by at least 10 feet. Construct slopes or berms immediately beneath these stepped lifts to prevent sloughing or failure that would result in loss of face support provided by the slopes or berms.

3.06 DRILLING

A. Select drill hole diameter to provide the minimum specified grout cover over the soil nail bar and to develop the specified load carrying capacity presented in approved submittals.

B. Water, mud drilling, or any other fluids used to assist in cutting are not permitted for drill holes.

C. A licensed, Professional Land Surveyor shall locate all soil nails prior to drilling.

D. Immediately cease drilling operations if there is evidence either of ground movement such that soil nail wall is being adversely affected or of adjacent structures being damaged as a result of drilling operations. Take steps to stabilize the condition immediately and notify the Resident Engineer.

3.07 SOIL NAIL TENDON INSTALLATION

A. Install soil nails prior to the application of shotcrete at the location and to the length indicated on the approved Soil Nail Construction Work Plan, and in accordance with the Contract Drawings. Remove tendons that cannot be easily inserted to their full design length. After the drill holes have been cleaned sufficiently to allow unobstructed installation of the tendon, reinstall tendons.

B. Centralizers are required for all soil nail tendons, including tendons installed using cased and augercast methods.

3.08 GROUTING

A. Leave no drill hole open for more than one hour prior to grouting. Grout drill hole after the installation of the soil nail tendon. Grouting prior to the installation of the soil nail tendon may be allowed upon demonstration, to the satisfaction of the Resident Engineer, that insertion of the soil nail tendon can be achieved without difficulty after the grouting. If the Resident Engineer allows grouting prior to insertion of the soil nail tendon, use neat cement grout.

B. Inject grout at the lowest point of each drill hole through a tremie pipe casing, hollow stem auger, or drill rods. Fill drill hole in one, continuous operation. Keep end of conduit that delivers the grout below the surface of grout as the conduit is withdrawn. Withdraw grouting conduit in a manner to prevent the creation of voids.
3.09 GROUT TESTING
A. Test the nail grout in accordance with ASTM C109 at a frequency of no less than one test per every 50 cubic yards of grout placed, or once every week, whichever comes first.

3.10 SOIL NAIL TESTING
A. Perform verification and proof tests at locations selected by the Independent Geotechnical Engineer and approved by the Resident Engineer. Perform soil nail pull-out tests when grout reaches at least 50 percent of its specified 28-day compressive strength.

B. Tests shall be witnessed and documented by the Independent Geotechnical Engineer. Submit results of all testing to the Resident Engineer.

C. When temporary casing of the unbonded length of test nails is provided, install the casing to prevent any reaction between the casing and the grout bond length of the soil nail and the stressing apparatus.

D. Independently support the jack and center over the soil nail so that the nail does not carry the weight of the jack. Place the stressing equipment over the soil nail in such a manner that the jack, bearing plate, and the stressing anchorage are in alignment. Position the jack at the beginning of the test such that unloading and repositioning of jack during the test will not be required.

3.11 TEST SOIL NAIL UNBONDED LENGTH
A. Provide temporary unbonded lengths for each test soil nail. Isolate test soil nail tendon from shotcrete facing and the reaction frame during testing. Isolation of the test soil nail through the shotcrete facing should not affect the location of the reinforcing steel under the bearing plate.

3.12 VERIFICATION TESTING
A. Perform a minimum of two verification tests in each different soil unit prior to installation of production nails to verify installation methods, soil nail pullout capacity, and design assumptions. The soil nails used for the verification tests will be sacrificial. Do not incorporate these soil nails into the production soil nails.

B. Construct verification test soil nails using the same methods and hole diameter as planned for the production soil nails. Additional verification testing is required for all changes in drilling equipment or installation methods. Provide additional verification testing at no additional cost to Sound Transit.

C. Use an unbonded length of the test soil nail of at least 3 feet unless approved otherwise. Determine the bonded length of the soil nail based on grade and size such that the allowable tendon load is not exceeded; however, do not use lengths less than 10 feet. Do not exceed an allowable tendon load during testing of 80 percent of the steel ultimate yield strength for grade 150 bars, or 90 percent of the yield strength for grade 75. For FRP tendons do not exceed 50 percent of the ultimate strength of the tendon during testing.

D. Determine the Design Test Load (DTL) by multiplying the bond length of the nail by the applicable bond strength as shown on the Contract Drawings:

E. During Verification testing, incrementally load test soil nails in accordance with the following schedule:
<table>
<thead>
<tr>
<th>LOAD</th>
<th>HOLD TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 DTL</td>
<td>10 Minutes</td>
</tr>
<tr>
<td>0.50 DTL</td>
<td>10 Minutes</td>
</tr>
<tr>
<td>0.75 DTL</td>
<td>10 Minutes</td>
</tr>
<tr>
<td>1.00 DTL</td>
<td>10 Minutes</td>
</tr>
<tr>
<td>1.25 DTL</td>
<td>10 Minutes</td>
</tr>
<tr>
<td>1.50 DTL (Creep Test)</td>
<td>60 Minutes</td>
</tr>
<tr>
<td>1.75 DTL</td>
<td>10 Minutes</td>
</tr>
<tr>
<td>2.00 DTL (Max. Load Test)</td>
<td>10 Minutes</td>
</tr>
</tbody>
</table>

F. For the alignment load (AL), the minimum load required to align the testing apparatus, do not exceed 0.05 DTL. Reset dial gauges to zero after the alignment load has been applied.

G. Measure nail movement to the nearest 0.001 inch with respect to an independent fixed reference point at each increment of load.

H. Hold each load increment for at least 10 minutes. Record nail movements at 1 minute, 2, 3, 4, 5, 6 and 10 minutes.

I. Monitor the verification test nail for creep for 60 minutes at 1.50 DTL load increment. Measure and record nail movement during the creep portion of the test at 1 minute, 2, 3, 5, 6, 10, 20, 30, 50, and 60 minutes.

3.13 PROOF TESTING

A. Perform proof testing on approximately 5 percent of the production soil nails in each shotcrete lift, or one nail per row, whichever is greater.

B. Incrementally load soil nail in 0.25 DTL increments to a maximum load of 1.50 DTL. Hold each load increment until the dial gage reading is stable.

C. For the alignment load (AL), the minimum load required to align the testing apparatus, do not exceed 0.05 DTL. Reset dial gauges to zero after the alignment load has been applied.

D. Maintain all increments within 5 percent of the intended load. Depending on performance, perform either a 10-minute or 60-minute creep test at 1.50 DTL. Measure nail movement and record at 1 minute, 2, 3, 4, 5, 6 and 10 minutes. Where the nail movement between 1 minute and 10 minutes exceeds 0.04 inch, maintain the maximum load an additional 50 minutes and record the movements at 20 minutes, 30, 50, and 60 minutes.

E. At the Contractor’s option, successful proof test nails meeting the acceptance criteria may be incorporated as production nails, provided that (1) the unbonded test length of the nail hole has not collapsed during testing, (2) the minimum required hole diameter has been maintained, and (3) the test nail length and tendon size are equal to or greater than the scheduled production nail length and tendon size. Grout the unbonded nail length for test soil nails meeting these requirements.

3.14 TEST NAIL ACCEPTANCE CRITERIA

A. Test nails will be considered acceptable when:
1. For verification and proof tests: a creep test rate less than 0.04 inch per log cycle of time between the 1 and 10 minute readings is observed, or a creep rate less than 0.08 inch per log cycle of time between the 6 and 60 minute readings, and the creep rate is linear or decreasing throughout the creep test load hold period.

2. For proof tests only: The total measured movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the test nail unbonded length.

3. For verification and proof tests: A pullout failure does not occur during testing. Pullout failure is defined as the load at which attempts to further increase the test load result in continued pullout movement of the test nail.

3.15 INADEQUATE SOIL NAIL PERFORMANCE

A. The Resident Engineer will evaluate the results of each verification test. Installation methods that do not result in satisfactory testing results will be considered inadequate. Propose alternate methods and perform additional replacement verification tests if the installation methods are deemed inadequate. Install replacement test soil nails and test at no extra cost to Sound Transit.

B. The Resident Engineer may require that the Contractor replace some or all of the production soil nails represented by an inadequate proof test soil nail. Alternatively, the Resident Engineer may require additional proof test soil nails to be installed and tested to verify the adequacy of the previously installed soil nails. The cost associated with installing and testing of additional test soil nails as a result of poor test nail performance will be the responsibility of the Contractor unless otherwise determined by the Resident Engineer to be due to causes beyond the Contractor’s control.

3.16 SOIL NAIL TOLERANCE

A. Do not extend soil nails beyond indicated right-of-way or easement limits, unless approved otherwise by the Resident Engineer and Sound Transit.

B. Center tendons within 1 inch of the center of the drill hole.

C. Position individual soil nails within 6 inches of the locations shown on approved Soil Nail Construction Work Plan.

D. Install nails at a nail splay angle of plus or minus 3 degrees of angle shown on approved submittals, unless clearances to utilities will be less than minimum values.

E. Relocate nails that encounter unanticipated obstructions, or remove obstructions.

F. Replace nails that do not meet the tolerance criteria due to construction methods.

3.17 SOIL NAIL INSTALLATION RECORD

A. Document and maintain accurate records of the soil nail wall construction. Include soil nail locations, top of wall elevations, and other information requested by Sound Transit.

3.18 FACING INSTALLATION

A. Install shotcrete facing as indicated on the Contract Drawings, and conforming to requirements of Section 03 37 13, Shotcrete for Temporary Support of Excavation Wall Facings.

END OF SECTION
PART 1 - GENERAL

1.01 DESCRIPTION:

A. This Section includes specifications for designing, furnishing, installing, monitoring, and leaving in place excavation support systems. Locations and extent of these systems are shown on the Contract Drawings.

B. This section applies to both owner-designed excavation support systems (Contract Drawings) and Contractor-designed excavation support systems (Working Drawings). Design requirements that apply only to Contractor-designed excavation support systems are noted accordingly. This section also applies to excavation support systems which will be used as permanent structural elements at the Maple Leaf Portal. Location and extents of the Permanent Soldier Pile wall system is shown on the Contract Drawings.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 05 15, Portland Cement Concrete
2. Section 05 12 00, Structural Steel Framing
3. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
4. Section 31 20 00, Earth Moving.
5. Section 31 23 19, Dewatering.
6. Section 31 51 00, Anchor Tiebacks

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

   a. ASTM A36 Standard Specification for Carbon Structural Steel
   c. ASTM A328 Specification for Steel Sheet Piling
   d. ASTM A500 Standard Specifications for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
   e. ASTM A572 Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
2. American Wood Preservers’ Association (AWPA):

3. Washington State Department of Transportation (WSDOT)
   a. Standard Specifications for Road, Bridge and Municipal Construction (WSDOTSS)

1.03 DEFINITIONS

A. Anchor Tieback: Refer to 31 51 00, Anchor Tiebacks.


C. Existing Construction: Adjacent structures, facilities, equipment, conveyances, and utilities present at the beginning of excavation.

D. Lagging: A horizontal element restraining the lateral movement of a cut soil face and supported by soldier piles. Lagging is typically timber, precast concrete, or shotcrete.

E. Neat Line: In-plan wall face that forms the inside face of excavation.

F. Parcel: An area of ground as indicated, including all existing construction upon or connected to it.

G. Raker: A sloping strut, typically supported on grade.

H. Restore: To return to pre-excavation condition by repair or replacement of portions damaged, altered, or removed by excavation activities.

I. Shore: A horizontal, inclined, or vertical element positioned against or beneath a structure, part of a structure, or utility to restrain movement.

J. Shoring: An excavation support system designed and installed to protect the public and property from potential impact due to excavation activities by limiting the horizontal and vertical movement of soil and adjacent construction. Shoring may be temporary or permanent.

K. Soldier Pile: A vertical element supporting lagging and supported by embedment into grade and tieback anchors, wales, struts, or rakers. Soldier piles are typically rolled steel W-, S- or H-shapes.

L. Strut: A horizontal element keeping two other elements a fixed distance apart, usually soldier piles or wales. Struts carry axial compression and are typically rolled steel pipe, tube or W-, S-, or H-shapes.

M. Tremie: A pipe used to place concrete under water or slurry, displacing the water or slurry during placement.

N. Tremie Concrete: Concrete placed under water or slurry using a tremie.

O. Wale: A horizontal element supporting lagging, sheets, sheet piling, or soldier piles, and supported by anchor tiebacks or struts.

P. Working Drawings: Drawings describing the excavation support system for Contractor-designed systems.
1.04 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Driller’s Qualifications.

C. Structural Engineer’s Qualifications: For contractor-designed excavation support systems.

D. Surveyor’s Qualifications.

E. Welder Certifications.

F. Construction Work Plan: In accordance with Section 01 45 00.20, Quality Assurance/Quality Control, submit a written program. Include the following:

1. An overall construction operation sequence and the sequence of shaft construction.

2. List, description, and capacities of proposed equipment including but not limited to cranes, drills, augers, bailing buckets, final cleaning equipment, and drilling units.

3. Details of shaft excavation methods including proposed drilling methods, methods of cleanout of the shafts, disposal plan for excavated material and drilling slurry (if applicable), and a review of method suitability to the anticipated site and subsurface conditions.

4. Details of the method(s) to be used to ensure shaft stability (i.e. prevention of caving, bottom heave, etc. using temporary casing, slurry, or other means) during shaft excavation and concrete placement. Include a review of method suitability to the anticipated site and subsurface conditions. If temporary casings are proposed, provide casing dimensions and detailed procedures for casing installation and removal. If slurry is proposed, provide detailed procedures for mixing, using, maintaining, and disposing of the slurry. Provide a detailed mix design for the proposed slurry, and a discussion of its suitability to the anticipated subsurface conditions.

5. Details of steel pile placement including internal support bracing and centralizing methods.

6. Details of concrete placement including proposed operational procedures for pumping and/or tremie methods.

7. Excavation sequence and schedule.

8. For Secant Pile Walls, details of the methods(s) to be used to trim secant piles to form excavation neat line.

9. Details of the protection measures to be used for existing construction.

10. Instrumentation and monitoring procedures.

11. Removal procedures and sequence (if applicable).


13. Field Quality Control Measures.
G. Working Drawings: For excavation support systems or components designed by the contractor, submit Working Drawings signed and sealed by a Structural Engineer. Include the following:

1. Element sizes and locations
2. Element assembly and connection details
3. Interface details for existing construction
4. Interface details for permanent elements

H. Calculations: For excavation support elements designed by the contractor, submit calculations to support design shown on the Working Drawings, signed and sealed by a Structural Engineer.

I. Structural Steel Shop Drawings: Submit in accordance with 05 12 00, Structural Steel Framing.

J. Soldier Pile and Secant Pile Logs: Include for each shaft:

1. Pile number, location, size, and location of splices, if present.
2. Date and time of start and completion of pile shaft excavation
3. Elevation of water table during excavation.
4. Soil conditions encountered during drilling.
5. Shaft diameter and any variations in diameter with depth.
6. Condition of shaft bottom at time of concrete placement.
7. Concrete mix data including design mix number, volume placed, and method of placement.
8. Date and time of installation of concrete encasement.
10. Final top and bottom elevations of pile and concrete encasement.
11. Final horizontal location of pile axis, and variation from design location.
12. Other documentation as may be dictated by construction conditions including problems encountered, and delays.

K. Mix Designs: Submit mix designs for all concretes and grouts, in accordance with Section 03 05 15, Portland Cement Concrete.

L. Monitoring Program Readings and Results.

1.05 QUALITY ASSURANCE

A. Drilling Contractor: Select drilling contractors having a minimum of 5 years of in drilling shafts for soldier piles, secant piles, or work of similar character.

B. Drill Rig Operator: Select a drill rig operator with a minimum of 2 years of experience in construction of drilled shafts.
C. Structural Engineer: For contractor-designed excavation support systems, select a licensed civil or structural engineer currently registered in the State of Washington, with a minimum of 5 years of experience in the design and construction of excavation support systems.

D. Professional Land Surveyor: Select a licensed professional land surveyor currently registered in the State of Washington, with a minimum of 5 years of experience in work of a similar character.

E. Welders: Certified as described in 05 05 23, Metal Fastenings.

1.06 EXCAVATION SUPPORT DESIGN REQUIREMENTS

A. Excavation support systems designed by the contractor shall meet the following criteria:


3. Support earth pressures indicated on Contract Drawings, including surcharge loads due to existing construction, equipment, traffic, and construction activities. Where earth pressures indicated on Contract Drawings are not applicable, derive appropriate lateral earth pressures consistent with the conditions described in the Geotechnical Baseline Report.

4. Driving of soldier piles or sheet piles with vibratory or impact hammers is not allowed.

5. Allow the required free excavated space for workers and groundwater control systems.

6. Design excavation support systems such that the deflections are less than those specified in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork or indicated on the contract drawings.

7. Compatible with conditions described in the Geotechnical Baseline Report.

1.07 CONTINGENCY REQUIREMENTS

A. Contingency Plan: Have materials and equipment readily available to implement mitigating measures to arrest potential excavation support movement. Mitigating measures shall be approved by the Resident Engineer.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General: Materials for temporary excavation support systems may be new or used, provided they are sound and free from strength-impairing defects. Materials used in permanent structures shall be new.

B. Concrete: Refer to Section 03 05 15, Portland Cement Concrete.

C. Metals: Refer to Section 05 12 00 Structural Steel Framing.
1. Permanent steel piles and attachments shall be shop painted after fabrication with one coat of inorganic zinc primer.

D. Tiebacks: Refer to Section 31 51 00, Anchor Tiebacks.
   1. Permanent tiebacks shall include an encapsulated double corrosion protection system.

E. Timber:
   1. Grade: As specified on the Contract Drawings or approved Working Drawings.
   2. Lagging: Lagging shall be rough-sawn. Lagging need not be new, but shall be in serviceable condition.
   3. Temporary lagging elements shall be designed by the contractor in accordance with the WSDOTSS Section 6-16.3(6)B. The contractor shall confirm the Soil Type based on field conditions confirmed by the Geotechnical engineer.
   4. Preservative Treatment: Pressure treat wood members left in place with preservative material in accordance with AWPA U1, Use Category 4A, Commodity Specification A.

F. Wall Drainage Network
   1. Geocomposite Drain Strips:
      a. Preformed grid of embossed plastic or a system of plastic pillars and interconnections forming a semirigid mat.
      b. Manufactured with a drainage core not less than 0.25 inches thick or more than 0.50 inches thick.
      c. Drainage core with a minimum compressive strength of 15,000 pounds per square foot (psf) covered with filter fabric capable of maintaining drainage void.
      d. Maintain full flow through drain strip splices.
   2. PVC Connector and Drain Pipes
      a. Pipe: ASTM D1785 Schedule 40 PVC, solid and perforated wall, cell classification 12454-B or 12354-C, wall thickness SDR 35.
      b. Drain Backfill: ASTM C33 No. 67 with no more than 2 percent passing the No. 200 sieve.

G. Do not use combustible waste or similar material for packing or soil retention in excavations.

PART 3 - EXECUTION

3.01 GENERAL

A. Construct excavation support systems in accordance with Contract Drawings or approved Working Drawings and in a manner that will ensure that supported faces will be stabilized.
3.02 FIELD QUALITY CONTROL

A. Monitoring Program: Monitor the excavation support at the locations indicated. Monitor in accordance with Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

B. Excavation Support System Installation: Retain the services of a geotechnical engineer to observe the installation.

C. Concrete Testing: Test concrete in accordance with Section 03 05 15, Portland Cement Concrete.

D. Utility Locations:

1. Utilities in close proximity to soldier piles and secant piles shall have their locations and depths verified by potholing prior to the start of shaft drilling. The contractor shall pothole any utilities that appear to be in potential conflict with the shoring. The Contract Drawings indicate the minimum utilities that must be potholed prior to construction. Representatives of SDOT and the utility owner will need to be present at the time of potholing, so notify them at least 10 days prior to potholing.

2. Proceed with caution in areas of utility facilities and structures. Expose existing utilities by hand-excavation or by other method acceptable to the utility owner.

3. If existing utility facilities and structures interfere with proposed method of excavation support, modify or relocate such facilities in accordance with the utility owner's recommendations or modify the excavation support systems.

3.03 SHAFTS

A. SEQUENCING AND SCHEDULING

1. Sequence pile installation such that no pile is excavated within a clear distance of 12 feet from concrete encasement less than 12 hours old.

2. Schedule work so that encasement is placed within twelve hours after excavation of pile.

B. SHAFT EXCAVATION

1. Excavate shafts to the required depth as shown on the Contract Drawings. Observe the drilling rate and resistance as the boring of each hole is advanced. Record the relative drilling rate.

2. Shaft minimum diameter as shown on the Contract Drawings.

3. Use temporary casing, slurry, or other methods specified in the Construction Work Plan to ensure the safety and stability of the shaft and surrounding soil during shaft excavation.

4. Do not allow vibration or excessive wheel loads within the immediate vicinity of any shaft. Maintain shaft excavation stability at all times.

5. For soldier piles and non-interlocking (primary) secant pile shafts, do not commence shaft excavation until the shaft backfill for the adjacent shafts has been placed and has reached a strength of 100 pounds per square inch (PSI).
6. For interlocking (secondary) secant pile shafts, do not commence shaft excavation until the shaft backfill for the adjacent (primary) shafts has been placed and has reached a strength of 250 PSI.

7. If used, leave the temporary casing in place through the cleaning and inspection operations of the shafts. Withdraw casing as the concrete is placed.

8. Begin extraction of casing only after sufficient concrete has been placed in the shaft to achieve a minimum height differential between the bottom of the casing and the top of concrete of 5 feet. Maintain the differential until the concrete achieves finish elevation.

9. In the event that groundwater is encountered during excavation operations, pumping of water from the shaft excavation will be permitted during construction, provided that the groundwater does not flow into the excavation rapidly enough to carry particles of soil or result in caving of excavation walls, bottom heaving, or ground settlement.

10. If groundwater inclusion endangers the stability of the excavation or adjacent structures, or exceeds reasonable pumping capacity, take such groundwater control measures as may be required in accordance with applicable regulations.

11. Monitor and discharge groundwater in accordance with Section 31 23 19, Dewatering.

12. After the holes have been bored to the proper depth, remove loose earth or debris, including water, from the bottom and sides of the hole. Leave bottom surfaces flat and level.

13. Measure drilled holes to verify the piles have been drilled to the depths indicated on the Contract Drawings or approved Working Drawings.

C. STEEL PILE INSTALLATION

1. Place the prefabricated steel piles and maintain in the center of the shafts using centering devices. Align the flange of the pile parallel to the future excavation line. Place steel pile after excavation bottom is inspected and accepted.

2. Cutting Off Steel Piles
   a. For pile installation where a longer pile than required was furnished, cut off the pile to the length required.
   b. Make the cut at the location necessary to maintain the tieback openings at the levels shown on the Contract Drawings or approved Working Drawings.
   c. Make all cuts perpendicular to the axis of the pile.
   d. Remove cut off sections of steel piles from the site and suitably dispose of.

3. Rebuilding or Extending Steel Piles
   a. Extend the steel pile installations where the depth of the shaft must be extended beyond the depth shown on the Contract Drawings or approved Working Drawings to obtain a non-yielding foundation for the pile, and where the length of the furnished pile is inadequate for the deepened hole.
b. Provide the length of extension necessary to extend the steel pile to the bottom of the shafts, while maintaining the tieback openings at the levels shown on the Contract Drawings or approved Working Drawings.

c. Provide extensions of the same section size and weight as the soldier pile to which it is spliced.

d. Submit splicing details to the Resident Engineer. Splice locations shall be identified in the Working Drawings.

D. SHAFT BACKFILLING

1. Backfill the excavated shaft with lean-mix concrete in accordance with Section 03 30 00, Cast-In-Place Concrete, and the following requirements:

a. Where noted on the Contract Drawings, the excavated shafts shall be filled with structural concrete below the bottom of adjacent excavation, and lean-mix concrete above the bottom of adjacent excavation.

b. Place concrete in dry excavations whenever practicable. Use all practicable means to obtain a dry excavation before and during concreting.

c. Place concrete for dry excavations by free fall or tremie methods. Place concrete equally around the steel pile where present. Place concrete in each shaft continuously to the top elevation.

d. If water accumulates in the shafts after cleaning and inspection, remove water by approved methods before backfilling, or place the concrete below the accumulated water using tremie methods.

1) When the groundwater infiltration rate is greater than 1/4-inch vertical rise in hole per minute, consider soldier pile excavations "wet" and place concrete using the tremie method.

2) Except when concreting by the tremie method, do not allow the total height of water in the bottom of the excavation to exceed 2 inches at the time of concrete placement.

2. Remove the temporary casing, if present. During extraction of the casing, prevent upward movement of the steel pile.

3. Vibrate only the top 5 feet of concrete after the casing has been withdrawn.

3.04 TIMBER LAGGING INSTALLATION (SOLDIER PILE WALLS)

A. Do not begin excavation and removal of concrete for lagging installation until the concrete is of sufficient strength that the material remains in place during excavation and lagging installation.

B. Install lagging to soldier piles walls as excavation progresses, from the top of the steel pile proceeding downward.

C. Install lagging in direct contact with the soil being retained. When and where lagging is not in full contact with the soil being retained, backfill the void with free-draining material as lagging is installed. Backfill lagging prior to excavating subsequent lift.

D. Do not allow more than four feet of exposed cut soil face.

E. Take immediate steps to prevent piping of soils through lagging if observed.
3.05 WALL DRAINAGE NETWORK INSTALLATION

A. Prior to any permanent fascia panel installation, attach Geocomposite Drain Strips to lagging in accordance with manufacturer instructions. Drain strips shall be installed full height of the concrete fascia panel, centered between soldier pile flanges.

B. Splicing of the drain mat shall be in accordance with the manufacturer’s recommendations. Contractor shall ensure that splices create a hydraulic connection between spliced mats, and that water flow is not impeded. Tape all joints in drain mats to prevent concrete intrusion.

C. Install drain grates and connecting pipes to drain mat in accordance with manufacturer instructions. Secure drain pipes such that movement does not occur during concrete placement of fascia.

3.06 SUPPORT SYSTEMS WITH INTERNAL BRACING

A. General: Provide wales, struts, and rakers as necessary to support excavation faces retained by soldier piles and lagging.

B. Bracing:

1. Provide wales where required, at each level of bracing. As excavation proceeds, place wales on open face of support system wall. Wedge, dry pack, and otherwise provide tight bearing between wales and support system wall, with ample bearing areas to provide uniform transfer of loads.

2. Include web stiffeners, plates, angles, or bracing as needed to prevent rotation, crippling, or buckling of connections and points of bearing between structural members. Design for eccentricities caused by field fabrication and assembly.

3. Design bracing support members for maximum loads which may occur during excavation and removal stages including surcharge loads.

3.07 EXCAVATION BELOW TIEBACKS AND BRACING

A. Complete tieback installation testing and stressing prior to excavating more than 2 feet below the centerline of the tieback. Complete internal bracing installation prior to excavating more than 3 feet below the bracing level.

3.08 TOLERANCES

A. Construct shafts at the locations shown on the Contract Drawings. Shafts shall be placed such that steel piles do not impinge on the neat line of excavation shown on the contract drawings and within the tolerances specified herein.

1. Install the shafts such that the axis at the top of the shaft is no more than 3-inches in any direction from the position shown in the Contract Drawings.

2. Install the shafts plumb, to within 0.5 percent of the length of the shaft based on the total length of the shaft.

3. To the extent possible, center steel piles within shafts while preventing steel piles from impinging on the neat line of excavation.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing, maintaining, and leaving in place temporary tiebacks (including buried tendons) as indicated on the Contract Drawings. Coordinate requirements of this Section with Section 31 50 00, Excavation Support and Protection.

B. Unless otherwise directed, the Contractor shall select the tieback type, drilling method, grouting method, grouting pressures, and, subject to the minimum values in the Contract Drawings, determine the bond length, free-stressing (unbonded) length, and anchor diameter. The Contractor shall be responsible for installing tiebacks that will develop the load-carrying capacity indicated on the Contract Drawings in accordance with the testing subsection of this Specification.

C. The work of this Section includes the following:

1. Install temporary tiebacks as required as excavation proceeds.

D. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 05 15, Portland Cement Concrete.
2. Section 03 11 00, Concrete Forming.
3. Section 03 20 00, Concrete Reinforcing.
4. Section 03 30 00, Cast-In-Place Concrete.
5. Section 31 23 01 Excavation Spoils and Muck Disposal
6. Section 31 50 00, Excavation Support and Protection.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

   a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded, and Seamless
   b. ASTM A416 Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete
   c. ASTM A500 Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
d. ASTM A572 Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

e. ASTM A722 Standard Specification for Uncoated High-Strength Steel Bars for Prestressing Concrete

f. ASTM A775 Standard Specification for Epoxy-Coated Steel Reinforcing Bars

g. ASTM A779 Standard Specification for Steel Strand, Seven-Wire, Uncoated, Compacted, Stress-Relieved for Prestressed Concrete

h. ASTM A882 Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand


j. ASTM C150 Standard Specification for Portland Cement

k. ASTM D1248 Standard Specification for Polyethylene Plastics Extrusion Materials For Wire and Cable


m. ASTM D1785 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

n. ASTM D4101 Standard Specification for Polypropylene Injection and Extrusion Materials

2. American Association of State Highway and Transportation Officials (AASHTO):

a. AASHTO M85 Portland Cement

b. AASHTO M183 Structural Steel

c. AASHTO M203 Steel Strand, Uncoated Seven-Wire for Concrete Reinforcement

d. AASHTO M222 High-Strength Low-Alloy Structural Steel with 50 ksi Minimum-Yield Point to 4-in Thick

e. AASHTO M252 Corrugated Polyethylene Drainage Pipe

f. AASHTO M275 Standard Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete

g. AASHTO M284 Standard Specification for Epoxy-Coated Steel Reinforcing Bars

3. Post-Tensioning Institute (PTI):

a. Recommendations for Prestressed Rock and Soil Anchors

b. Post-Tensioning Manual

4. Washington State Department of Transportation (WSDOT)
1.03 DEFINITIONS

A. Anchor Tieback: System used to transfer tensile loads to soil or rock. Includes all prestressing steel, centralizers, spacers, anchorage devices, grout, coatings, sheathings, corrosion protection, and couplers if used, and final concrete facing.

B. Tremie Concrete: see Section 31 66 17, Slurry Diaphragm Walls.

C. Alignment Load: A nominal minimum load applied to an anchor tieback during testing to keep the testing equipment correctly positioned.

D. Bondbreaker: A sleeve placed over the tendon in the unbonded length to ensure unobstructed elongation of the tendon during stressing.

E. Encapsulation: A corrugated or deformed tube protecting the prestressing steel against corrosion.

F. Tendon: The complete anchor assembly (excluding grout) including prestressing steel (strands or bar), corrosion protection, sheathings, coatings, and spacers and centralizers.

G. Bond Length: The length of the anchor tieback that is bonded to the surrounding soil and capable of transmitting the applied tensile load to the soil.

H. Tendon Bond Length: The length of the tendon that is bonded to the surrounding grout and capable of transmitting the applied tensile load to the grout.

I. Unbonded Length: The designed length of the tendon that is not bonded to the grout during stressing.

J. Working Drawings: See 31 50 00, Excavation Support and Protection.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit calculations for design of the tendons, unbonded lengths, bonded lengths, bearing plates, and wedge plates for review and approval prior to commencement of this work. Ensure calculations are prepared, sealed, and signed by an anchor tieback design engineer.

C. Working Drawings indicating tieback system and installation procedures. Include:

1. Anchor tieback schedule showing each anchor tieback number, design load, tendon type, anchor diameter, minimum bond length, minimum tendon bond length, and minimum unbonded length.

2. Details for spacers and locations, centralizers, anchorage and trumpet.

3. Details for encapsulation and corrosion protection system, including transition details from bonded zone to unbonded zone and unbonded zone to anchorage.
D. Grout mix design.

E. Mill test reports for prestressing steel and bearing plate steel.

F. Calibration data for each test jack, load cell, primary pressure gage, and reference pressure gage to be used. Calibration records shall include the date tested, the device identification number and the calibration test results, and shall be certified for an accuracy of at least 2 percent of the applied certification loads by a qualified independent testing laboratory within 90 days prior to submittal.

G. Grouting records indicating cement type, quantity injected, and grout pressures; anchor test results and graphs, and as-builts showing location and orientation of each anchor tieback, capacity, tendon type, total anchor length, bond length, and locations of all instruments.

H. Test data and results for all testing required herein.

I. Driller's qualifications.

J. Anchor Tieback Design Engineer’s qualifications.

1.05 QUALITY ASSURANCE

A. Drillers shall be skilled in tieback installation work, for the purpose of drilling and installing tiebacks, and have a minimum of five years of experience in drilling and installing work of similar scope and complexity.

B. Anchor Tieback Design Engineer shall be a professional civil or structural engineer currently registered in the State of Washington.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Handle and store tendons in such a manner as to avoid damage or corrosion. Damage to prestressing steel as a result of abrasions, cuts, nicks, welds, and weld spatter will be cause for rejection.

B. Protect prestressing steel if welding is to be performed in vicinity. Grounding of welding leads to prestressing steel is forbidden. Protect prestressing steel from dirt, rust, deleterious substances, or excessive heat. A light coating of rust on steel is acceptable. If heavy corrosion or pitting is noted, Resident Engineer will reject affected tendons.

C. Do not cause excessive bending during lifting of pre-grouted tendons, which can de-bond the prestressing steel from the surrounding grout.

D. Tendon bond length must be free of dirt, manufacturer’s lubricants, and corrosion inhibiting coatings or other deleterious substances that may significantly affect the grout tendon bond.

1.07 PROJECT CONDITIONS

A. Refer to Geotechnical Baseline Report.

B. Existing Utilities: Verify location of existing utilities prior to commencement of excavation activities. Proceed with caution in areas of utility facilities and structures. Expose existing utilities by hand-excavation or by other method acceptable to the utility owner.
PART 2 - PRODUCTS

2.01 MATERIALS

A. General: Use new materials that are sound and free from strength-impairing defects.

B. Anchorage Devices:

1. Stressing Anchorages: Combination of either a steel bearing plate with wedge plate and wedges, or a steel bearing plate with a threaded anchor nut. The steel bearing and wedge plate may also be combined into a single element. Ensure anchorage devices are capable of developing 95 percent of the specified minimum ultimate tensile strength of the prestressing steel tendon. Ensure anchorage devise conforms to the static strength requirements of the PTI Post Tensioning Manual.

2. Bearing Plates: Conform to the requirements of ASTM A572, Grade 50.

C. Wedges: Design to preclude premature failure of prestressing steel due to notch or pinching effects under static and dynamic strength requirements of the PTI Post-Tensioning Manual. Do not reuse wedges.

D. Bondbreakers: Fabricate from smooth plastic tube or pipe having the following properties:

1. Resistant to chemical attack from aggressive environments, grout or corrosion inhibiting compound;
2. Resistant to aging by ultra-violet light;
3. Fabricated from material non-detrimental to tendon;
4. Capable of withstanding abrasion, impact, and bending during handling and installation;
5. Enables tendon to elongate during testing and stressing;
6. Allows tendon to remain unbonded after lock-off.

E. Cement Grout: Type I, II, III, or V portland cement conforming to the requirements of ASTM C150. Use grout of a pumpable neat mixture of cement and water and that is stable (bleeds less than two percent), fluid, and provides a minimum 28-day compressive strength of at least 4000 pounds per square inch (psi) measured in accordance with ASTM C109 at time of stressing. Admixtures that control bleed, improve flowability, reduce water content, and retard set may be used in the grout. Ensure admixtures are compatible with the prestressing steels and mixed in accordance with manufacturer's recommendations. Expansive admixtures may only be added to grout used for filling sealed encapsulations, trumpets, and anchorage covers.

F. Centralizers and Spacers: Plastic or material non-detrimental to prestressing steel.

G. Corrosion-Inhibiting Compound: For the corrosion-inhibiting compound placed inside the sheath in the free length, use an organic compound such as wax or grease with appropriate polar moisture displacing, corrosion-inhibiting additives and self-healing properties. Use a compound that permanently stays viscous and is chemically stable and non-reactive with the prestressing steel, the sheathing materials, and the anchor grout.

H. Grout Tubes: Have adequate inside diameter to enable grout to be pumped to bottom of drill hole. Strong enough to withstand grouting pressures.
I. Tendons: Tendons to conform to ASTM designation and all components to be compatible with the tendon system:

1. Strand: Seven-wire cables of 0.5 inch or 0.6 inch nominal cross sectional area. Comply with ASTM A416, Grade 270.

2. Bar (including buried tendon): ASTM A722, Grade 150

J. Couplers: capable of developing 100 percent of minimum specified ultimate tensile strength of steel bar.

K. Sheath: Use as part of the corrosion protection system for the unbonded length portion of the tendon. Fabricate from one of the following:

1. A polyethylene tube pulled or pushed over the prestressing steel. Use Type II, III, or IV polyethylene as defined by ASTM D1248, or approved equal. Use tubing that has a minimum wall thickness of 1/16 inch.

2. A hot-melt extruded polypropylene tube. Use cell classification B5542-11 polypropylene as defined by ASTM D4101, or approved equal. Use tubing that has a minimum wall thickness of 1/16 inch.

3. A hot-melt extruded polyethylene tube. Use high density Type III polyethylene as defined by ASTM D1248, or approved equal. Use tubing that has a minimum wall thickness of 1/16 inch.

4. Steel tubing conforming to ASTM A500. Use tubing that has a minimum wall thickness of 3/16 inch.

5. Steel pipe conforming to ASTM A53. Use pipe that has a minimum wall thickness of 3/16 inch.

6. Plastic pipe or tube of PVC conforming to ASTM D1784 Class 13464-B. Use pipe or tube that is Schedule 40 at a minimum.

7. A corrugated tube conforming to the requirement of the tendon bond length encapsulation.

L. Concrete and Grout: Refer to Section 03 11 00, Concrete Forming, Section 03 20 00, Concrete Reinforcing, Section 03 30 00, Cast-In-Place Concrete, and Section 03 05 15, Portland Cement Concrete, for requirements.

M. Corrosion Protection System: Anchor tiebacks shown on the Contract Drawings to receive a double corrosion protection system shall include the following:

1. The tendon bond length shall be corrosion protected by encapsulating the tendon in a grout-filled tube. The grout filled tube shall be encapsulated within the soil bond grout of the drilled hole.

2. Corrosion protection of the unbonded length shall be provided by a greased sheath. The sheath system shall prevent bond with the encapsulation grout.

3. Corrosion protection of the anchorage shall include a trumpet for transition from the corrosion protection of the unbonded length to the anchorage system.
PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL

A. Anchor Tieback installation: Retain the services of a geotechnical engineer to observe the installation, including observation and recording of tests.

3.02 TIEBACK TENDON DESIGN CRITERIA

A. Refer to Section 31 50 00, Excavation Support and Protection, for system design requirements.

B. Determine bond length necessary to develop design load indicated on Contract Drawings or in approved working drawings. Bond length shall not be less than 15 feet.

C. Extend the unbonded length for tiebacks beyond the no load zone as shown on the Contract Drawings.

D. Anchor tiebacks shall be capable of being re-stressed as required.

3.03 FABRICATION

A. Shop or field-fabricate tiebacks. Cut prestressing steel with abrasive saw or, with approval of prestressing steel Supplier, an oxyacetylene torch. Perform pre-grouting of encapsulated tendons on an inclined, rigid frame or bed by injecting grout from low end of tendon.

3.04 INSTALLATION

A. Select the drilling method, grouting procedure, and grouting pressure to be used for installation of anchors as necessary to satisfy the testing and stressing requirements.

B. Locate drill hole such that longitudinal axis of drill hole and longitudinal axis of tendon are parallel. Do not drill hole in a location that requires tendon to be bent in order for bearing plate to be connected to supported structure.

C. Prior to inserting tendon in drill hole, examine tendon for damage to encapsulation and sheathing. If required, repair encapsulation in accordance with Supplier’s recommendations. Repair damage to sheathing with high molecular weight polyethylene tape. Spiral wind the tape around the tendon to completely seal damaged area. Spiral wind at a pitch which ensures double thickness at all points.

D. Where centralizers are required, space them at no greater than 10 feet on center with the deepest centralizer located one foot from the end of the anchor and the upper centralizer for the bond zone located no more than five feet from the top of the tendon bond length.

E. Ensure spacers permit grout to freely flow around tendon and up drill hole. Place spacers at a maximum interval of 10 feet.

F. Place tendons in accordance with recommendation of tendon manufacturer. Insert tendon in drill hole to desired depth without difficulty. Do not drive or force partially inserted tendons into drill hole. Remove tendon from drill hole and clean or re-drill the hole to permit insertion.

G. Control the rate of placement of tendon into drill hole such that sheathing and grout tubes are not damaged during installation of tendon. Do not subject anchor tendons to sharp bends. Bottom end of tendon may be fitted with a cap or bullnose to aid its insertion into the hole, casing, or sheathing.
H. Drill holes for tiebacks in a manner that will minimize loss of ground and at the locations and to the length, inclination, and diameter shown on Contract Drawings or approved working drawings.

3.05 GROUTING

A. Use a neat cement grout or sand-cement grout. Ensure cement does not contain lumps or other indications of hydration. Use grouting equipment that produces grout free of lumps and undispersed cement.

B. Use a positive displacement grout pump. Equip the pump with a pressure gage to monitor grout pressures. Ensure pressure gage is capable of measuring pressures of at least 150 pounds per square inch or twice the actual grout pressure used whichever is greater. Size grouting equipment to enable grout to be pumped in one continuous operation. Ensure mixer is capable of continuously agitating the grout.

C. Inject grout from lowest point of drill hole. Pump through grout tubes, casing, hollow-stem augers, or drill rods. Place before or after insertion of tendon. Record quantity of grout and grout pressures. Control grout pressures and grout takes to prevent excessive heave or fracturing.

D. Do not use pressure grouting in free length zone. Ensure the grout at the top of the drill hole does not contact the back of the structure or the bottom of the trumpet.

E. Clean and protect stressing tail from damage until lock-off. After anchor has been stressed and accepted by the Resident Engineer, cut tail to final length according to tendon manufacturer's recommendations.

F. Install anchor bearing plate and anchor head or nut perpendicular to tendon, within plus or minus three degrees and centered on bearing plate, without bending or kinking of prestressing steel elements. Wedge holes and wedges shall be free of rust, grout, and dirt.

G. Dispose of spilled, discarded, and wasted grout and related materials in accordance with Section 31 23 01, Excavation Spoils and Muck Disposal.

3.06 STRESSING, LOAD TESTING, AND ACCEPTANCE OF TIEBACKS

A. Test each tieback anchor. Do not apply a load greater than 10 percent of the design load to the anchor prior to testing. Do not apply a maximum test load greater than 80 percent of the specified minimum ultimate tensile strength of the prestressing steel of the tendon. Simultaneously apply test loads to the entire tendon. Stressing of single elements of multi-element tendons is not permitted.

B. Test Equipment

1. Use a dial gage or vernier scale capable of measuring displacement to 0.001 inch to measure tendon movement. Ensure it has adequate travel so total movement can be measured without resetting the device.

2. Use a hydraulic jack and pump to apply the test load. Use the jack and a calibrated pressure gage to measure the applied load. Use a pressure gauge that is graduated in 100 psi increments or less. When the theoretical elastic elongation of the total anchor length at the maximum test load exceeds the ram travel of the jack, include the procedure for recycling the jack ram in the working drawings. Apply each increment of test load in one minute or less.

3. Maintain a calibrated reference pressure gage at the site. Calibrate the reference gage with the test jack and pressure gage.
4. Provide an electrical resistance load cell and readout when performing a creep test.

5. Place the stressing equipment over the tendon in such a manner that the jack, bearing plates, load cell, and stressing anchorage are axially aligned with the tendon and the tendon is centered within the equipment.

C. Performance Test

1. Conduct four successful performance tests on tieback anchors, as selected by the Resident Engineer. Drill and install the performance test anchors in the same manner as the production anchors, with the exception that additional or larger tendons should be included so that the test load does not exceed 80 percent of the specified minimum ultimate tensile strength of the prestressing steel of the tendon. Changes in methods, personnel, materials or equipment may require additional performance testing as determined by the Resident Engineer.

2. Performance test selected anchors as indicated in the following schedule. Raise load from one increment to another immediately after recording tendon movement.

3. Measure and record tendon movement to the nearest 0.001 inch with respect to an independent fixed reference point at the alignment load and at each increment of load. Monitor load with a pressure gage. Place reference pressure gage in series with the pressure gage during each performance test. If load determined by reference pressure gage and load determined by pressure gage differ by more than 10 percent, recalibrate the jack, pressure gage, and reference pressure gage. At load increments other than the maximum test load, hold the load just long enough to obtain the movement reading.

### PERFORMANCE TEST SCHEDULE

<table>
<thead>
<tr>
<th>Load</th>
<th>Load (continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment Load (AL)</td>
<td>AL</td>
</tr>
<tr>
<td>0.25P*</td>
<td>0.25P</td>
</tr>
<tr>
<td>AL</td>
<td>0.50P</td>
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<tr>
<td>0.25P</td>
<td>0.75P</td>
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<tr>
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<td>1.50P*</td>
</tr>
<tr>
<td>0.25P</td>
<td>AL</td>
</tr>
<tr>
<td>0.50P</td>
<td>0.25P</td>
</tr>
<tr>
<td>0.75P*</td>
<td>0.50P</td>
</tr>
<tr>
<td>AL</td>
<td>0.75P</td>
</tr>
<tr>
<td>0.25P</td>
<td>1.00P</td>
</tr>
<tr>
<td>0.50P</td>
<td>1.50P</td>
</tr>
<tr>
<td>0.75P</td>
<td>2.00P* = Maximum performance test load</td>
</tr>
<tr>
<td>1.00P*</td>
<td>Reduce to lock-off load (0.80P)</td>
</tr>
</tbody>
</table>

* = Graph required, as specified herein.

AL = alignment load

P = design load
4. Record the anchor movement relative to the fixed reference point for the maximum performance test load at 0 time, 30 seconds, 1 minute, 2 minutes, 3 minutes, 5 minutes, 6 minutes, and 10 minutes. Also record at 20 minutes, 30 minutes, 50 minutes, and 60 minutes if creep criteria are not met at 10-minute interval. Re-pump the jack as necessary in order to maintain a constant load.

5. Creep Criteria are as follows:
   a. Total anchor movement between the 1 and 10-minute intervals should not exceed 0.04 inch.
   b. Total anchor movement between the 6 and 60-minute intervals (if required) should not exceed 0.08 inch.

6. Construct a graph showing a plot of anchor movement versus load for each load increment marked with an asterisk (*) in the performance test schedule, and a plot of the residual anchor movement at each alignment load versus the highest previously applied load. Submit graph format to the Resident Engineer prior to use.

D. Proof Test

1. Proof-test all production anchors as indicated in the following schedule. Raise the load from one increment to another immediately after recording of the tendon movement.

2. PROOF TEST SCHEDULE

<table>
<thead>
<tr>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment Load (AL)</td>
</tr>
<tr>
<td>0.25P</td>
</tr>
<tr>
<td>0.50P</td>
</tr>
<tr>
<td>0.75P</td>
</tr>
<tr>
<td>1.00P</td>
</tr>
<tr>
<td>1.20P</td>
</tr>
<tr>
<td>1.33P = Maximum proof test load; Evaluate creep</td>
</tr>
<tr>
<td>Reduce to lock-off load (0.80P)</td>
</tr>
</tbody>
</table>

P = design load

3. After reaching the maximum proof test load of 1.33P, maintain the load for 10 minutes to evaluate creep based on the observed deflection behavior. Record measurements at 0 time, 30 seconds, 1 minute, 2 minutes, 3 minutes, 4 minutes, 5 minutes, 6 minutes, and 10 minutes. If the movement between the 1 minute and 10 minute hold is equal to or exceeds the creep criteria, maintain the load for an additional 50 minutes. Record measurements at 20 minutes, 30 minutes, 50 minutes, and 60 minutes.

4. Creep Criteria are as follows:
   a. Total anchor movement between the 1 and 10-minute intervals should not exceed 0.04 inch.
   b. Total anchor movement between the 6 and 60-minute intervals (if required) should not exceed 0.08 inch.
5. Measure and record the tendon movement to the nearest 0.001 inch with respect to an independent fixed reference point at the alignment load and at each increment of load. Use the pressure gage and reference pressure gage to measure the applied load, and use the load cell to monitor small changes of load during the constant load-hold period. Re-pump the jack as necessary to maintain the constant load.

6. Compare the results of the proof tests to the results of the performance tests. If any significant variation from the performance test is observed, as determined by the Resident Engineer, re-evaluate the design capacity of this and subsequent anchors.

E. Load Test Acceptance Criteria

1. Evaluate the results of each anchor test in order to determine anchor acceptability. An anchor will be acceptable provided:
   a. The total movement obtained from a performance and proof test exceeds 80 percent of the theoretical elastic elongation of the design free stressing length.
   b. The measured creep rate during the proof test load does not exceed the specified creep criteria and is a linear or decreasing creep rate, regardless of tendon length and load.

2. Reload anchors that do not meet the first acceptance criterion up to two times from alignment load to test load and repeat the calculation on these cycles. If the criterion is still not met, do not incorporate the tieback into the wall unless detensioned to prevent transfer of load to the no-load zone. Anchors that do not meet the second acceptance criterion cannot be incorporated into the wall at their design load, but may be accepted at a lesser load either determined from other production tests or additional tests. Lock off anchors that satisfy the acceptance criteria at the design lock-off load, which is 80 percent of the tieback anchor design load.

3. When a tendon fails, modify the design or installation procedures. The modifications may include, but are not limited to, installing a replacement tendon, reducing design load by increasing the number of tendons, modifying the installation methods, increasing the bond length or changing the anchor type. Submit modifications that require changes to the structure for review to the Resident Engineer.

4. Retesting of anchors will not be permitted, except that re-grouted tendons may be retested.

3.07 TOLERANCES

A. Deviation of anchor projection angle shall be not more than 2 degrees vertically and horizontally.

B. Locate the exposed end of the tieback within 6 inches of the location shown on the Contract Drawings of approved Working Drawings.

C. Anchor clearance to existing utilities or foundations shall be not less than 3 feet.

3.08 TIEBACK DE-TENSIONING

A. De-tension temporary tiebacks in sequence with completion of permanent structure or backfill as follows:
1. Where permanent structure is to be built in direct contact with excavation support system, de-tension tiebacks after floor or walls above have attained design strength and after obtaining approval from Resident Engineer. Leave openings in walls as necessary to provide access to tieback for de-tensioning.

2. Where backfill is placed in direct contact with excavation support system, de-tension tiebacks after compacted backfill is placed against piles to within no more than 2 feet below center of tieback elevation.

B. Tiebacks designated as Permanent on the Contract Drawings shall not be detensioned.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the geotechnical investigation program, design, installation, and execution of ground freezing operations used for ground improvement at cross passage locations.

B. The location and extent of the required ground improvement zone at the Ground Support Category 3 cross passages are shown on the Contract Drawings. The geometry of the ground improvement zone assumes freezing will be performed from the ground surface. If freezing is performed from the tunnel, alternative freeze geometries may be used if the contractor can demonstrate that they deliver a similar level of performance.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 12 19, Contract Interface.
2. Section 01 57 19, Temporary Environmental Controls.
3. Section 01 74 00, Cleaning and Waste Management
4. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
5. Section 31 09 13.50, Tunnel Instrumentation and Monitoring of Earthwork.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. Codes and regulations of the City of Seattle.
2. WAC 173-160 Minimum Standards for Construction and Maintenance of Wells

1.03 DEFINITIONS

A. Average Freeze Zone Temperature: Average temperature of a Freeze Zone taken versus its thickness at a certain location.

B. Closure: When all of the Freeze Zone has been frozen completely and to a sufficient thickness through all soil layers such that external groundwater is isolated from and does not flow into the extent of the cross passage excavation..

C. Coolant: Medium that flows through the Freeze Pipes to withdraw the heat from the soil. Also referred to as brine.

D. Cooling Agent: Circulating refrigeration gas or fluid inside a freeze unit to chill the Coolant (brine).
E. Down pipe (inner pipe): Open-ended inner pipe inserted into the center of the closed-end Freeze Pipe. The down pipe is used for the supply of the Freeze Pipe with a coolant.

F. Emergency Condition: Condition endangering the stability of the Freeze Zone or the life safety of personnel.

G. Excavation Phase: Concurrent period with maintenance of freeze when the soils inside the Freeze Zone are excavated.

H. Freeze Pipe Header: Header valve connecting the coolant supply line with the Down Pipe and the return line (brine) with the annulus between Freeze Pipe and Down Pipe.

I. Freeze Pipe: Underground closed-ended outer pipe through which the coolant flows. The coolant is supplied through the Down Pipe and flows to its deepest point and back through the annulus between Down Pipe and Freeze Pipe.

J. Freeze System: Entire system to operate the freezing operation including plant, all supply and return lines, freeze casing pipes, Freeze Pipes, and manifold system.

K. Freeze Unit: Single unit for re-cooling of brine, usually consisting of chiller, vaporizer, and compressor. Several freeze units can be combined to a more powerful Refrigeration Plant.

L. Freeze Zone: Frozen Ground formed by circulation of chilled brine through Freeze Pipes that provide ground support for an internal excavation and that isolates groundwater from the excavation.

M. Frozen Ground: A ground temperature less than -2 degrees C.

N. Initial Freeze: The freezing operation from the onset of freezing start to that point of time when the Freeze Zone has achieved its specified areal extent and required temperature.

O. Manifold: Lines from the plant that connects the supply lines and the Freeze Header.

P. Maintenance: The freezing operation after that point of time, when the Freeze Ring has achieved its required thickness and required average temperature.

Q. Primary Circulation: A closed circulating of refrigeration gas or fluid (Cooling Agent) inside a Freeze Unit to chill the brine.

R. Refrigeration Plant (Freeze Plant): Plant to chill the brine consisting of either a single freeze unit or several combined units.

S. Spacing: Center-to-center distance between pipes, and or distances between temperature devices.

T. Stand-up Time: Time duration, when the Freeze Zone provides ground support for an internal excavation.

U. Temperature Measurement Pipe: Pipe used to encase temperature measurement devices to monitor the ground temperature.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit the ground freezing subcontractor's and ground freezing design engineer's names, qualification, resumes of supervisors and documentation of past ground freezing work experience for approval by Sound Transit.
C. Prior to the start of the ground freezing operation, perform a Geotechnical Investigation Program. The geotechnical investigation program shall consist of at least 3 borings for each cross passage categorized in Ground Support Category 3. A sufficient number of undisturbed soil samples shall be extracted to perform the frozen soil tests as required by the designer. Submit the suggested ground investigation program for approval by Sound Transit.

D. Prior to the start of the ground freezing operation, submit a Work Plan and Method Statements for approval by Sound Transit.

1. The Work Plan and Method Statements shall contain, but not be limited to:

   a. Details of means for placing and protection of pipes below grade.

   b. Details of the Freeze Pipe and Temperature Measurement Pipe installation procedures and equipment:

      1) Method of drilling and supporting the drill holes.

         a) Include type of temporary casing and drilling fluid.

         b) Demonstrate ability to meet installation tolerances.

      2) Methods and criteria for pressure testing of each installed pipe.

      3) Methods and equipment to be used for in-hole surveys.

   c. Details of method of Freeze Pipe installation capable of minimal deviation from planned line and grade to prevent creating unequal separation between Freeze Pipes with depth which may lead to insufficient freezing resulting in windows in the frozen boundary.

   d. Details of equipment, including manufacturer's specifications, for all monitoring instrumentation used for monitoring of freezing operation, Freeze Ring development, and deformation survey.

   e. Operation of the Refrigeration Plant, distribution system, brine handling and disposal of all used fluids/gas.

   f. Quality assurance, including testing method and criteria to confirm that ground freezing design assumptions.

   g. Procedure for decommissioning, dismantling and removal of the ground freezing system.

   h. Methods for protecting and insulating the interior surface of precast concrete tunnel lining.

   i. Methods for filling Freeze Pipes after decommissioning the freezing system and re-establishing watertightness of the precast concrete tunnel lining at Freeze Pipe and Temperature Measurement Pipe penetration locations.

   j. Methods for freezing ground adjacent to and below the precast concrete tunnel lining.

   k. Methods of decommissioning freeze pipes after cross passage construction is complete.
E. Prior to the start of the ground freezing operation, submit a Ground Freezing Design for approval by Sound Transit. The ground freezing design shall be prepared, stamped, signed, and dated by an engineer licensed in the State of Washington.

1. The ground freezing design shall include, but not be limited to:

   a. Thermal calculations for design of the Freeze Plant system, including:
      1) Determination of energy required for Initial Freeze and Maintenance phases.
      2) Coolant pump requirements and circulation.
      3) Time estimates for achieving closure.

   b. Calculations demonstrating the temperature criteria for the Frozen Ground provided by the proposed system. Include:
      1) A Finite Element (FE) 2D analysis to model thermal changes in the ground due to heat extraction by Freeze Pipes and phase changes of water into ice and vice versa.

   c. Results and evaluation of the thermal calculations:
      1) Required initial freeze time.
      2) Temperature development vs. time at critical points (e.g. areas with largest spacing).
      3) Temperature development vs. time for selected as-built locations to compare with monitored data during operation.
      4) Temperature contour lines for Initial Freezing (start of freezing, Closure, required Freeze Zone thickness).
      5) Temperature contour lines during Maintenance Freeze (at three times showing steady state conditions).
      6) Temperature contour lines for thawing (time when all temperatures are warmer than -2 degrees C, two additional time points between that time point and start of thawing).
      7) Freeze zone thickness vs. time.
      8) Average Freeze Ring temperature vs. time.
      9) Energy required for Initial Freezing and Maintenance phases.

   d. Refrigeration Plant Design:
      1) Show adequacy of power supply.
      2) Show sufficient capacity to cool the brine of primary freezing and to maintain the brine cooled thereafter, for refrigeration plant operation.

   e. Calculations showing capability of pumps, valves, and conveyance system to circulate the brine in a balanced manner with a small temperature differential between supply and return during Maintenance.
f. Freeze Pipe spacing and installation tolerances.
   1) Indicate the installation tolerances.
   2) Designer shall establish a criteria for both drilling tolerance and deviation that if exceeded will require an additional Freeze Pipe to be installed to reduce distance between pipes.

2. Layout of the Ground Freeze System including:
   a. Plan and profile drawings that show Freeze Zone geometry, Freeze Pipes, Temperature Measurement Pipes and cross passage extents. Plan shall also include the associated surface access constraints as shown on the contract drawings.
   b. Drawing of supply and collection headers, connection piping, pumps and valves for circulating and controlling chilled brine. Include flow diagram and valve/pipe schematic.
   c. Freeze Pipe Schematic details of the Freeze Pipe including drill hole, outer and inner Freeze Pipe diameter, and type, size and construction of the outer and inner Freeze Pipes and outer Freeze Pipe backfill details including any insulation used to restrict the Freeze Zone to a certain depth.
   d. Freeze Pipe layout plan that includes location of each pipe and installation sequence.
   e. Table of Freeze Pipes indicating planned tip elevation, diameter, and wall thickness of pipes to be installed with unique identification number for each pipe.
   f. Schematic detail of the Freeze Header assembly at the head of the Freeze Pipe.
   g. Schematic detail of the brine circulation manifold.
   h. Manifold and head insulation details.

3. Plans and manufacturers’ specifications and off-site performance test results for the Refrigeration Plant. Include:
   a. Type of coolant.
   b. Size and power capacity of the compressor.
   c. Size and type of condenser.
   d. Size, type, and temperature drop of the chiller/evaporator.
   e. Type and expected temperature range of the brine and the volume capacity of brine circulation pump.
   f. Maximum and average operating ranges.

F. Submit a Construction Schedule covering all activities related to the Ground Freezing operations, including but not limited to the pre-freezing geotechnical site investigation and laboratory testing, freeze pipe installation, freeze plant installation, piping and coolant circulation system installation, freezing system operation and maintenance of frozen
ground, thawing of the frozen soil and demobilization of the freezing plant, piping/circulation system and related equipment.

G. Submit the Designer’s Certification in order to:

1. Provide evidence that Design Engineer has reviewed and approved the following documents:
   a. Work Plan and Methods Statements
   b. Contingency Work Plan
   c. Monitoring Reports
   d. Closure Analysis
   e. Quality Control Reports:
      1) Installation and Testing of Freeze Pipes.

H. Submit a Contingency Work Plan for approval by Sound Transit.

1. The Contingency Work Plan sets forth a plan of action if Freeze Zone failure caused by either insufficient thickness or temperature, or groundwater leakage through the Freeze Zone during the following phases of operation:
   a. Freeze Zone installation.
   b. Cross passage excavation.
   c. Construction of the permanent Cross Passage lining.

2. The Contingency Work Plan shall address the following scenarios for each of the following events:
   a. Sudden loss of brine, leakage unknown.
   b. Sudden loss of brine, location of leakage due to identified damage.
   c. Failure of Refrigeration Plant.
   d. Failure of power supply.
   e. Damage of Freeze Pipes.
   f. Freeze Pipe failures:
      1) One Freeze Pipe.
      2) Two adjacent Freeze Pipes.

I. Submit to Sound Transit the following Record Documents:

1. Freeze System: Provide the surveyed plan location and ID number for Freeze Pipes, Temperature Measurement Pipes,

2. Drilled profile of each Freeze Pipe and Temperature Measurement Pipe based on in-hole survey.

3. Notation of deviation from design location and required additional Freeze Pipes.
4. Maximum surveyed spacing of:
   a. Freeze Pipes.
   b. Temperature Measurement Pipes to the nearest two Freeze Pipes.

J. Submit Monitoring Reports to Sound Transit documenting the following:

1. During Ground Freezing, Excavation and Maintenance, submit weekly summary reports that include plots versus time of:
   a. Ground temperature, including baseline readings for ground temperature.
   b. Brine temperature.
   c. Temperature splits at the Freeze Plant; and each piping loop.
   d. Brine flow rate.
   e. Include narrative of changes in Freeze Plant operation.
   f. Evaluation of data including comparison with results of thermal calculation.

2. Freeze System performance:
   a. Monitoring reports shall include the following:
      1) Supply coolant temperature in the manifold.
      2) Return coolant temperature for each pipe or grouped series of pipes.
      3) Coolant manifold pressure.
      4) Coolant manifold flow.
      5) Brine tank level.
      6) Brine density.
      7) Ammonia concentrations inside and in the immediate vicinity of the Refrigeration Plant.
   b. Data shall be prepared and plotted showing:
      1) Acquired value versus time.
      2) Temperature versus temperature measurement pipe length (ground temperature points).
      3) Temperature versus distance from closest Freeze Pipe (ground temperature points).

K. Abandonment reports for the decommissioning of the Freeze Pipes, monitoring instrumentation, and connection pipe works shall be submitted to Sound Transit for approval.
1. Submit to Sound Transit procedures for demobilizing the freeze plant, coolant distribution system, and all other associated systems when freezing operations are complete.

2. Submit to Sound Transit documentation that the coolant is disposed of in an approved manner once the freezing system is demobilized.

1.05 QUALITY ASSURANCE

A. Qualifications of Ground Freezing Subcontractor and Design Engineer:

1. The contractor/subcontractor performing the work specified herein shall have minimum 5 years of experience providing ground freezing work and have performed successfully a minimum of 5 projects utilizing ground freezing for ground stabilization and groundwater cut-off within the last 10 years.

2. The ground freezing design engineer performing the work specified herein shall have minimum 5 years of experience providing ground freezing designs that have performed successfully in a minimum of 5 projects within the last 10 years. The engineer performing the ground freezing design shall be approved by Sound Transit.

3. Ground freezing work shall be overseen by a supervisor with minimum 5 years of experience with the implementation of ground freezing work and shall have supervised a minimum of 3 successful ground freezing applications within the past 5 years. The supervisor shall be approved by Sound Transit.

4. Freeze Pipe and Temperature Measurement Pipe position and alignment shall be surveyed after the installation. The method of Freeze Pipe installation chosen shall facilitate the installation of the pipes with minimal deviation from their design location.

1.06 DESIGN CRITERIA

A. Freezing System shall support the soil and groundwater conditions encountered in the exploration borings required herein.

B. The implemented freezing system shall provide the ability to turn on and turn off every other adjacent Freeze Pipe (as determined in the freezing design) during the Maintenance phase, while maintaining a nearly constant operation of the Freeze Plant.

C. Instrumentation and monitoring equipment to:

1. Verify the thickness and continuity of Frozen Zone.

2. Determine and monitor temperature, width and depth of the frozen soil mass.

   a. No less than four temperature monitoring pipes. Temperature monitoring pipes to be installed across the full width and depth of the Frozen Zone.

   b. Maximum spacing between temperature measurement devices in the temperature measurement pipes not more than four feet, not less than three devices in each soil layer.

   c. Additional temperature measurement devices located one foot from either end of the temperature measurement pipes.

   d. All temperature measurement devices shall be connected to an automated data monitoring acquisition and storage system.
e. Accuracy of all temperature measurement devices shall be ± 0.5 degrees C.

D. Provide alternating brine circulating system piping between alternating Freeze Pipes using coolant piping distribution system.

E. Freeze Piping System Requirements:

1. At a minimum, include a brine balance tank, insulated flow and return mains, and appropriate pumps, air release valves, temperature and flow measurement instruments.

2. Each Freeze Pipe shall have a control isolating valve and an air bleed valve.

3. Brine circulation system shall have an automatic shut-off control when there is a sudden drop in brine pressure to limit loss if a leak develops.

4. Each series of Freeze Pipes arranged in a loop between the supply and return manifolds shall contain provision for brine temperature measurements for both supply and return, and the temperature "split" between supply and return shall be determined during Initial Freezing and Maintenance.

5. All fluids and gas shall be used in accordance with environmental laws and requirements.

F. Power System Requirements:

1. Provide power supply from two independent power grids or equivalent power sources.

2. Power failure alarm (optical and acoustic) shall be installed independent of the Refrigeration Plant.

G. Refrigeration Plant Requirements:

1. Sized as self-contained, fully enclosed, and of sufficient volume to freeze the earth to the limits as required and maintain the Freeze Zone during the excavation and final lining construction of the cross passages.

2. Noise generated by the operation of the Refrigeration Plant shall be controlled and limited in accordance with Section 01 57 15, Temporary Construction Noise and Vibration Control.

3. In combination both primary and stand-by refrigeration plants shall be capable of Initial Freezing and individually of Ground Freeze Maintenance.

1.07 DRILL LOGS AND START CARDS

A. Start Card (Notice of Intent) filed with Washington Department of Ecology.

B. Logs of the Freeze Pipe, Temperature Measurement Pipe and the groundwater monitoring instrumentation borings (in a standard, legible format), including:

1. Detailed soil descriptions per Unified Soil Classification System (USCS).

2. Detailed descriptions of Freeze Pipe, Temperature Measurement Pipe and instrument installations, including temperature measurement devices, and completion information.
PART 2 - PRODUCTS

2.01 MATERIALS

A. As specified by Design Engineer to meet design requirements.

B. Provide appropriate referenced standards and quality control requirements as part of design submittals.

PART 3 - EXECUTION

3.01 PREPARATION

A. Prior to start of work, calibrate all temperature monitoring devices. Maintain files of calibration test reports of all temperature monitoring devices and make available, upon request, to Sound Transit.

B. Pressure test manifold assembly to two times the anticipated working pressure. Maintain results of pressure testing of all Freezing System components on site and make available, upon request, to Sound Transit.

C. Prior to start of Ground Freezing install the instrumentation as indicated in the design as approved by Sound Transit.

D. Install temperature measurement devices and monitor ground temperatures a minimum of two weeks before any freezing operation.

3.02 PIPE INSTALLATION

A. Establish, install and maintain the Ground Freeze System in accordance with the Submittal as approved by Sound Transit.

B. Install Temperature Measurement Pipes:

1. Installed where the relative spacing of Freeze Pipes is greatest based on the completed Freeze Pipe survey information.

C. Install calibrated ground temperature measurement devices inside the Temperature Measurement Pipes in accordance with Contractor Method Statement.

D. Leak test all installed Freeze Pipes and Temperature Measurement Pipes with water under pressure as indicated in Section 3.03 prior to further connection to the freeze system.

E. Fill Temperature Measurement Pipes with brine after installation of temperature measurement devices.

3.03 FIELD QUALITY CONTROL

A. Perform quality control and quality assurance monitoring during installation of the Freeze Pipes, Temperature Measurement Pipes and all other components of the freeze system.

1. Freeze Pipe and Temperature Measurement Pipe survey:

   a. Perform in-hole survey of each pipe.

   b. Perform analysis based on each pipe and its closest two Freeze Pipes
1) Document deviation from design location and spacing between the pipes vs. depth.

2) Document the exact location of each Freeze Pipe and each Temperature Measurement Pipe.

c. Install additional Freeze Pipes:
   1) To meet design requirements.
   2) To meet design temperature criteria.
   3) To meet the design maximum allowable spacing.

2. First pressure testing Freeze and Temperature Measurement Pipes:
   a. After installation, pressure test each outer Freeze Pipe and Temperature Measurement Pipe for leak detection by filling with water and pressurizing to 10 bar.
   b. Each pipe shall hold 10 bar pressure for no less than 15 minutes.

3. Second pressure testing (Freeze Pipes, Temperature Measurement Pipes, and Freeze System):
   a. Perform a second pressure test of the Freeze System following the completion and installation and after initial cool down to its operation temperature has been achieved.
   b. Test at a minimum pressure of two times the design operating pressure of the system.
   c. The whole system and each single pipe shall hold this pressure for no less than ten minutes.

3.04 OPERATION OF FREEZING SYSTEM

A. During Excavation Phase, ground freezing supervisor shall evaluate the performance of the ground freezing system continuously when excavation operation is conducted.

B. Ground freezing shall be controlled continuously including:
   1. Monitoring, operating, and maintenance of the Refrigeration Plant.
   2. Removal of air from brine circulation system.
   3. Locate anomalies in brine temperature splits and areas drawing greater energy indicating windows or openings in the Frozen Ground.
   4. Modifying system to close windows or openings, including installing additional Freeze Pipes to preclude the inflow of groundwater.

3.05 MONITORING

A. Monitor ground temperatures throughout the depth of the Freeze Ring at locations where the relative spacing of Freeze Pipes is greatest.

   1. Determine baseline temperature readings at least seven days prior to activation of Freeze System.
2. Monitor brine temperature and ground temperatures to evaluate progress of ground freezing and maintenance daily:
   a. Adjust the system to provide the design ground temperatures or lower temperatures.
   b. Notify Sound Transit of deviation from submitted schedule within 24 hours of readings.
   c. Implement Contingency Plan as appropriate and notify Sound Transit of implemented contingency measures.

B. Monitor performance of Refrigeration Plant:
   1. Prepare a daily report which indicates performance of the refrigeration plant, brine flow volume, and temperature in circulation and possible leakage of brine.
   2. Maintain daily reports on site and make available to Sound Transit upon request.

C. Maintain monitoring instruments during decommissioning and the Refrigeration Plant demobilization and continue monitoring temperature, settlement, and inclinometer/extensometers through Thaw Cycle.

D. Perform surveillance and maintenance of all freezing equipment at least twice a week. Inspection methods to be tailored to site circumstances and shall include as a minimum a check for valve operation and a visual inspection of all lines for coolant fluid leakage.

3.06 REPAIR AND RESTORATION

A. Stand-by equipment and replacement components
   1. Provide stand-by equipment and replacement components to ensure the Refrigeration Plant and the ground temperature monitoring functions at all times as required.
   2. Stand-by Refrigeration Plant to provide uninterrupted service in the event of an emergency situation.
      a. A stand-by plant may be used to assist Initial Freezing, but shall be kept on site during the maintenance phase of the ground freezing operation.
   3. Replacement parts for all critical components shall be available within no more than 24 hours.

3.07 FREEZE SYSTEM DECOMMISSIONING

A. File notice of intent to decommission with the Washington Department of Ecology.

B. Purge all pipelines and tanks of brine and evacuate brine from Freeze Pipes flush with fresh water.

C. Decommission Freeze Pipes, Temperature Measurement Pipes, and groundwater monitoring wells in accordance with Chapter 173-160 WAC guidelines.

D. Dispose of brine offsite in an approved manner. Remove all coolant distribution pipes, manifolds, tubes and insulation from the site.

END OF SECTION
SECTION 31 71 19
TUNNEL EXCAVATION BY TUNNEL BORING MACHINE

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the Tunnel Boring Machine (TBM), twin tunnel excavation using TBMs, final lining consisting of precast concrete segments, tunnel walkway, and tunnel invert.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 12 19, Contract Interface.
3. Section 01 55 00, Vehicular Access and Parking.
4. Section 01 57 24 Temporary Site Water Discharge.
5. Section 01 71 23, Field Engineering.
6. Section 01 74 00, Cleaning and Waste Management.
7. Section 03 30 00, Cast-in-Place Concrete.
8. Section 03 35 00, Concrete Finishing.
9. Section 05 52 14, Metal Handrails.
10. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
11. Section 31 09 13.50, Tunnel Instrumentation and Monitoring.
12. Section 31 23 01, Excavation Spoils and Muck Disposal.
13. Section 31 23 19, Dewatering.
15. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.
16. Section 31 71 26, Tunnel Rescue Teams.
17. Section 31 73 23, Tail Void Grouting.
18. Section 31 74 16, Precast Concrete Tunnel Lining.
1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Petroleum Institute (API)
   a. API 13A, Drilling Fluids Materials


3. United States Environmental Protection Agency (US EPA)

4. Washington Administrative Code (WAC)
   a. Chapter 296-36 WAC, Compressed Air Work
   b. Chapter 296-350 WAC, WISHA Administrative Rules
   c. Chapter 296-24 WAC, Part L Electrical
   d. Chapter 296-46B WAC Electrical safety standards, administration, and installation

5. Revised Code of Washington (RCW)
   a. Chapter 49.24 RCW Health and Safety, Underground Workers

6. Mine Safety and Health Administration (MSHA)
   a. MSHA 30 CFR 36, Approval Requirements for Permissible Mobile Diesel-powered Transportation Equipment

7. International Organization for Standardization (ISO)
   a. ISO 13500, Petroleum and Natural Gas Industries -- Drilling Fluid Materials -- Specifications and Tests

8. American Society of Mechanical Engineers (ASME)
   a. Boiler and Pressure Vessel Code (BPVC) Section VIII – Rules for Construction of Division 1 Pressure Vessels

1.03 DEFINITIONS

A. Mechanical Abrasion: Detrimental wear of TBM and plant components from excavation and muck handling processes.

B. Action Level(s): As defined in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

C. Active Support Pressure: Application of the Required Support Pressure to counteract earth pressure and hydrostatic head at the tunnel face. During TBM advance and stoppage the Active Support Pressure is applied to the excavated face by a pressurized
support medium like earth paste (EPB TBM) or bentonite slurry (Slurry TBM) and supplemented by safety factors and operational tolerances, to prevent Lost Ground, and excess groundwater and soil inflow into the Excavation Chamber

D. Breathing Air: Compressed air specially filtered and cooled and suitable for human consumption and supplied to support workers in the airlocks or within the Excavation Chamber while working or decompressing.

E. Blow-Out: Uncontrolled over pressurization within the Excavation Chamber that negatively impacts the ground surface, a water body, utility or other void space as a result of the pressurized air fracturing the ground or flowing rapidly through discontinuities, voids, or permeable zones in the ground.

F. Boulder Stop: A stoppage of the tunnel advance with worker entry into the Excavation Chamber to break and remove boulder(s).

G. Cutting Tools: Disc cutters, picks, drag tools, scrapers, and ripper tools mounted in the cutterhead for loosening, cutting, dislodging, and fracturing of materials indicated in the Contract Documents.

H. Conditioners: Bentonite, foam, polymers and other materials added to the excavated materials (cuttings) to modify them. Conditioners are required to mix with the excavated material to form an earth paste in the Excavation Chamber, and to reduce the abrasive nature of the materials indicated in the Contract Documents.

I. DTA: Design Tunnel Axis determined by the Contractor in order to comply with tunnel elevation and grade indicated in the Contract Documents.

J. Earth Pressure Balance (EPB) TBM:

1. A fully-shielded TBM with an Active Face Support system.
2. Required Support Pressure is applied to the tunnel face by a highly viscous earth paste/rubble formed by the excavated material mixed with conditioners.
3. Earth paste/rubble is mixed within the tool gap and Excavation Chamber and pressurized by controlling the flow of material into the Excavation Chamber and out of the screw conveyor.
4. The rate of advance is governed mostly by the cutting efficiency of the tools and the cutterhead rotation speed combined with the flow of material through the Excavation Chamber and out of the screw conveyor.

K. Excavation Chamber: The enclosed space directly to the rear of the cutterhead and ahead of the main bulkhead for the EPB TBM and ahead of the buffer wall in the Slurry TBM.

L. Face Stability Assessment: Evaluation of the stability of the tunnel face carried out prior to personnel entry for inspection and maintenance in the Excavation Chamber for the purpose of confirming or reducing or dispensing with the calculated air pressure, or recommending abandonment of the entry.

M. Factory Tests: Tests performed on equipment that certifies the equipment is in compliance with this Section in addition to the manufacturers’ specified requirements.

N. Foam Expansion Ratio (FER): Ratio between the volume of the foam and the volume of foaming solution used.

O. Foam Injection Ratio (FIR): Ratio between the volume of foam injected at atmospheric pressure and the volume of the ground in place.
P. Ground Conditioning System (GCS): The GCS is a system which permits the metered delivery of soil conditioners into the tool gap, Excavation Chamber, and screw conveyor of the TBM.

Q. Groundwater Seepage: Defined in Section 31 23 19, Dewatering.

R. Hyperbaric Intervention: TBM maintenance or inspection work carried out in the Excavation Chamber under higher than atmospheric conditions.

S. Inspection Stop: A regular stoppage of the tunnel advance either with or without worker entry into the Excavation Chamber to visually inspect condition of cutting tools, cutterhead, and other components.

T. Lost Ground: Loss or removal of material in excess of the volume excavated by the cutterhead periphery, including ground that runs, flows, pipes with groundwater inflows, squeezes, and ravels creating voids, or softened or loosened ground outside of the tunnel. Lost Ground also includes volume change associated with stress change and convergence.

U. Maintenance Stop: A stoppage of the tunnel advance with worker entry into the Excavation Chamber to repair, replace, and change cutting tools and maintain cutterhead and other components.

V. Muck: Excavated material consisting of a mixture of soil cuttings and water removed from the tunnel. Muck may include conditioner, bentonite, polymer, fragments of wood, cobbles, and boulders.

W. Open Mode Condition: A condition where the Active Support Pressure is below the Required Support Pressure, when partial or no Active Face Support is applied, or during compressed air use in the Excavation Chamber for any reason.

X. PLC: Programmable Logic Controller used for operation, control and monitoring of TBM systems and sub systems with operation and control screens displayed and accessed at the operators console.

Y. Pressurized Face TBM: Slurry or EPB TBM

Z. Programmed Unit Weight: The average weight of the “in-bank” engineering soil unit indicated in the contract documents for a given tunnel station interval.

AA. Required Support Pressure: The calculated pressure at the face or the ambient pressure noted at equilibrium that is required to be fully counterbalanced by the Active Support Pressure.

BB. Steering Gap: Annular space between the extrados of the shield and the overcut profile created by the cutterhead mounted over cutting tools.

CC. Slurry TBM:

1. A fully-shielded TBM with an Active Face Support system.

2. Required Support Pressure is applied to the tunnel face through a bentonite-water or bentonite-water-polymer slurry mixed with the excavated soils.

3. Excavated soils are removed from the Excavation Chamber and transported out of the tunnel as suspended solids in the bentonite slurry.

4. Compressed Air Cushion: A system which regulates the support pressure and minimizes pressure variations due to a difference between slurry inflow and outflow volumes into and out of the Excavation Chamber.
DD. Tail Void: Space between the extrados of the precast concrete segments and the surrounding soil behind the tail shield formed by the overcut of the TBM cutterhead, thickness of the TBM shield, and clearance between the intrados of the shield and the extrados of the segments.

EE. Tunnel Boring Machine (TBM): A shield with excavation, ground control, steering, lining assembly and propulsion equipment, including trailing gear and support equipment required for performing tunnel excavation. A general term comprising the class of tunneling machines which is fully shielded, utilizes a full-diameter rotating cutterhead equipped with cutting tools, advances using propulsion cylinders that thrust against an initial tunnel lining erected as a ring of segments within the shield tail.

FF. Tunnel Launch: Exit of the TBM from an excavation through an eye that is cut or formed within the wall of the excavation ground support system

GG. Tunnel Reception: Entry of the TBM into an excavation through an eye that is cut or formed within the wall of the excavation ground support system

HH. Working Air: Compressed air used in the tunnel for anything other than Breathing Air.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Qualifications: for requirements see 1.05 this Section.

C. Tunnel Boring Machine (TBM): Detailed description of the proposed TBM to be used including preliminary drawings and plans within 90 calendar days of Notice to Proceed (NTP).

D. Tunnel System Plans:

1. Tunneling Excavation Plan: One integrated and structured file that presents an organized collection of data, shop drawings, plans, and method statements for the tunneling equipment and the tunneling process describing in detail and which incorporates sections for the specified aspects of the tunneling work. Submit draft version within 90 calendar days and a fully detailed Tunneling Excavation Plan within 270 Days of NTP. For completeness, include or cross-reference pertinent related components as specified in the Related Sections. Cover the following components in the Tunneling Excavation Plan:

   a. Tunneling Methods: Detailed description of the tunneling method including shop drawings of TBM to be used, method statements and drawings of the TBM operation and the tunneling process, in addition to the TBM Factory Test report.

   b. Tunnel Systems and Plant: Detailed method statements and drawings including, but not limited to, systems and plant arrangement and operation.

   c. Preparation Plan: Detailed description and drawings of Tunnel Launch and Reception including, but not limited to, seals and supplemental supports and all installations required for the TBM launching and receiving operations.

   d. Proposed Hold Points: Including but not limited to Tunnel Launches at Maple Leaf Portal for each tunnel drive, Tunnel Launches at both Roosevelt Station and re-launch from U Station, under-passing of the Ravenna Boulevard sanitary sewer, 15th Ave NE, prior to commencing...
tunneling operations beneath the University of Washington campus and Tunnel Receptions at University of Washington Station for each tunnel drive.

e. Working Plans including detailed method statements on the tunneling operations in the geologic conditions described in the Contract Documents including, but not limited to:

1) Assembly, and disassembly operations.
2) TBM launching and receiving operations.
3) Tunnel excavation with face support application to maintain face stability.
4) TBM guidance.
5) Precast segmental lining erection.
6) Tail void grouting.
7) Compressed air operations including prevention of blow-outs.
8) Working in the Excavation Chamber including visual cutterhead inspection.
9) Refilling of the Excavation Chamber after inspection.
10) TBM maintenance.
11) Tunnel system monitoring.

f. Provide a detailed description of the means and methods necessary to meet the specified requirements:

1) Tunnel launch at Maple Leaf Portal, Roosevelt Station and re-launch at U Station to keep ground and structure movements at or below Action Levels.
2) Ring erection and clearances for the indicated tunnel geometry.
3) Prevention of blow-out during compressed air inspection and maintenance.
4) Work in the Excavation Chamber including cutterhead inspection and maintenance.
5) Soil conditioning, based on parameters identified by testing performed under paragraph 3.01 A. 3.
6) Keeping ground and structure movements at or below Action Levels.
7) Measures for protection of adjacent property.
8) Ventilation.
9) Air Quality monitoring.
10) TBM fire suppression.
g. Daily meetings to explain work to be done with tunnel crews prior to each shift.

h. Spare parts list recommended by the Manufacturer, the storage location and conditions.

2. Training Plan: Develop a comprehensive plan for orientation and training of all personnel based on all the documents within the Tunneling Excavation Plan.

3. Tunnel Safety Plan:
   a. Provide detailed descriptions of the health and safety elements of tunneling including a Tunnel Safety Plan that meets the specified health and safety requirements indicated.
   b. Include drawings and method statements for health and safety equipment installations including those required for air quality monitoring, fire protection, gas detection, and certifications from manufacturers that equipment meets applicable regulatory requirements.
   c. Ensure compliance with all local, state and federal regulations including CFR 1926

4. Tunneling Quality Plan:
   a. Include all required certifications and qualification documents including a detailed plan of the site organization and responsibilities of all planned personnel.
   b. Field Quality Control: Details of TBM data acquisition and monitoring including type of data, muck control and handling systems, ground movement monitoring, reporting, and documentation.
   c. Product Quality Control: Product information, certifications, and details of any probing and testing program.
   d. Remedial Plan: Detailed description of remedial plans including:
      1) Tunneling modifications if excessive Lost Ground occurs including plans to fill any subsurface voids or subsidence.
      2) Corrective actions to be utilized for each Action Level associated with settlement and groundwater monitoring.
      3) Plans for protection of adjacent facilities and property if excessive Lost Ground occurs or ground movements exceed Action Levels.
      4) Plans for sealing of groundwater inflows if Tunnel Launch seal, Tunnel Reception seal, TBM seals and/or tunnel lining leakage result in flow rates that exceed limits allowed or cause detrimental Lost Ground.
      5) Plan for correcting TBM alignment deviation.
      6) Plans for repair of unacceptable segment off-sets, damage or segment spalling: Section 31 74 16, Precast Concrete Tunnel Lining.

5. Compressed Air Work Plan:
a. Prepared by the Hyperbaric Consultant.

b. Requirements for compressed air work below 3.5 bar.

c. Include plant and equipment for the supply and use of compressed air, oxygen decompression, including but not limited to generator, stand-by equipment, air flow system control, air locks, medical locks, lighting, decompression chamber, and ventilation.

d. Include details of supervision, personnel entry, decompression, safety, and emergency procedures specific to work in compressed air.

e. Coordinate with Section 01 35 29.20, Health, Safety, Security and Emergency Response Procedures.

E. Certification of Compliance: at least 60 calendar days prior to TBM launch for:

1. Conditioners.
2. Lubricants, oils, greases, etc.
3. Fire resistant hydraulic oil.
4. Class 1 Division 2 for TBM and trailing gear.
5. TBM Fire Suppression Systems.
6. Conveyor belts in accordance with NFPA
8. Main bearing and seal manufacturer.
9. Lifting and hoisting equipment.
10. Air locks and compressed air equipment.
11. From the TBM manufacturer that the new-TBM and associated components meet all the requirements indicated in the Contract Documents.
12. TBM and Tunnel Electrical systems meet Chapter 296-24 WAC and Chapter 296-46B of the WAC

F. Test Reports: within one week of testing for:

1. TBM Factory Tests.
2. TBM site tests and re-calibration.
4. Slurry preliminary suitability tests.
5. Tail void grouting preliminary suitability tests (see Section 31 73 23, Tail Void Grouting).

G. Calculations: at least 60 calendar days prior to TBM launch for:

1. Ventilation system flow and capacity.
2. Face support calculations, including Required Support Pressure, based on piezometric level information presented in the Contract Documents.

3. Programmed Unit Weight to be input into the Muck Control Program incorporated in the TBM PLC.

H. Daily submission of:
   1. Shift reports.
   2. Ring Reports.
   3. Settlement monitoring and instrumentation reports: Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
   4. TBM data logger records.
   5. Tail Void grouting reports.
   6. Muck samples and sampling report.
   7. Items 1., 2., 3., 5., may be combined as a single report in a approved electronic database format.

I. Weekly submission of:
   1. Electrical inspection records.
   2. Ventilation performance records.
   3. Muck haulage records.
   4. Testing of Tail Void grout samples taken during production grouting.
   5. Records of water discharge from muck storage area: Section 01 57 24, Temporary Site Water Discharge.

J. Monthly Submission of:

K. Event submission within 24 hours:
   1. Hyperbaric Interventions including video of pre-intervention monitoring
   2. Inspection Stop documentation report.
   3. Cutterhead maintenance report.
   4. TBM maintenance report.
   5. Lost Ground reports.
   6. Reports of combustible or toxic gas.
   7. Documentation of actual excavated weights exceeding theoretical by more than ten percent.
L. Contingency Plans: detailed description of the actions and procedures to be taken for the following events at least 60 calendar days prior to TBM launch.

1. Lost Ground.
2. TBM outside DTA tolerance window.
3. Inundation events.
5. Loss of communications.
6. Fire.
7. Injury during a Hyperbaric Intervention.
8. Failure of main bearing.
9. Gas alarm activation and TBM shutdown.

M. Muck Handling Plan:

1. For slurry TBM:
   a. Slurry separation plant design and system layout showing the type and number of each process component used. Include details of system capabilities to deal with clay clogging potential and slurry separation of clay soils.
   b. Total plant slurry process rate.
   c. Process flow and tonnage capacity for each system component.
   d. Pipe sizing and piping network plan.
   e. Slurry pumping design including velocity requirements for soil transport.
   f. Slurry materials mix design and spoil loading capacity.
   g. Materials handling for slurry recirculation and waste disposal.
   h. Separated tunnel spoil solids containment and handling method.

2. For EPB TBM:
   a. Narrative and drawings describing in-tunnel muck handling facilities including rail and rolling stock or conveyor details.
   b. Surface muck handling and storage including supernatant or other water discharge from the muck.

N. Tunneling Pre-Submittal Meeting Agenda and Minutes:

1. Agenda to include general information regarding:
   a. Tunneling methods, including equipment layout, TBM operation, and tunneling process.
   b. Tunneling operations.
c. Means and methods.
d. Orientation and training.
e. Tunneling health and safety: Section 01 35 29.20, Health, Safety, Security and Emergency Response Procedures.
f. Access for maintenance and inspection under varying pressures.
g. TBM data monitoring.
h. Contingency plans.

2. Meeting to be held at least 30 calendar days prior to first TBM launch.

O. TBM inspection and maintenance.
P. TBM removal at Roosevelt Station:
   1. Submit TBM and related equipment removal plan.

Q. Muck Sample Reporting Plan:
   1. Include:
      a. Sampling method
      b. References of third-party testing agency
      c. Proposed tests to be carried out.
      d. Sample test reports

1.05 QUALITY ASSURANCE

A. Qualifications:
   1. Site Superintendent: Have a minimum of five years total on-the-job tunnel supervision experience with:
      a. The type of TBM proposed for use.
      b. Tunneling of similar size.
      c. Segmental Lining consisting of bolted, gasketed, precast concrete segments.
      d. Tunnels driven through ground conditions similar to those indicated in the Contract Documents.
   2. Shift Foremen: Have a minimum of three years total on-the-job tunnel crew supervision experience with EPB TBMs or Slurry TBMs of similar size, with initial tunnel lining by bolted gasketed precast concrete segments, and in similar ground conditions.
   3. TBM operators: Have experience with at least two projects operating and guiding the type of machine approved in the Bid Evaluation (EPB TBM or Slurry TBM) of similar size, with initial tunnel lining by bolted gasketed precast concrete segments, and in similar ground conditions.
4. TBM Manufacturers Representative: A senior technician with a minimum of ten years experience training contractor personnel in all aspects of TBM operation and maintenance.

5. Hyperbaric Consultant: Experience on at least two projects providing hyperbaric consulting and management services with personnel entry into a TBM Excavation Chamber at pressures up to 3.5 bar.

1.06 SITE CONDITIONS

A. Geological and hydro-geological conditions are presented in the Geotechnical Baseline Report (GBR) and Geotechnical Data Report (GDR). Baseline ground and groundwater conditions are established in the GBR. Boring logs, laboratory testing results and geotechnical data are provided in the GDR.

B. Review the Contract Drawings and area available for TBM launch including the time and area constraints governing the work at the Roosevelt Station Site.

C. Hazardous Gas:
   1. Tunnel Classification: Due to expected organic soil deposits and methane gas, the tunnel is classified as potentially gassy.
   2. Hazardous gas control measures specified herein are supplemental to OSHA requirements. Consider measures specified herein minimum additional measures.
   3. Assume sole responsibility for development and implementation of measures to control gas emissions and for proposing alternative or more stringent means, if necessary, to accomplish the objectives of these provisions.
   4. Additional measures are indicated in Article 2.02 E. 19. d.

1.07 TRAINING

A. Ensure foremen, shift engineers, TBM operators, and technicians are trained, qualified, and familiar with TBM, tunnel system and plant, and trained using the written procedures and work plans contained in the Tunneling Excavation Plan adhering to the following minimum training schedule:
   1. Initial training prior to TBM launch.
   2. Start-up training.
   3. Periodic re-training as required for changes to staff, equipment or conditions.
   4. Specialized preparation and training for compressed air workers.

B. At least one member of each tunnel crew working underground shall hold a valid first-aid certificate.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Precast Concrete Tunnel Lining: Section 31 74 16, Precast Concrete Tunnel Lining.

B. Slurry or EPB Soil Conditioners: Inert or biodegradable, accompanied by the manufacturers’ certificate of compliance.
C. Tail Void Grout: Section 31 73 23, Tail Void Grouting.

D. Oil and Grease: Flame resistant and biodegradable and accompanied by the manufacturers’ certificate of compliance, compatible with segment gasket material and in accordance with TBM manufacturer recommendations.

2.02 EQUIPMENT

A. General:

1. TBM(s): Capable of excavating the N125 twin running tunnels and erecting the bolted and gasketed precast concrete segmental lining indicated while maintaining face stability and minimizing ground settlements in the geological conditions described in the Contract Documents and in accordance with the schedule requirements.

2. Fulfill all requirements listed in Article 2.02, herein, prior to work commencement of work in accordance with Article 3.01, herein.

B. Ensure that TBM(s), tunnel systems and plant meet all OSHA and Washington Industrial Safety and Health Administration (WISHA) regulatory requirements.

C. Fully assemble and integrate all TBM subsystems for the Factory Test TBM(s) and trailing gear prior to shipment to Site. Upon reassembly at Site, re-test the TBM and re-calibrate all components.

D. Factory Test the Ground Conditioning System (GCS) integrated into the TBM and adjust so that all functions are within the manufacturers’ recommendations prior to the TBM delivery. Tests carried out prior to integration on the TBM do not replace the integrated test requirement.

E. Tunnel Boring Machine (TBM):

1. General:

   a. Provide Pressurized Face TBM(s) for twin running tunnels between Maple Leaf Portal and Roosevelt Station

   b. Provide two Pressurized Face TBMs for twin running tunnels between Roosevelt Station and University of Washington Station.

   c. Provide ability for drilling equipment to be mounted in the TBMs, and provide drilling ports equipped with valves incorporated into the TBM shield to permit drill casings to be sleeved through glands into ground when drilling ahead of the TBM.

   d. All items and requirements listed for the TBMs in Article 2.02E, herein, are required for the TBMs to be utilized on the Contract

2. Cutterhead and Tools:

   a. Design and configure new or like-new cutterheads with wear protection to enable efficient excavation of the ground indicated in the Contract Documents:

      1) Provide sufficient cutting tool spacing to permit efficient excavation of the material at the tunnel face with sufficient tool gap and penetration for both disc and ripper type cutters.

      2) Incorporate adjustable gauge cutters.
3) Design the cutterhead to permit the use of both disc cutters and ripper type cutters which can be replaced from the Excavation Chamber (back loading) and are interchangeable with each other.

4) Wear indicators located on the gauge and face positions with status indication at the TBM operator position.

5) Ensure the cutterhead limits the size of boulders which can be admitted to the screw conveyor on an EPB machine or the stone crusher on a Slurry TBM.

6) Provide a minimum of five ports on the cutterhead to permit the injection of ground conditioning agents.

3. Excavation Chamber:
   a. Provide mixing arms on the rear of the cutterhead and on the Excavation Chamber bulkhead.
   b. Provide a minimum of six ports in the Excavation Chamber bulkhead.
   c. Provide two suitably robust camera ports at approximately 11 and 1 O’clock designed to permit remote viewing and video capture of Face Stability Assessments prior to Hyperbaric Interventions.
      1) Provide wash water system at each port to permit fog-free operation.

4. Cutterhead Drive System and Main Bearing:
   a. Adequate torque and power to the cutterhead so that the machine is not torque limited while operating under any of the ground conditions indicated in the Contract Documents.
   b. A reversible, variable-speed cutterhead drive system with two speed ranges capable of starting at maximum torque.
   c. Provide certification from the main bearing manufacturer that the bearing is suitable for the speeds and loads anticipated based on the geotechnical conditions indicated in the Contract Documents as calculated by the TBM manufacturer and that the main bearing has a minimum bearing life of two times the anticipated operational hours.
   d. Oil or grease lubricated main bearing with pumping and filtration circuits equipped with accessible sampling points.
   e. Ensure main bearing is new and replaceable from within the tunnel.

5. Face Support System:
   a. Design the TBM to allow operator controlled application of Active Face Support at all times:
      1) EPB TBM:
         a) During TBM advance or extended stoppage by earth paste.
b) Provide six earth pressure sensors within the Excavation Chamber: two sensors near the crown, tunnel spring line and invert replaceable from the atmospheric side of the main bulkhead at any time.

2) Slurry TBM:
   a) During TBM advance or extended stoppage by slurry.
   b) Four pressure sensors capable of measuring air and slurry pressure at crown level.
      i) Two sensors to be installed at the buffer wall within the Excavation Chamber.
      ii) Two sensors to be installed at the bulkhead replaceable from the atmospheric side of the main bulkhead under the design operating conditions.
   c) Two additional redundant liquid level sensors at the bulkhead that utilize different sensor technology than the other four sensors. Verify sensor accuracy is consistent with required face pressure control tolerances.
   d) Compressed air cushion between the buffer wall and main bulkhead for automatic regulation of the face support pressure.

3) EPB and Slurry TBM:
   a) During inspection, maintenance, and boulder stops, by a continuous bentonite membrane and compressed air within the Excavation Chamber with supplementary support, if necessary.
   b) Measure support pressure with calibrated, abrasion resistant pressure sensors.
   c) Pressure sensor accuracy of ±1 psi and a range of 0 to 100 psi.

6. Seals:
   a. Incorporate the following into the Main Drive sealing system:
      1) New main bearing seals designed to handle maximum Active Face Support pressure with minimum dynamic safety factor of 1.5.
      2) Ensure the two forward main bearing seals are replaceable from within the Excavation Chamber without necessitating cutterhead removal.
   b. Incorporate the following into the articulation joint seals:
      1) Designed for maximum Active Face Support pressure, and grouting pressure with a minimum safety factor of 1.25.
2) Designed to allow adjustment and replacement of the seals from within the shield.

3) An inflatable safety seal deployable when work is carried out on the seals or in an emergency where leakage cannot be controlled by any other means.

c. Incorporate the following into the shield tail seal:

1) A switchable automatic with manual override grease fed minimum triple wire brush sealing system capable of sealing hydrostatic, earth, and tail void grouting pressures and compatible with Section 31 74 16, Precast Concrete Tunnel Lining and Section 31 73 23, Tail Void Grouting.

2) Spring steel sealing plates designed to prevent the steering gap from grout ingress.

3) A minimum of three rows of wire brush seals with at least two rows replaceable from within the tunnel.

4) An inflatable safety seal deployable when work is carried out on the brush seals or in an emergency where leakage cannot be controlled by any other means.

7. Propulsion and Steering System:

a. Propulsion system that can advance the TBM under the combined maximum loads of tool, earth and hydrostatic pressure, shield friction, and trailing gear drag with a minimum safety factor of 1.5.

b. Propulsion cylinder extensometers at four positions separated by 90 degrees.

c. Incorporate a propulsion cylinder retraction control system for each cylinder that prevents hard bottoming and eliminates noise and vibration emanating from the cylinders when they are retracted during ring building.

d. Ensure that maximum thrust contact pressure at any point and at any time on the precast segmental lining does not exceed 50 percent of the maximum permissible jacking load in the precast segmental lining design.

e. Propulsion cylinder shoes or partial jacking rings as required to distribute thrust loads across the leading edge of the precast segment ring without developing eccentric loading on the segment ring for which the segments were not designed.

f. The propulsion cylinders: Concentric with segmental ring centerline.

8. Shield Articulation:

a. A selectable active/passive articulation joint between the main shield and the tail shield equipped with hydraulic cylinders to permit the TBM to follow the DTA.

b. Sufficient injection ports around the circumference of the articulation joints such that cleaning or other operations can be easily carried out.
c. Extensometers at four positions on both the active and passive cylinders.
d. Sufficient extension/retraction to permit disengagement of the cuttinghead tools from an obstacle.

9. Operator Position:
a. An ergonomic operator position which permits access to all controls, gauges and monitoring devices to permit safe operation of the TBM.
b. Displays for PLC input/output and continuous guidance system monitoring.

10. Resident Engineer Position:
a. A position near the operator’s console for the Resident Engineer permitting a view of grouting and ring building activities, including access to the TBM gauges and monitoring devices.
b. A dedicated computer with monitor and printer equipped with appropriate software to view historic and real time TBM data from the Data Monitoring System indicated in 2.02 E. 17.

11. Erector system:
a. Assemble segments by an erector mechanism into rings under protection of the tail shield in the orientation and to the tolerance specified in Section 31 74 16, Precast Concrete Tunnel Lining, without causing damage to the precast segments or gaskets.
b. Use an erector system that is compatible with the TBM and precast segmental lining and meet the requirements specified in Section 31 74 16, Precast Concrete Tunnel Lining.
   1) Design the lifting and gripping mechanism (mechanical or vacuum) to handle all loads with an adequate factor of safety in the axial, radial, and circumferential directions, and in the three articulation angles corresponding to the six degrees of freedom.
   2) Provide sufficient rigidity and longitudinal travel to permit installation or removal of a segmental ring located on the wire brush seals.
   3) Incorporate safety devices to ensure segments cannot be released during handling. In the event of a loss of power, ensure the erector permits safe lowering of the segments.
   4) The segment feeder Supply the erector with segments at the correct orientation and be capable of reverse operation for the removal of damaged or incorrect segments.
   5) Ensure segment erector arm has sufficient capacity to adequately compress the precast segments longitudinal joint gaskets for correct installation.

12. Grouting System:
a. TBM Tail Void grouting system: Capable of continuous grouting during TBM advance through lines integrated into the tail shield in accordance with Section 31 73 23, Tail Void Grouting.
1) Provide four grout injection ports including: pipes, valves, flushing lines, necessary hardware and controls around the circumference of the shield, designed to inject a two component grout continuously while maintaining filling and pressure with the maximum advance rate of the TBM.

2) Equip each grout line with a pressure sensor accurate to ±0.1 bar and manual stop valve at the tail shield connection.

3) Provide a scale device and/or ultrasonic sensor for measuring weight and/or volume of grout injected and display at Operator’s position and to data logger.

b. PLC controlled grout pumps: Provide pressure and volume measurement for each of the lines continuously to the TBM display and data logging system.

c. Dedicate one pump to each grout injection line.

d. A minimum of two injection lines must be used at all times.

e. Equip pumps with water/bentonite connection to facilitate flushing.

f. Drilling equipment and associated staging to enable recovery of Tail Void grout samples and proof grouting at any position around the ring in accordance with Section 31 73 23, Tail Void Grouting.

13. **Muck Handling System:**

a. Design the muck handling components for abrasion resistance and durability for the indicated ground conditions.

b. **EPB TBM:**

1) Size and configure the GCS as required to form a homogeneous earth paste suitable for control of Required Support Pressure for all ground conditions indicated in the Contract Documents. Use a computer controlled system with interactive parameter setting at the operator position.

2) Provide a dedicated foam generator with bypass pump and flow measurement system to each outlet on the cutterhead.

3) Provide a reversible double screw with primary and secondary sections which are equipped with dedicated drives and separated with a guillotine gate. Provide the capability for the automatic charging and releasing of excavated material from the secondary screw which will permit the controlled excavation of non-cohesive materials under groundwater pressure indicated.

a) As a substitute for the secondary screw a positive displacement device or similar equipment which permits the controlled release of pressurized material from the primary screw and is equipped with a positive closure device may be used.
4) Locate the screw conveyor inlet at the bottom of the Excavation Chamber and equip the inlet with bulkhead doors designed to isolate the screw conveyor from the Excavation Chamber. Fit the screw conveyor sections with wear-resistant plate removable from the screw sleeves in the tunnel.

5) Fit the secondary screw outlet with a guillotine gate designed to operate and seal maximum hydrostatic and earth pressure in all soil types indicated.

6) Equip the screw conveyor sleeves with:
   a) A minimum of two pressure sensors, one located near the inlet of the primary screw and the other near the outlet of the secondary screw.
   b) Injection points along its length to permit the introduction of ground conditioners into the screw.
   c) Removable inspection hatches fitted with valves to permit access to mechanical linkages and for the removal of blockages which may occur within the screw.
   d) Provide equipment required to refill the Excavation Chamber.
   e) Accumulator with automatic valve which will close the screw guillotine in the event of a power failure.

c. Slurry TBM:

1) Minimum of eight slurry injection nozzles, four within Excavation Chamber and four in the stone crusher/discharge inlet area within the Excavation Chamber.

2) Abrasion resistant closed circuit mucking system capable of discharging solids through a slurry discharge line and discharge pumps that are sized for the muck volume and advance rate anticipated. Include:
   a) Bypass line and associated valves.
   b) Hydraulic accumulators to ensure closure of all bulkhead flanges in case of power loss.

3) Equipment to measure weight of the excavated material at the separation plant:
   a) Flow and density meters in the supply and discharge slurry lines.
   b) Locate density meters in the return lines in the station excavation and fitted to the vertical pipes carrying the slurry up to the separation plant.
   c) Bentonite slurry recharge flow meter.
   d) An operational status of the slurry plant including key pumps and level indicators and weight of discharged muck.
14. **Muck Control System:**
   a. Equipment to measure the amount of excavated material during advance for each segmental ring.
   b. Designed to assist the TBM operator by comparing the theoretical excavated material relative to propulsion cylinder stroke to the actual excavated material at a given stroke length and display these in real-time to the operators' position.
   c. **EPB TBM:**
      1) Include twin conveyor scales connected to the TBM PLC integrated with propulsion cylinder stroke measuring units.
      2) Provide direct measuring conveyor scales that provide instantaneous and total weight measurements of excavated soil to the TBM PLC which are programmed to compare weights and volumes to the Programmed Unit Weight of each ring.
      3) If a continuous conveyor is used, provide a twin belt scale weighing system connected to the TBM PLC with values continuously displayed in the Operator's position.
      4) Non-weighing nuclear density sensors or laser scanners are not acceptable substitutes for scales.
   d. **Slurry TBM:**
      1) Include flow and density meters in the supply and discharge slurry lines and TBM PLC propulsion cylinder stroke measuring units integrated together to provide volumetric and unit weight measurements for each segmental ring.
      2) Density meters in the return lines located in the station box excavation and fitted to the vertical pipes carrying the slurry out of the excavation.

15. **Active Face Support Pressure Control System:**
   a. Equip the TBM(s) with an automatic pressure compensation system for applying bentonite to the Excavation Chamber and Steering Gap in the event that the measured face pressure falls below the minimum Required Face Support pressure.
   b. Provide at least one dedicated bentonite feed line to the Excavation Chamber and a minimum of six lines through the shield
   c. Continuously data log the bentonite consumed during TBM operation.

16. **TBM Guidance System:**
   a. TBM with a computerized laser-theodolite based guidance system and related software.
   b. Capable of displaying the precise position and orientation of the TBM on a continuous basis with numerical and graphical display of horizontal and vertical deviation from the DTA and direction with respect to the DTA.
c. Capable of displaying the position and orientation of the erected rings with the horizontal and vertical deviations from the DTA.

d. Capable of calculating and displaying correction curve with interactive parameter setting.

e. Monitor, record, and display:
   1) Date, time, and tunnel station continuously.
   2) Segment ring, DTA stationing values, as-driven coordinates and elevations, horizontal and vertical offsets from DTA.
   3) The number and orientation of tapered segment rings required to achieve the desired alignment and the location of the axis of each ring relative to the axis of the tail shield.
   4) Extensions of propulsion and active/passive articulation cylinders.

17. TBM Data Monitoring and Acquisition System:

a. System for real-time data monitoring and acquisition, storage and display system for:
   1) Propulsion cylinder stroke at a minimum of four positions. Show pressure, average instantaneous advance rate and total thrust for all cylinders.
   2) Extensions of propulsion and active/passive articulation cylinders at a minimum of four positions, pressure and total thrust.
   3) Cutterhead rpm, direction and torque.
   4) Electric motor status and power consumption.
   5) Main bearing and main bearing sealing system oil pressure, temperature and flow.
   6) TBM Guidance System data.
   7) Face support pressure.
   8) Compressed air pressure and air flow for both working air and breathing air.
   9) Muck Control System data including instantaneous and total muck weights, actual and programmed muck weights compared to propulsion jack position.
   10) Bentonite Injection volumes from the Active Face Support Pressure Control system.
   11) GCS data including water, polymer and foam solution flows and pressure, air flows and pressure, Foam Injection Ratio (FIR) and Foam Expansion Ratio (FER) for each individual line.
   12) Discharge system from Excavation Chamber including screw conveyor rotation speed and guillotine gate position indication.
13) Stone Crusher and Bulkhead valve status for the Slurry TBM.
14) All gases included in the air quality monitoring system.
15) Pressures and volumes of shield tail grouting and tail seal grease.

b. Record data at a time interval of ten seconds or less and display in real-time at:
   1) TBM operator’s position.
   2) The Contractor’s Site office.
   3) The Resident Engineer’s Site office.

c. Store and record data via an automated acquisition system in digital form for later use and retrieval. Supply the Resident Engineer with the data on a continuous basis.

d. Secure Internet-based access to real time data for use by the Resident Engineer in the Resident Engineer’s Site office.

e. Maintain hardware necessary for recording and real time viewing of data at the Site. In the event of downtime due to hardware within the Contractor’s control, notify the Resident Engineer of the issue, repair hardware, and restore Internet-based access to real time data within 48 hours of hardware failure. Maintain recording of data at all times.

f. Maintain redundant data logging on the TBM at all times and make this data available in the event that downtime described in Article 2.02 E 18 e. herein occurs.

18. Spare Parts:
   a. Provide spare parts inventory for the duration of TBM excavation as recommended by the TBM Manufacturer.
   b. Available on Site at all times:
      1) Guidance system and data logger system spares.
      2) Provide and maintain one complete set of each type of (disc, ripper and scraper) of cutting tools and associated mounts and seals.
   c. Available at the Site within ten days:
      1) Provide one spare main bearing and associated seals, one spare screw conveyor assembly (screw, casing, associated mounts and seals).

19. Tunnel Systems and Plant:
   a. Communication Systems:
      1) Hard wired telephone communication system operable at all times, Include phones at TBM, along the tunnel alignment at intervals of 800 feet, corresponding to cross passage locations at...
California switches, at the station box excavation bottom, and at ground surface.

2) Wireless communication system on locomotives linked with station box excavation bottom and TBM.

3) Signaling system for trains entering the TBM back-up area.

b. Compressed Air Equipment:

1) Include all equipment required for applying face support by compressed air for worker access to the Excavation Chamber in accordance with all applicable regulations.

2) Comply with requirements of ASME BPVC Section VIII, WAC 296-36 and Section 01 35 29, Health, Safety, and Emergency Response Procedures.

3) A compressed air lock system for minimum three persons each which permits safe access into the pressurized Excavation Chamber fitted to the pressure bulkhead of the TBM and equipped with pressure equalization valves between Excavation Chamber and airlocks.

4) An integrated transport system for the air lock or material lock which permits seamless passage of materials such as excavation tools into the Excavation Chamber.

5) Telephone within the compressed air lock and connection for telephone within Excavation Chamber.

6) Capable of providing and maintaining compressed air pressure in the Excavation Chamber at any required level up to 3.5 bars.

7) Capable of providing airflow capacity sufficient to maintain air pressure in the Excavation Chamber at the desired level during maximum expected air loss through the face.

8) Equipment for oxygen decompression in both air locks.

9) Breathing masks with independent air supply for welding within the Excavation Chamber.

10) Utility hookups required for work under compressed air within the Excavation Chamber.

c. Materials Handling for Working in the Excavation Chamber:

1) Appropriate materials handling equipment to permit the safe passage of excavation tools and other materials from the end of the segment feeder into the Excavation Chamber.

2) Provide attachment points for safety harnesses and lifting devices.

3) Provide steps for safe personnel access.

d. Electrical System:
1) Design the TBM and trailing gear to Chapters 296-24 and 296-46B WAC

2) Design the TBM and trailing gear according to Class 1 Division 2 standards for gassy locations and all other requirements set forth in 1) and other applicable regulatory agencies.

3) The primary power distribution system with the means for limiting high-voltage fluctuations when starting up or shutting down the TBM.

4) An emergency standby generator with a capacity and configuration to automatically come on-line in the event of a power failure to operate ventilation, lighting, pumping, communications, air compressors and other systems without interruption.

5) Power interrupt: Automatically shut down power to the TBM and trailing equipment upon detection of an air quality event such as explosive or toxic gas levels exceeding the regulation limits, while maintaining power to the: ventilation, emergency lighting, dewatering pumps, and safety support systems.

e. Lighting Systems:

1) Primary lighting system for the entire length of the tunnel to NEC Class 1 Division 2 standard.

2) Additional lighting in tunnel: Sufficient for inspection of construction operations by the Resident Engineer.

3) Flashlights: Approved by MSHA as permissible.

4) The use of flame safety lamps is prohibited.

f. Water Pumping in Tunnel:

1) Pumping capacity at the Excavation Chamber and TBM as required to remove accumulations of water from construction discharges and any groundwater inflows at the heading or through shield articulations or wire brush seals.

2) Sufficient intermediate pumping stations and pumping capacity along the tunnel as required to remove water accumulations from construction discharges and any groundwater seepage and to maintain accumulated water levels below tunnel railheads.

3) Sump, pump, and discharge lines at the shaft/station locations as required to remove water accumulations from construction discharges, Groundwater Seepage, and sudden water inflows.


g. Slurry TBM Feed and Discharge Lines:

1) Design slurry lines, valves, and pumps to transport the materials indicated in the Contract Documents.

2) Use intermediate pumps along the tunnel alignment sufficient to provide slurry flow rate and pressure needed for Required Support Pressure and slurry discharge for the anticipated maximum TBM advance rate and tunnel length.
3) A minimum of two abrasion resistant pressure sensors along the slurry charge (feed) line segment and two additional abrasion resistant pressure sensors along the slurry discharge line which can be replaced under operating conditions.

h. Slurry TBM Bentonite Mixing and Separation Plant:

1) Design slurry separation plant to separate bentonite slurry and the excavated soil material generated from tunneling through the indicated conditions including areas of ground improvement.
   a) Capable of handling the anticipated volume rates, types, and quantities of materials anticipated.
   b) Capable of balancing the removal of solids from suspension with the Slurry TBM advance rate.

2) Recirculate the processed slurry and provide means of reconditioning and replacing lost slurry as required by ground conditions at heading.
   a) Ability to increase slurry density to counter slurry loss and to prevent face collapses.
   b) Slurry suspension reserve with a minimum volume of 15,000 gallons for use if a sudden, high flow rate slurry loss occurs during tunneling in highly permeable soils.

i. Personnel and Materials Transportation System:

1) For the transportation of material, supplies, compressed air support equipment, persons, and injured persons with consideration of higher tunnel gradients at California switches and ramps.

2) Locomotives and Rail Cars: Conform to the requirements of MSHA 30 CFR 36.
   a) Equipped with all-wheel fail-safe braking system.
   b) Equipped with a suspension system which minimizes noise and vibration transmitted into the temporary track work.
   c) Equipped with new or reconditioned wheels
   d) Ensure ongoing weekly inspection and maintenance of wheels to ensure flat spotting and other damage liable to increase noise and vibration from wheels running on rail is eliminated

3) Fit all rolling stock and any trackless equipment to be used in the tunnel with a fail-safe braking system.

4) Any trackless equipment to be used in tunnel must be fitted with a parking brake capable of holding itself while fully loaded on the steepest slope to be encountered.

5) Trackless equipment:
a) Fitted with adaptive wheels which run at 90 degrees to the tunnel intrados

b) Alternatively fit the tunnel with guide rails
c) Alternatively run on a temporary level invert

6) Provide derailed and/or barrier mechanisms at points along the tunnel track work.

7) Limit train speed to 10 mph.

8) Reduce train speed to 5 mph in the final 2000 ft of both the north bound and southbound tunnels between Roosevelt Station and University of Washington Station

9) Install track:
   a) Such that the adjacent rail profiles at each joint in the trackwork have the same profile
   b) With rails free of pitting and damage on the running surface
   c) With maximum gap between adjacent rail not to exceed 1/8”
   d) With a maximum vertical offset at rail joints not to exceed 1/16”
   e) With staggered rail joints such that the joints between adjacent rail are 30 inch offset from each other
   f) Locate track sleepers under each joint and at maximum 30” centers

10) Carry-out a comprehensive track work maintenance and housekeeping regime to maintain rail tolerances to those specified in 9).

11) Carry out weekly inspections with the Resident Engineer to ensure the tolerances in 8) are being adhered to throughout the tunnel.

j. Muck Transport Conveyor System for EPB TBM:

1) Provide a continuous conveyor muck transport system integrated with the TBM including related safety equipment.

2) Where the continuous conveyor is used in a curve fit belt safety guards designed to prevent accidental straightening of the conveyor belt.

3) Do not advance the TBM more than 600 feet on either the north or south bound tunnels until the continuous conveyor for the TBM has been fully installed and commissioned.

k. Ventilation System:
1) Meet all OSHA and WISHA regulatory requirements and in accordance with the NEC Class 1 Division 2 standard.

2) Fully reversible with ability to meet all performance and air quality criteria in exhaust or intake mode.

3) Make main ventilation duct of non-combustible materials.

4) Locate exhaust stacks of the ventilation system to prevent recirculation of exhaust air into the air intake shaft or station box excavation.

5) Design:
   a) Unless otherwise indicated, meet or exceed minimum requirements of OSHA.
   b) When the tunnel or other underground excavations are occupied, design the primary ventilation system to deliver fresh air to the heading at a volumetric flow rate of at least 90 feet per minute multiplied by the excavation cross section measured in square feet.
   c) Configure and operate fans to minimize recirculation of air in the TBM.
   d) Where the ventilation system in the TBM is operating in an exhaust mode, provide ventilation by a supplementary fan positioned to minimize recirculation.
   e) Provide additional equipment for ventilating confined areas of the TBM not reached by the main ventilation system, including the Excavation Chamber when occupied by personnel.

6) Ensure power to the primary ventilation system is not interrupted in the event of a gas detection system alarm.

I. Use primary ventilation and booster fans for tunnel ventilation and related electrical equipment and cables located within the tunnel or station box excavations approved for use in gassy locations.

20. Health and Safety Equipment:
   a. In addition to the health and safety requirements in Section 01 35 29.20, Health, Safety, Security, and Emergency Response Procedures, meet the following requirements for equipment used in tunneling:
      1) Equip TBM with integrated safety systems as described in this Section and in accordance with applicable regulatory requirements for underground construction equipment.
      2) All equipment: Rated for use in Class 1 Division 2 hazardous locations.
   b. Minimum Fire Protection Requirements:
      1) Manually operated fire suppression systems within TBM and along trailing gear for all electro-hydraulic installations, heat sources, and the TBM transformer.
2) A clear emergency escape way from the TBM along the trailing gear.

3) Fire suppression system on all haulage equipment.

4) Fire extinguishers at the TBM control panel, in the air locks, and at 25 feet intervals along the trailing gear.

5) A water curtain at the rear end of the trailing gear.

c. Equip all personnel entering the tunnel with oxygen re-breather type self rescuers.

d. Air Quality Monitoring:

1) An air quality monitoring and alarm system to monitor gas concentrations including but not limited to, carbon monoxide, nitrogen oxides, hydrogen sulfide, oxygen, methane and airborne particulate concentrations in the tunnel atmosphere.

2) Continuous air quality monitoring on the TBM with readings captured by the TBM Data Monitoring and Acquisition System and recorded by data logger at intervals of 10 seconds or less.

3) Design the alarm system to de-energize the TBM, at no more than 20 percent of LEL for methane or any other combustible gas.

4) Position sensors at locations that provide the most effective measurement of combustible and toxic gases. Do not place sensors within a fresh air stream.

5) Use handheld multi-gas detectors including, but not limited to, carbon monoxide, hydrogen sulfide, oxygen and methane by properly trained personnel when entering the chamber under free air conditions.

PART 3 - EXECUTION

3.01 PREPARATION

A. TBM Testing:

1. Fully assemble and Factory Test TBM(s) and trailing gear prior to shipment to Site. Upon reassembly at Site, re-test the TBM and re-calibrate all components.

2. Provide travel, accommodations, and meals for two persons from the Resident Engineer team to attend Factory Tests.

3. Factory Test the Ground Conditioning System (GCS) and adjust so that all functions are within the manufacturers’ recommendations prior to the TBM delivery.

B. Before TBM launching and start-up operations, the following preparation and installations are required:

1. Install and baseline geotechnical instrumentation: Before commencement of tunnel launch, ensure that all specified geotechnical instrumentation has been
installed, is functional, has been base-lined and is being monitored as specified in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

2. Provide an on-site TBM manufacturer’s representative to train the Contractor’s personnel in the operation and maintenance during start-up and the initial 1000 feet of tunnel advance.

3. Commission compressed air plant and related services required to supply each TBM.

4. Prior to launch and start-up operation of an EPB TBM determine the required soil conditioner properties in order that workable mixtures of earth paste and soil conditioners for the anticipated soil types may be determined.
   a. Carry out systematic testing of the different soil types to determine the range of soil conditioning parameters, including foam expansion ratios (FER), foam injection ratios (FIR), types and concentrations of foam agents, polymers or other materials, in order to be ready to apply when required.
   b. Carry out calibration of the GCS in order to ensure consistent conditioner application.

5. Prior to launch and start-up of the Slurry TBM, determine and check the properties of the slurry to be utilized.

6. Confirm that the Field Quality Control section, specified in Section 31 32 13.36, Jet Grouting Soil Stabilization, has been completed.

7. Tunnel Rescue Teams in place per Section 31 71 26, Tunnel Rescue Teams.

8. TBM Data Monitoring and Acquisition System is tested and fully operational.

9. All site water discharge systems for Section 01 57 24, Temporary Site Water Discharge including sump, pump, and discharge lines are tested and ready for operations that meet discharge requirements indicated.

10. Complete all necessary training for workers required to perform work under compressed air.

11. Verify correct operation of all safety equipment and material handling equipment including operation of equipment for the supply of materials and equipment to the excavation chamber to the satisfaction of the Resident Engineer.

12. Demonstrate safe locomotive and rolling stock operation.

13. Tunnel System Plans have an acceptable disposition.

C. Launching from Maple Leaf Portal Site and Roosevelt Station:

1. Provide all installations in the portal/station excavation for TBM launching, start-up and tunnel operation, including installation of supplementary supports or bracing required for structural support, thrust abutment, and launch cradle.

2. Provide launch sealing structure for TBM launch which seals the gap between the headwall, soil and TBM and the gap between head wall, soil and the extrados of the segmental lining.

3. Provide anti-roll devices on the TBM shield during the launch operation.
D. Reception at Roosevelt Station and University of Washington Station

1. Provide all installations in the portal/station for TBM reception, including installation of supplementary supports or bracing required for structural support, thrust abutment, and reception cradle.

2. Provide reception sealing structure for TBM reception which seals the gap between the headwall, soil and TBM and the gap between head wall, soil and the extrados of the segmental lining.

E. Active Face Support Pressure Calculations:

1. Provide support pressure calculations for entire tunnel drive for advancing, non advancing, and inspection, maintenance, and boulder stoppage based on anticipated ground and groundwater conditions. Include with calculations:
   a. Description of calculation method used and references used.
   b. A table and a tunnel profile showing the proposed Active Support Pressures with depth across tunnel face for each tunnel advance along the tunnel alignment. These calculations may be reduced to reaches no longer than the interval between boreholes as indicated in the Contract Documents. Likewise, integrate the tail void grouting pressures and volume related to the face support pressures along the alignment in accordance with Section 31 73 23, Tail Void Grouting.
   c. Include groundwater pressure, earth pressure, and tolerance component in calculating the Required Support Pressure.
   d. Detail descriptions of factor of safety used for both groundwater and earth pressures.
   e. Include a tolerance of 0.3 bar for face support by earth paste (EPB TBM), 0.1 bar for face support by slurry (Slurry TBM), and 0.05 bar for face support by compressed air.

2. Check resulting Required Support Pressures for safety against air blow-out and adjust air pressure if necessary to provide a minimum factor of safety of 1.2.

F. Pre-Tunneling Meeting:

1. At least 30 calendar days prior to TBM launch, conduct a meeting with the Resident Engineer to discuss aspects of the tunneling work relating to the monitoring, data acquisition and reporting, communications, testing plan, safety, quality procedures, and tunnel rescue teams.

G. Daily Reports as Required by Quality Control.

3.02 CONSTRUCTION

A. Excavation:

1. Advance tunnel heading through all ground conditions encountered using Required Support Pressure to minimize Lost Ground as required to comply with ground movement limits.

2. Operate TBM with Active Support Pressure during TBM advance; Open Mode operation is not permitted during TBM advance.

3. Maintain a minimum distance between TBMs of 3 tunnel diameters.
B. Face Support Application:

1. Provide Active Face Support by pressurized slurry or earth paste at all times during tunnel excavation; adjust as appropriate within improved ground if present adjacent to launching and receiving portal.

2. Modify Active Face Support pressure from that previously calculated to adapt to the ambient ground conditions and groundwater pressure encountered, as necessary, to comply with ground movement limits and to ensure face stability and minimize Lost Ground at all times:
   
a. Operate the pressure control system to keep Active Face Support pressure within the following operational tolerances of target pressure specified for the TBM type utilized:
      1) EPB TBM: plus or minus 0.3 bar.
      2) Slurry TBM: plus or minus 0.1 bar.

3. Adjust composition and properties of the slurry (for Slurry TBM) to the local ground conditions and properties of the make-up water in order to achieve a reliable Active Face Support including impacts from tunneling through zones with high permeability ground and organic soils.

C. Tunnel Excavation under Critical Structures:

1. Excavate and build rings on a continuous 24-hour per day basis.

2. Inject bentonite into the Steering Gap to ensure filling and pressurization while monitoring injection volumes such that losses into the tail void or into the excavation chamber are minimized.

3. Locations apply to both the north bound and south bound tunnels:
   
a. Station 1214+50 through 1212+50 – North Interceptor Sewer.
   
b. Station 1249+50 through 1247+50 – UW School of Social Work.
   
c. Station 1302+00 through 1300+00 – North Trunk Sewer.

D. Face Support during TBM Stoppage:

1. Control and stabilize the tunnel face during Inspection, Maintenance, and Boulder Stops, and any other heading or Excavation Chamber work using compressed air.

2. Prior to entry into the Excavation Chamber under compressed air, introduce bentonite slurry into the tool gap or flooded into the Excavation Chamber such that a substantial and continuous bentonite cake is formed on the tunnel face.

3. Apply calculated target air pressure within Excavation Chamber with supplementary face support, if necessary.

4. Prior to carrying out any work in the chamber, ensure a competent person conducts a Face Stability Assessment. Ensure the competent person immediately advises the Resident Engineer of any changes in compressed air pressure or abandonment of the entry due to ground conditions.

5. Compressed air support may be reduced or eliminated based on the evaluation of the competent person.
6. Maintain bentonite cake and supplementary face support during the Excavation Chamber entry.

7. Continuously control air pressure and compressed air consumption within a tolerance of plus or minus 0.05 bar for face support by compressed air.

8. Refill Excavation Chamber with earth paste or slurry and pressurize before restart of the TBM after Inspection, Maintenance, and Boulder Stops.

E. Support by Precast Concrete Segments:

1. Refer to Section 31 74 16, Precast Concrete Tunnel Lining.

2. Grip and erect segments in a manner to accurately position and align segments and gaskets within specified tolerances as specified in Section 31 74 16, Precast Concrete Tunnel Lining.

3. Handle segments to avoid damage.

4. Clean all faces of each segment and gasket prior to fitting adjacent faces together.

5. Lubricate key segment gaskets prior to installation.

6. Maintain the ring erection area free of debris and accumulations of muck and water prior to and during the ring building process.

7. Packing on the ring leading edge where propulsion cylinder shoes make contact is prohibited.

8. Where the tunnel exceeds specified tolerances, perform remedial work.

9. Perform plane checks as directed by the Resident Engineer.

10. Packing on the leading edge of the ring is prohibited unless directed by the Resident Engineer for the purpose of correcting the plane of the ring.

11. Perform grouting to meet segment Groundwater Seepage requirements per Section 31 74 16, Precast Concrete Tunnel Lining.

F. Tail Void Grout Injection:

1. Carried out such that complete filling and pressurization of the void is simultaneous with TBM advance in accordance with Section 31 73 23, Tail Void Grouting.

2. Stop the TBM advance when grouting equipment is not functioning.

G. Muck Handling:

1. Handle and convey muck through the Excavation Chamber and TBM to the ground surface.

2. Dispose of excavated materials in accordance with Section 31 23 01, Excavation Spoils and Muck Disposal.

3. Submit copies of disposal records in accordance with Section 01 55 00, Vehicular Access and Parking.

H. Removal of Water:
1. Remove all accumulating water and groundwater inflow from the TBM and tunnel using methods and equipment necessary to prevent damage to any portion of the work.

2. Disposal of all water per Section 01 57 24, Temporary Site Water Discharge.

3. Limit flows to requirements of Section 31 74 16, Precast Concrete Tunnel Lining.

I. Tolerances

1. Line and Grade:
   a. Control TBM position as required to maintain dynamic envelope of light rail vehicles and permit installation of precast concrete segment linings in accordance with requirements indicated and the following:
      1) Deviation not to exceed 4 inches in any direction from the DTA
   b. Make corrections with due consideration of required tolerances for the segmental lining, as specified in Section 31 74 16, Precast Concrete Tunnel Lining.

2. Heave and settlement per Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

3. Groundwater seepage per Section 31 74 16, Precast Concrete Tunnel Lining.

J. Prevention and Remediation of Lost Ground:

1. Measure and record the amount of muck excavated on a per ring basis using the Muck Control System.
   a. Calibrate the Muck Control System at regular intervals, but no less than monthly.
   b. Record the excavated volume of muck for each completed ring.

2. Immediately notify Resident Engineer and modify face support pressure or muck handling system as necessary for better control and to minimize Lost Ground at face if verified muck weight and volume exceeds theoretical excavation weight and volume by greater than five percent per ring.

3. Fill voids within four hours and repair any damage to underground utilities, surface structures, roadways, or any other features resulting from Lost Ground, settlement, and heave. Work with the Resident Engineer to determine the most appropriate action including drilling and grouting from a surface location.

4. Document Lost Ground void filling and submit Lost Ground records within four hours of completing remedial work.

5. Work with Resident Engineer and owner of the structure or utility to determine what mitigation and repairs are required as a result of the Lost Ground.

6. For all losses and damage arising from Lost Ground including, but not limited to, damage to underground utilities, surface structures, roadways or any other feature that may occur in the prosecution of the work:
   a. Follow the procedures required by the Owner Controlled Insurance Policy (OCIP) in the General Conditions.
b. Responsible for:

1) All deductibles for OCIP-insured claims
2) All costs resulting from claims not insured by the OCIP.

K. Ventilation System:

1. Operate the tunnel main ventilation system continuously 24 hours per day, seven days per week.

2. During extended periods of inactivity and when tunnel and associated excavations are unoccupied, the volumetric flow rate may be reduced to one-half that required during operation.

3. Advance the ventilation system continuously with the normal excavation cycle.

4. Operate and maintain mechanical ventilation systems in tunnel and portal excavations in which work of any kind is being performed.

5. Monitor the performance of the ventilation system as required by OSHA and WAC, and as often as deemed necessary to fully protect workers, but not less than once every seven calendar days to verify that it conforms to the minimum requirements.

a. Measure the flow rate of fresh air delivered by the ventilation system at the following minimum locations:

1) Within the TBM shield in the ring build area.
2) In the tunnel at a position eight tunnel diameters behind the back end of the TBM trailing gear.
3) In the tunnel at a position eight tunnel diameters from the nearest open portal.

b. Perform weekly smoke tube tests in the tunnel heading to identify air recirculation and areas of dead air. Modify or adjust the ventilation system as necessary to eliminate deficiencies.

c. Air monitoring equipment:

1) Check all with a known mixture of gas and calibrate, if necessary, at least once every 30 calendar days.
2) Maintain in accordance with the manufacturer's recommendations.
3) Maintain calibration records and make available to the Resident Engineer on request.

d. Maintain records of all observations, and make available to the Resident Engineer on request.

6. Report indications of combustible or toxic gas in tunnels and portals to the Resident Engineer immediately.

7. In the event of primary ventilation system failure for any reason, withdraw all persons from the tunnel. Permit limited access to those working to restore normal ventilation. Following restoration of ventilation flow, verify the air quality and
modify ventilation system as required to meet OSHA and WAC requirements, prior to permitting re-entry of personnel.

8. After the tunnel is holed through, maintain appropriate air flow and/or OSHA minimums for the work activity being undertaken until the tunnel is completed and accepted.

9. Advise the Resident Engineer before the main ventilation system is reversed.

L. Movement Monitoring System:

1. Monitor, document, and evaluate movements of the ground, tunnel lining, adjacent property, and other pertinent facilities during the tunneling process observations as necessary for a controlled and safe tunneling operation.
   a. Geotechnical instrument monitoring: Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
   b. Survey Information: Section 01 71 23, Field Engineering.

M. Inspection Stops:

1. Carry out Inspection Stops at each cross passage location in both the north bound and south bound tunnels.
   a. Limited to locations adjacent to a subsurface investigation borehole as indicated in the Contract Documents.
   b. Geological conditions as indicated in the Contract Documents.
   c. Within the TBM driven tunnels from Maple Leaf Portal to University of Washington Station:

2. Use any inspection method considered useful to the Contractor, but include at least one visual method and direct measurement of cutter wear. Visual inspection methods include:
   a. personnel access
   b. use of a remote camera.

3. Submit documentation report of all the items inspected and their condition within 24 hours of the inspection stoppage. Include:
   a. Written condition report of head, saddles, and other components.
   b. Details of cutting tool wear, including identification of any replaced during the stoppage.
   c. Photographs, video, or other record made during the inspection.

4. Document observed conditions during inspection stoppage, including face stability, groundwater inflows, and Excavation Chamber pressures.

N. TBM Maintenance:

1. Complete as often as necessary to keep the cutting tools, cutterhead, Excavation Chamber equipment, pressure sensors, muck handling equipment, and other TBM equipment in good operating condition, and as per manufacturers' recommendations.
2. Test hydraulic oil, seal oil, and bearing lubricating oil and grease at least once per every 100 operating hours, monthly, or in accordance with manufacturer recommendations, whichever is more frequent. Maintain records of these tests and make available to the Resident Engineer upon request. Clearly indicate the contaminant levels and overall condition including changes since last testing and maintenance action indicated.

3. Do not conduct Maintenance Stops when the heading is below a water main, railway, highway, or settlement sensitive utility and ground cover, which is less than 50 feet between the crown of the outside of the tunnel and the invert of a structure, utility, or bottom of the roadway and railway including subgrade, unless appropriate ground treatment has been carried out in advance.

4. Modify the cutter types as needed to adjust for varying ground conditions.

5. Optimize cutting tools for best TBM performance with consideration of: production, cutter, and cutterhead wear, and fracturing of cobbles and boulders sufficiently at the heading for proper handling within the Excavation Chamber and mucking system.

6. Submit observed cutter and cutterhead conditions, face stability, groundwater inflows, Excavation Chamber pressures, and all maintenance work completed during each maintenance stop.

7. Recalibrate or replace sensors being logged by the data acquisition system upon discovery of damage or the observation of erroneous readings.

O. Boulder Removal:

1. Perform when a boulder is detected which cannot be ingested by the screw conveyor or stone crusher.

2. Do not conduct Boulder Stops when the heading meets criteria listed in Article 3.02 L herein.

3. Blasting is prohibited. Use splitting, jack-hammering, sawing, chiseling, or other acceptable means for cutting, fracturing, and removal.

4. Document observed face stability, groundwater inflows, and Excavation Chamber pressures for work completed during Boulder Stops.

P. Electrical System Monitoring:

1. To remain acceptable for use in Class 1 Division 2 hazardous locations, maintain Essential Services electrical equipment as indicated:
   
   a. Inspect as often as deemed necessary to protect workers, but not less than once every seven days by a competent person.

   b. Maintain in condition suited to its intended use.

   c. Inspect explosion-proof enclosures for loose or missing screws, for damage to gaskets, threaded connections, covers, or seals, and for other impairments to a tight condition.

   d. Inspect cables for cuts, abrasions, and other impairments.

2. Maintain records of these inspections and make available to the Resident Engineer on request.
Q. Provide for safe access and egress of personnel to and from the heading. Include procedures for personnel working in all tunnel locations and include, as appropriate, separate walkways, refuges, personnel transfer equipment and authorization systems for working and walking on the track way.

1. Provide a continuous temporary safety walkway along the tunnel which is not within the envelope of the mucking or transport equipment and meets the height of the TBM gantry walkway

2. Walkway platform: Not less than 2 feet wide and equipped with toe boards and hand rails on the track side of the walkway.

3. Provide walkway access points at tunnel entry, along the tunnel at the proposed cross passage locations and at the rear of the TBM gantry to provide safe access to tunnel invert or cross passage locations.

R. Temporary Tunnel Sump:

1. Provide a temporary tunnel sump sized to fit within the tunnel envelope located at the tunnel low point.

S. Tunnel Launch at Maple Leaf Portal Site:

1. Provide details of ground improvement or ground support and dewatering to the extent permitted by Section 31 23 19, Dewatering, for ground and groundwater control at the portal launch structure prior to tunnel launch.

T. Tunnel Reception:

1. Provide details of ground improvement or ground support and dewatering to the extent permitted by Section 31 23 19, Dewatering, for ground and groundwater control at the receiving structure prior to tunnel reception.

U. Segment Repair and Lining Clean-Up Prior to installation of final track bed and walkway: Section 31 74 16, Precast Concrete Tunnel Lining.

V. Daily Meetings: Conducted between the Contractor and Resident Engineer to discuss safety, quality, operating parameters, instrumentation monitoring, production and submission of reports from previous day(s) production.

3.03 INSTALLATION

A. Concrete Invert and Walkway

1. Pour Cast-in-place concrete in accordance with Section 03 30 00, Cast-in-Place Concrete.

2. Before placement of concrete, take care to determine that all embedded items are firmly and securely fastened in place as indicated on the Contract Drawings.

3. Drill dowels for safety walkway at drilling locators as indicated on the Contract Drawings. Clean holes and grout dowels in accordance with the grout manufacturer’s recommended procedure.

4. Finish concrete as follows, in accordance with Section 03 35 00, Concrete Finishing:

   a. Invert slab: Troweled Finish, except under rail plinths. Under rail plinths provide scratched finish.

c. Side of safety walkway: Smooth Form Finish.

5. Tunnel Surveys: As-Built Invert Survey

a. Survey as-built tunnel invert as follows:

1) Measure distance from track centerline to face of walkway as indicated in the Drawings at 10-foot intervals.

b. At same location, take invert elevations at off sets of 2 feet 4-1/4 feet either side of theoretical track centerline.

6. Tunnel Surveys: Brass Plug Installation Survey

a. Description:

1) Use brass plugs to provide a permanent record of reference line sub tangents and track centerline sub tangent locations.

2) Use Brass plugs (BPs) consisting of a 1/2-inch Star Tampin and a 1/2-inch diameter anchor bolt, 1-1/2 inches in length, installed so that top of plug is flush with adjacent concrete surface.

b. After completion of invert and safety walkway concrete, install BPs at following locations:

1) In tangent track areas at maximum station intervals of 300 feet, place two BP witness monuments on a single witness line set at right angles to centerline of track. Place one BP on safety walkway and one on the invert concrete at random offsets as directed by the Resident Engineer. Record station, two offset distances and elevations.

2) In curved track areas, at all PIs and sub-PIs along track centerline traverses as directed by Sound Transit, place two BP witness monuments on a single witness line set through PI at random angles to track center line tangents. Place a BP on safety walkway and another on concrete invert at random offsets to PI. Record angles between witness line and ahead and back tangents. Record two offset distances and elevations.

B. Tunnel Handrail

1. Fabricate and install tunnel handrail to the requirements for Metal Handrails, non-public exterior (galvanized) as specified in Section 0 5 52 14, Metal Handrails except as modified below.

2. Anchors, Fasteners and Accessories: Comply with the requirements of Section 05 52 14, Metal Handrails.

3.04 FIELD QUALITY CONTROL

A. General:

1. TBM Data: Review data transmitted real-time for TBM system monitoring and provide complete unaltered digital records in an agreed format directly to Resident Engineer.
2. EPB Muck Control:
   a. Prepare the Programmed Unit Weight for the expected ground types to be encountered in accordance with the contract documents and make them available for use by the TBM PLC for continuous weight measurements during excavation.
   b. During the excavation of the tunnel, observe the muck passing over the belt for changes in its appearance.
   c. Ensure the Muck Control System provides data on a continuous basis to the operator display and data logger for both instantaneous and total weight. Also take volume measurements by observation of the muck car filling when these are used. Record both measurements on the ring reports and used for calculated unit weight.
   d. Determine bulking factor of the excavated soil for each ring and compare to the actual muck volume observed when muck cars are used.
   e. Promptly notify Resident Engineer and provide documentation if calculations indicate that actual weights (or volumes) for a shove exceed theoretical by more than ten percent.

3. Slurry Muck Control:
   a. Control the material properties of the slurry every time, fresh suspension is being mixed and once every shift. Record the slurry density once per shift.
   b. Determine, monitor, and test material flow characteristics such as density, filtrate loss, viscosity, yield point and others as identified within the Submittal with Acceptable Disposition.
   c. Record total weight of excavated material on a ring basis.
   d. Record the total weight of the discharged material on a shift basis.
   e. Record the total volume of bentonite slurry added to the system on a shift basis. Promptly report bentonite losses in writing to the Resident Engineer.
   f. Maintain Slurry Muck Control records on a shift basis of quality control tests including slurry density and volume of slurry and conditioner used and make available to the Resident Engineer upon request.

4. Daily Reporting and Documentation during Tunneling:
   a. Shift Reports:
      1) Submit the daily shift reports by 10 am the following day in both an agreed digital and hardcopy format and include the following information:
         a) Date, location, shift, beginning and ending face station, list of personnel by name, classification, and function working that shift, list of the number and type of equipment, including amount of and reason for any idle or down time, list of all materials used in the work.
b) Description of materials being excavated, volume of excavated materials using methods as mutually agreed when not otherwise specified.

c) Description and locations of Lost Ground, water inflows and other events.

d) Cutting tool and muck system component changes, including time and date of replacement, cutter or component position or number, and reason for change.

b. Submit Ring Reports in both an agreed digital and hardcopy format and include the following:

1) Date, shift, ring number, beginning and ending face station, start and end time for excavation and ring erection, face support pressure, total excavated weight and volume, type and total volume of conditioners injected, calculated unit weight, GBR unit weight, total volume and pressure of grout injected through each line, bentonite injected, observed material density, and calculation of bulking factor.

2) Guidance system information, including present and predicted position, propulsion and articulation cylinder extensions, ring gap before and after ring erection, key position, and roll of ring.

3) Observations and damage to precast segments or gaskets:
   a) Record of segments damaged due to transport, handling or installation.
   b) Locations of leakage, including estimated rates and remediation actions. Include results of any remediation actions taken.

c. Provide Air Quality Monitoring Report in both an agreed digital and hardcopy format:

1) Maintain records of air quality measurements and reports and make available to the Resident Engineer upon request.

2) Indications of combustible or toxic gas in tunnels or portals to the Resident Engineer immediately on the same day that these indications occur.


e. When feasible, combine reports.

5. Daily Soil Sampling: In accordance with Article 1.04. P herein and the following minimum requirements:

a. Take a muck sample directly from the conveyor when a change in appearance is noted by the Contractor or when directed by the Resident Engineer.

b. At a minimum, take a 0.5 cubic foot sample once per each day of excavation. Identify samples to location and date. Place sample within watertight plastic bag, and seal. Identify location on the bagged sample. Provide bag sample to Resident Engineer.
c. Note GCS settings along with stationing and other pertinent data on the soil sample report form and include as part of the daily report submittals.

d. Testing:
   1) Provide an Independent Testing Laboratory for soil samples.
   2) Carry out soil classification studies on each soil sample taken including:
      a) Atterberg limits on fine grained soils in accordance with ASTM D4318.
      b) Soil gradation in accordance with ASTM D422.
      c) pH testing of soil in accordance with US EPA SW-846, Method 9045D.

B. Tunnel Surveys: As-Built Tunnel Lining Survey and Final Alignment

1. Immediately after completing each tunnel, carry out a 1:50,000 survey utilizing a closed traverse to establish accurate line, elevation, and stationing. Make survey agreement with the Resident Engineer and submit with as-built data to compare with theoretical setting out data.

2. On this survey locate every third lining ring through the tunnel. Where the survey shows that a section of tunnel is outside specified tolerances, locate every ring throughout that section plus a length of ten rings on each side. Include within this survey the following:
   a. Horizontal offsets from theoretical centerline to each inside face of tunnel.
   b. Vertical offsets to crown and invert measured from theoretical centerline.
   c. Four radial offsets through theoretical centerline measured at angles of 45 degrees from vertical.
   d. Measure horizontal stationing of points where measurements are taken and at openings and at all other features as required by the Resident Engineer.

3. Perform survey so that results may be entered directly into a computer program to check tunnel alignment.

4. For all measurements taken, calculate differences between actual and theoretical positions. Submit all information together with copies of a graphical representation of differences from theoretical.

5. Sound Transit will assess above information.
   a. Assessment of any length of tunnel cannot be completed until as-built survey data have been supplied for at least 250 feet into adjacent lengths of tunnel.
   b. Sound Transit may design and adopt an amended alignment at Sound Transit's sole discretion.
   c. Pay all of Sound Transit's costs that are associated with designing and adopting an amended alignment.
6. If an amended alignment is adopted, carry out all subsequent work in accordance with that amended alignment.

7. Survey:
   a. Coordinate survey work with Section 01 71 23, Field Engineering.
   b. Provide surveyor and Resident Engineer access and assistance as necessary for confirmation of the tunnel alignment and stationing.
   c. Immediately initiate alignment corrections and alignment control changes if a survey error and out of tolerance alignments are identified. Notify the Resident Engineer immediately upon discovery of TBM out of tolerance.
   d. Be responsible for the accuracy of the work and for correcting it, as required.

C. Remedial Measures:

1. Precast Segmental Lining Defects: Quality and water tightness in accordance with Section 31 74 16, Precast Concrete Tunnel Lining.
   a. Promptly stop or control leakage causing piping or erosion of fines during tunneling to prevent Lost Ground.
   b. Repair unacceptable segment spalling and damage prior to invert installation in accordance with Section 31 74 16, Precast Concrete Tunnel Lining.

2. Grout to fill voids in accordance with approved submittals.

D. Ground Movement: refer to Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

3.05 CLEANING

A. Perform weekly scheduled tasks to:

1. Clean the tunnel interior and invert muck, grout, debris, and other foreign materials.

2. Maintain sumps, collection points, and pumps clear of trash and in good operating order.

3. Maintain clear passage of the flow of personnel, equipment, and materials.

3.06 PROTECTION

A. Whenever there is a condition which is likely to endanger the stability of the excavation or adjacent work or structures, notify the Resident Engineer and work with a full crew for 24 hours per day including weekends and holidays without interruption until those conditions are mitigated.

B. Follow the Tunnel Safety Plan for tunnel evacuation and for tunnel re-entry in the event that the air monitoring system alarms or automatic power shutdown occurs. Post the evacuation and re-entry plans in a readily visible location at the entrance portal. Train workers in tunnel evacuation procedures.
C. Give tunnel crews daily safety briefings and sufficient time at shift change hand-over to identify any hazardous conditions or safety issue that may exist and have not been corrected.

D. Notify the Resident Engineer immediately upon:

1. Encountering an emergency condition likely to endanger the tunnel integrity, including but not limited to: seepage with soil erosion or piping of fines at heading, tail seal seepage, precast concrete segment joint seepage, portal seal seepage, excessive lining deformations, significant lining cracks and other detrimental observations.

2. Encountering an emergency condition likely to endanger structures adjacent to the tunnel axis.

3. Any TBM or tunnel air quality alarm or warning.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for excavation and support of the cross passages utilizing the Sequential Excavation Method (SEM).

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 57 24, Temporary Site Water Discharge
2. Section 31 09 13.50, Tunnel Instrumentation and Monitoring
3. Section 31 20 00, Earth Moving
4. Section 31 23 01, Excavation Spoils and Muck Disposal.
5. Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine
6. Section 31 74 19.05, Shotcrete for SEM Tunnels
7. Section 31 74 19.10, Initial Shotcrete Tunnel Lining

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents. In case of a conflict between the requirements of this Section and those of a listed document, the requirements of this Section shall prevail.

1. American Society for Testing and Materials (ASTM)
   a. ASTM A36 Standard Specification for Carbon Steel
   b. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   c. ASTM A82 Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
   d. ASTM A1064 Standard Specification for Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
   e. ASTM A325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105ksi Minimum Tensile Strength
   f. ASTM A501 Standard Specification for Hot-formed Welded and Seamless Carbon Steel Structural Tubing
   g. ASTM A615 Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
1.03 DEFINITIONS

A. Cross Passage Type: Either the typical cross passage configuration or low point sump cross passages 31, as indicated in the Contract Documents.

B. Theoretical Excavation Line: Theoretical line of excavation inside of which no earth or surrounding ground shall protrude.

C. SEM Excavation: Tunnel excavation using sequences and support measures as shown on the drawings for various support categories. Installation of pre-support, sequential excavation of limited round lengths, with support installed immediately following excavation.

D. Excavation and Support Sequence: Prescribed sequence to complete the cross passage excavation and initial support lining using SEM.

E. Length of Round: Length of exposed ground opened up during one excavation increment and immediately sealed with flashcrete, as indicated.

F. Over-excavation: Intentional or unintentional excavation of ground beyond the theoretical excavation line.

G. Ground Improvement: Modification of naturally existing soils by dewatering, grouting or other approved methods.

H. Pre-Support: Support elements installed prior to excavation of the ground, including rebar spiling, and grouted pipe spiling.

I. Flashcrete: Minimum two-inch thick layer of steel fiber reinforced shotcrete placed immediately after excavation on exposed ground surfaces as indicated.

J. Initial Shotcrete Lining: Shotcrete lining of minimum thickness and reinforcement as shown on the Contract Drawings.

h. ASTM C109 Standard Test Method for Compressive Strength of Hydraulic Cement Mortars Using 2-inch or [50mm] Cube Specimens

i. ASTM C144 Standard Specification for Aggregate for Masonry Mortar

j. ASTM C150 Standard Specification for Portland Cement
K. Final Lining: Reinforced concrete or shotcrete lining placed after installation of initial shotcrete lining and waterproofing system.

L. Groundwater Control Measures: Work and equipment required to collect and remove groundwater ahead of the face of excavation or penetrating into the cross passage. Included are temporary construction drainage and gravity dewatering from well points, vacuum dewatering, drainage mats, PVC-hoses or similar materials used to collect and drain off groundwater from areas at either the excavated ground surface before applying shotcrete lining to prevent hydrostatic pressure build-up behind the shotcrete lining and/or for dewatering of seepage through the shotcrete lining, including pumps as required to convey seepage to discharge locations.

M. Rebar Spiling: Reinforcing bar without end hardware driven into the ground, or installed and grouted into pre-drilled holes ahead of cross passage excavation.

N. Grouted Pipe Spiling: Perforated steel pipes driven, placed in pre-drilled holes, or self-drilling anchors installed ahead of the cross passage excavation and grouted in place.

O. Face Stabilization Wedge: Unexcavated portion of the heading temporarily left in place to enhance face stability.

P. Grouting: Permeation grouting ahead of the face to stabilize loose or granular soils by injection of cementitious or chemical grouts.

Q. Vacuum Dewatering: Installation of wells surrounded by a filter medium to dewater soil layers by means of maintaining a vacuum in the well.

R. Probe Drilling: Geologic exploration of ground conditions by means of probe holes.

1.04 SUBMITTALS:

A. Qualifications:
   1. SEM Superintendent
   2. SEM Surveyor
   3. SEM Tunnel Project Engineer

B. General Cross Passage Approach Plan

C. Work Plan for Cross Passage Excavation.

D. Shop drawings with detailed description for the sequence, materials, and installation procedures for the SEM work for each cross passage, signed by the SEM Tunnel Project Engineer.

E. Certifications

F. Reports:
   2. Groundwater Monitoring Reports.
   3. Excavation Summary Reports for each cross passage.

G. Contingency Plans:
   1. Encountering loose or unstable soil at cross passage excavation.
2. Unanticipated groundwater inflows during cross passage excavation.

1.05 QUALITY ASSURANCE

A. SEM Tunnel Project Engineer shall have a minimum 10 years experience in underground construction, three years experience in SEM construction, including at a minimum two completed projects utilizing SEM and Shotcrete similar to that indicated.

B. SEM Surveyor: Shall be a licensed Professional Land Surveyor registered in the State of Washington, with a minimum of 10 years experience in underground construction, including at least three projects where cross passages were constructed as indicated.

C. Certify, through records of training and a written statement that Contractor’s SEM crew are prepared and equipped to apply or install all support measures indicated for each Cross Passage Type.

D. SEM Superintendent shall have a minimum 12 years construction experience utilizing SEM with shotcrete support.

1.06 GENERAL CROSS PASSAGE APPROACH PLAN

A. Submit a general cross passage approach plan a minimum of 180 days before SEM tunneling work. Include:

1. Statement of anticipated soil and groundwater conditions for each cross passage. Include any confirmatory probing data obtained during Bored Tunneling and extensometer installation that is available.

2. Cross passage construction schedule for dewatering, ground improvement, SEM excavation and installation of the permanent concrete liner.

3. For Ground Support Category 2 Cross Passages:
   a. Describe the dewatering approach that will be used, including the number and type of wells to be installed and the anticipated groundwater discharge volumes and discharge locations.

4. For Ground Support Category 3 Cross Passages:
   a. Describe the method of ground improvement that will be used.

1.07 WORK PLAN FOR CROSS PASSAGE EXCAVATION

A. Submit SEM Work Plan a minimum of 180 days before start of associated SEM tunneling work. Work plans can be submitted separately for each excavation or for groups of cross passages in the same Ground Support Category. Include drawings, sketches, product data and written text describing the overall approach to the SEM work. Include:

1. Statement of anticipated conditions for each cross passage. Include confirmatory probing data obtained during Bored Tunneling and extensometer installation. Refer to Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

2. For excavation and support sequences differing from the ones given in the design documents, drawings and calculations, signed and sealed by a Professional Engineer registered in the State of Washington, which show required initial shotcrete thicknesses, stages of excavation and support, anticipated deformations, and other information pertinent to cross passages construction.
3. Required construction tolerances dictated by the excavation, support methods required for break-out from the Bored Tunnels.

4. Deformation predictions for both Bored Tunnel and SEM linings; and how the dimensions and materials used will accommodate same.

5. Proposed materials, facilities, and equipment to be used.

6. Key excavation plan including proposed excavation and support sequence. For each type of cross passage show:
   a. Sequence and timing of top heading and bench/invert excavation and anticipated advance rates.
   b. Methods of construction including shotcrete lining installation details, all pre-support and support elements;
   c. Methods of construction for break-outs of running tunnels:
      1) Measures to support the Bored Tunnel segmental lining.
      2) Removal of lining segments.
      3) Protective measures for lining segments at break-outs.
      4) Excavation and support sequences at break-outs.
      5) Void grouting.
      6) Method for sealing holes in precast segmental lining for pre-support and dewatering measures.
      7) Method of controlling line and grade of linings.
      8) Details on excavation and removal of all temporary pre-support and temporary shotcrete.
      9) Installation of in-tunnel water control measures, including well points, temporary sumps, construction drains.
     10) Vacuum dewatering material specifications and procedures.

B. Equipment:

1. Excavation equipment for all SEM tunnel excavations including make and model numbers, manufacturer’s literature and maintenance record.

2. Shotcrete batching plants.

3. Shotcrete pumps.

4. Drilling Equipment.

5. Dewatering Equipment.

C. Discussion of any dewatering and or ground improvement measures required. Note that separate work plans are required for each dewatering or ground improvement operation per the requirements of 31 23 19, Dewatering, 31 32 13.36, Jet-Grouting, 31 54 00 Ground Freezing and 31 32 21 Permeation Grouting.

D. Materials:
1. Materials for grouted pipe spiling and permeation grouting.
2. Lattice Girders.
3. Spiling

1.08 CONTINGENCY PLANS

A. Prepare Contingency Plans to address unanticipated conditions which may occur during the SEM work. At a minimum, include plans for:
   1. Unanticipated loose and unstable soils, face instability.
   2. Unanticipated groundwater inflows.
   3. Lining deformations which exceed specified limits.
   4. Surface/building deformations beyond specified allowable limits.

B. Include steps used to assess conditions that require additional measures not described herein.

C. Address modifications in the proposed excavation sequences and lining requirements, that would be needed to continue under safe working conditions for each of the unanticipated conditions.

D. Include in each Contingency Plan:
   1. Name and qualification of personnel responsible for implementing contingency procedures.
   2. Surveillance during stoppages such as weekends and holidays as well as directed stoppages.
   3. Measures required to be put in place prior to the re-start of excavation.

1.09 DELIVERY, STORAGE, AND HANDLING

A. Have adequate supply of required materials for cross passage Support ready for application at all times during cross passage excavation as follows:
   1. Flashcrete, Shotcrete: Have sufficient amount of steel fiber reinforced flashcrete and shotcrete available at the cross passage heading to be applied at each excavation face during the entire excavation period for immediate application to complete excavation round.
   2. Reinforcement: Have lattice girders and other reinforcing materials readily available on site for next excavation round of each heading before commencing excavation.
   3. Groundwater Control: Have sufficient drainage mats, pipes, hoses, well points, pumps and other materials for installation and operation of water control available on site before commencing excavation.

B. Store materials in accordance with the Suppliers’ specification. Maintain materials in a clean and undamaged condition.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Shotcrete
   1. See Section 31 74 19.05, Shotcrete for SEM Tunnels.

B. Initial Shotcrete Lining
   1. See Section 31 74 19.10, Initial Shotcrete Tunnel Lining.

C. Rebar Spiling
   1. No. 10 standard deformed steel reinforcing bars with pointed tip, 12 feet in length, conforming to ASTM A615, Grade 60.
   2. At breakout from TBM tunnels. No. 10 standard deformed steel reinforcing bars with pointed tip, 10 feet in length, or 24 feet in length with couplers as required for the different support categories, conforming to ASTM A615, Grade 60.
   3. Self-drilled and grouted anchors or bolts may be used as approved by the Resident Engineer.

D. Grouting Pipe Spiling
   1. Pipes:
      a. Perforated steel pipe.
      b. Diameter: two inches minimum.
      c. Typical length: 12 feet.
      d. Length at TBM breakout location: 10 feet, or 24 feet in length with couplers as required for the different support categories.
      e. Steel: ASTM A53 Grade B.
   2. Grout Mix Design: Ingredients that are compatible, non-corrosive to steel and free from calcium chloride.
      a. Minimum compressive strength: 100 pounds per square inch (psi) in 4 hours.
      b. Water: Potable.
      c. Cement: ASTM C150. Use Type I or III cement, fresh and not containing any lumps or other indication of hydration or "pack set".
      d. Sand: ASTM C144, except maximum particle size limited to Size 18 sieve.

E. Drainage Mats
   1. ENKADRAIN, AKWADRAIN, MiraDRAIN, or Sarnafil Drainage Panel or approved equal.

F. Well Points:
1. Pointed steel dewatering pipes of minimum 2 inches diameter to be driven or drilled into the ground.

2. Perforated or slotted to allow sufficient dewatering of perched water in sand/silt lenses or sand/silt layers and minimize migration of fines.

G. Vacuum Dewatering

1. Vacuum wells: Two inch diameter rigid PVC or steel pipe with filter fabric, slotted screen, length as required and approved by the Resident Engineer.

2. Screen-filter criteria:
   a. Slots: Minimum filter diameter of 85 percent size ($D_{85}$) / slot width greater than 1.2.
   b. Holes: Minimum filter $D_{85}$ / hole diameter greater than 1.0.

3. Filter-aquifer criteria:
   a. Maximum filter diameter of 15 percent size ($D_{15}$) / minimum aquifer $D_{85}$ less than 5.
   b. Maximum filter diameter of 15 percent size ($D_{50}$) / minimum aquifer $D_{85}$ less than 25.
   c. Minimum filter $D_{15}$ / maximum aquifer $D_{15}$ greater than 5.

4. Use shotcrete or other sealant to seal the vacuum well to allow the build-up of vacuum.

PART 3 - EXECUTION

3.01 GENERAL

A. Temporary Ventilation

1. Provide, operate and maintain for duration of the project a temporary ventilation system that will conform to RCW code health and safety requirements of jurisdictional authorities or specified by Sound Transit.

2. Perform air quality testing at least as often as required by WAC 296-155-730 for oxygen, toxic and hazardous gases and other atmospheric impurities. Maintain records of all air quality testing, and make available to the Resident Engineer upon request.

3. Prepare a daily Excavation Report which includes the following information:
   a. Face Mapping: Prepare a geologic map of each cross passage heading once per shift and documentation reporting all pre-support and support measures for each heading.
      1) Signed by SEM Tunnel Project Engineer and SEM Superintendent.

B. Prepare an Excavation Summary Report on geologic conditions encountered, support and pre-support measures installed and problems encountered after completion for each cross passage within 30 days of completion of the shotcrete lining of same.
C. Observe and record average flow rates and time of operation of each dewatering system used. Provide appropriate devices, such as flow meters, for observing flow rates. Prepare a daily Groundwater Monitoring Report during operating period of each dewatering system. Use format approved by the Resident Engineer.

D. SEM Tunnel Project Engineer shall perform the following:
   1. Supervise excavation to ensure the safety and quality of construction.
   2. Devise and implement contingency procedures as required by ground conditions or directed by the Resident Engineer.
   3. Coordinate remedial measures when ground loss at tunnel heading or instability of tunnel occurs, or when they appear likely.
   4. Prepare Daily Excavation Reports.
   5. Evaluate instrumentation readings and submit monitoring reports as specified elsewhere.
   6. Prepare Excavation Summary Reports.
   7. Be available on site at all times during all SEM related excavation

E. Safety Requirements
   1. Perform Work in a manner that minimizes safety hazards and exposure of personnel and equipment to hazardous and potentially hazardous conditions.
   2. Assess all ground and groundwater conditions, ground movement, lining deflection and surface deformations at all times during the construction period and act prudently and react swiftly to all indicators and conditions.
   3. Provide safe work spaces, temporary platforms and stands at all times.
   4. Illuminate all underground spaces sufficiently to carry out inspections at all times during the construction period.
   5. In case of emergency or work stoppage likely to endanger excavation or adjacent structures, continuously maintain full work force 24 hours per day including weekends and holidays until emergency or hazardous conditions no longer jeopardize stability and safety of the structures.
   6. Support ground continuously in a manner that prevents loss of ground, keeps lining perimeters and maintains stability of tunnel faces, and other underground openings.

F. Detection of Movement
   1. Install and monitor instruments shown and in accordance with Section 31 09 13.50, Tunnel Instrumentation and Monitoring.

3.02 EXCAVATION AND SUPPORT
A. Expect excavation in all materials identified in the GBR.
B. Seal all pre-support and dewatering holes installed through the segmental lining at the completion of the excavation and lining for each cross passage.
C. Excavate to excavation limits as indicated on the Contract Drawings:
1. Use equipment and methods that do not damage previously placed reinforcing bars, lattice girders, and instrumentation in the vicinity of the tunnel circumference.

2. Grades and dimensions as indicated on Contract Drawings do not include tolerances for construction and deformation of the excavated opening. To maintain the theoretical dimensions required, over-excavation, which also allows space for steel parts protruding from the shotcrete lining, including the protection and smoothing layers for the waterproofing system, shall be accounted for.

3. Ensure neither the shotcrete lining nor other support measures intrude into clearances required for the placement of the final lining.
   a. Total unsupported length shall not exceed the maximum round length as shown on the Contract Drawings plus a maximum handling space of 18 inches.

D. Temporary Invert Protection:

1. Protect the initial shotcrete lining in the invert area of all cross passages from damage caused by construction equipment traffic until placing of the final invert concrete by means of a working slab.

2. Utilize gravel, or other suitable material approved by the Resident Engineer with a minimum thickness of two feet.

E. Dispose of excavated material in accordance with requirements indicated in Section 31 20 00, Earth Moving.

F. Probe Drilling

1. For Probe Drilling of holes ahead of the excavation face, use rotary drilling techniques that are intended to confirm the predicted geological situation and to detect groundwater, sand lenses, zones of wet silt, and other potentially unstable soils.
   a. Notify the Resident Engineer prior to start of Probe Drilling.
   b. Locate the probe holes as indicated in the Contract Documents or as approved or directed by the Resident Engineer.
   c. Core drilling is applied for additional exploration and probing purposes, the main objective being to recover cores with a minimum diameter of 3-1/2 inches. Adapt the drilling pressure during drilling to varying ground conditions. Avoid excessive pressure as well as core compression. Use dry core drilling method where feasible. Extract cores over the defined probe length. Place cores in foil lined cases, label with permanent writing and make available for inspection immediately after extraction. Take color photos immediately after placing the cleaned cores into the marked casings using a tripod which allows for a perpendicular shot of the cores. Store core cases on site to render them accessible for inspection at all times. Keep an accurate log from each drilling operation indicating drilling progress as related to time, installation and removal of core sample, advancing of casing tube, description of core using the Unified Soil Classification System and all extraordinary events such as water ingress or smells. Submit the logs to Sound Transit within 24 hours after completion of the respective core drilling.
d. Position and number of probe drill holes as shown and specified in the Contract Documents. Alter position of probe drill holes as approved or directed by the Resident Engineer.

e. Where a probe hole indicates water inflow apply further investigation by drilling an additional probe hole approximately 2 feet below the water bearing probe hole. Repeat this procedure until invert level of the heading or the bottom of the water bearing strata is reached. Install and grout in place a vibrating wire piezometer in the lowest water bearing probe hole according to manufacturer’s specification. Operating pressure range of the piezometer shall be a minimum of 1.5 times the cross passage depth below groundwater.

f. Interpret cores and discharge of probe holes with regard to soil behavior during excavation ahead of the tunnel heading.

2. Drillings for drainage (without core extraction):
   a. Minimum diameter shall be 3-1/2 inches.
   b. Prepare a log of the drilling indicating drilling progress, loose ground, voids, installation of casing tubes, observation of drilling water, water ingress and any extraordinary events.

G. Groundwater Control Measures – In-Tunnel Water Control
   1. Drain, collect and pump out of the cross passage all infiltrating groundwater.
   2. Remove groundwater and construction water from the operation as quickly as possible without causing damage.
   3. Dispose of groundwater and construction water in accordance with Section 01 57 24, Temporary Site Water Discharge.
   4. Prior to application of the shotcrete lining, collect all seeping groundwater or local groundwater inflow by means of drain hoses and/or drainage mats to prevent build-up of hydrostatic pressure behind the shotcrete lining and deterioration or reduction of the strength properties of the fresh shotcrete.
   5. Collect water seepage through shotcrete and drain away by means of drain hoses.
   6. Install and maintain at all times temporary drainage systems to control inflow of water into the excavation in order to permit all work to be performed in dry conditions.
   7. Vacuum dewatering: Install vacuum wells as indicated or as required by hydrological conditions.

H. Excavation Sequence and Support Measures
   1. Follow the excavation and support sequence for cross passages as indicated.
   2. Evaluate the ground conditions encountered and confirm that Cross Passage Support Type indicated is appropriate:
      a. Review Probe Drilling data and results of the drilling for drainage pipes and spiling through bored tunnel concrete linings.
b. Continuously review conditions encountered as the bored tunnel lining is broken out and removed.

3. Install face support of steel fiber reinforced shotcrete for work stoppages longer than 24 hours as indicated in the design drawings.

4. Top Heading, Bench-Invert Excavation:
   a. Use top heading, bench-invert excavation sequence and maximum round lengths as indicated. Apply a minimum two inch layer of Flashcrete on all exposed ground surfaces immediately after excavation to seal and protect ground from the deleterious effects of exposure (e.g., initial loosening, moistening or desiccation).

5. Initial Shotcrete Lining.
   a. Install after installation of the flashcrete.
   b. Grout voids behind the shotcrete lining caused by erosion or fallouts of soil behind the lining.

6. Rebar Spiling: Install by driving the spiles into the ground ahead of the tunnel excavation face or inserting them into pre-drilled holes as indicated. Fill pre-drilled holes with grout prior to rebar insertion. Self-drilled grouted anchors may be used in lieu of rebar spiles as approved by the Resident Engineer.

7. Grouted Pipe Spiling: Install by driving or jacking the perforated steel pipes into the ground ahead of the face or inserting them into pre-drilled holes as indicated. Grout the pipes through the perforations to achieve permeation and compaction of soil around the spile. Adjust grouting pressure as required to suit ground conditions.

8. Face Stabilization Wedge: Leave wedge of unexcavated material in place during excavation to support the face as indicated.

9. Pocket Excavation: Excavate soft or loose soil in partial drifts and immediately support with flashcrete as indicated.

10. Metal sheets: Install by driving the sheets into the ground ahead of the excavation face or as support for the bench, invert excavation as indicated. Grout behind metal sheets to fill any void between metal sheets and soil.

11. Grouting: Permeation grouting ahead and in the vicinity of the tunnel face in order to stabilize zones of loose soils as shown and specified in the Contract Documents. Utilization of grouting, grout types, grout volumes and grouting pressures as approved or directed by the Resident Engineer.

3.03 FIELD QUALITY CONTROL

A. Do not allow initial shotcrete to encroach on final lining clearance line as shown in the Contract Documents.
   1. Submit survey reports and plotted profiles no later than 14 days after excavation.

B. Document stability of Cross passages by monitoring as specified. Prove the absence of any continuing and significant deformation before installing the waterproofing system and the final lining.
   1. Submit monitoring protocols as part of the Daily Excavation Reports.
C. Allowable Tolerances:

1. Place initial shotcrete lining to the following tolerances (including lining deformations):

   a. Deviation of tunnel alignment from theoretical line or grade shown in the Contract Documents as measured from working point of tunnel: One inch.

   b. Variation in thickness of lining at any point: Minus zero inches.

D. End of shift:

1. Do not leave the work site each day until satisfied that all excavated areas have been supported as specified.

2. Do not leave exposed, un-shotcreted surfaces except where indicated in the Contract Documents.

3. Install the entire structural lining system (welded wire fabric, lattice girders and shotcrete) prior to leaving the work site each day.

E. Pre-support and dewatering holes through the segmental lining shall be sealed to meet requirements of Section 31 74 16 for groundwater inflow.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes the Contract requirements, procedures, and training for providing initial First Responder Level (FRL) fire and life safety tunnel rescue actions at the site prior to the arrival of the Seattle Fire Department (SFD) Tunnel Rescue Team.

1. Contractor is responsible for cost of providing First Responder Level fire and life safety tunnel rescue, and the coordination of the requirements of same with the SFD’s Tunnel Rescue Teams.

2. Sound Transit is responsible for the cost of work performed by SFD, which includes providing the project’s Tunnel Rescue Teams, and the training of same.

B. This Section is intended to supplement and reinforce the requirements of MSHA 30 CFR 49 for this Contract.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine
2. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. Mine Safety and Health Administration (MSHA)
   a. 30 CFR 23 Telephones and Signaling Devices
   b. 30 CFR 49 Mine Rescue Teams
   c. 42 CFR 84 Approval of Respiratory Protective Devices

2. Washington Industrial Safety and Health Act (WISHA)
   a. WAC 296-155-730 Tunnels and shafts, Section 10 Rescue Teams

1.03 DEFINITIONS

A. First Responder Level (FRL) tunnel rescue: The initial fire and life safety actions provided by the Contractors on-site personnel in the event of an emergency occurring within the Site underground environment in the time period prior to the arrival of the SFD Tunnel Rescue Team.

B. Primary Tunnel Rescue Responder: Tunnel rescue services coordinated and provided by the SFD Tunnel Rescue Team in the case of a notified emergency occurring in the Site underground environment.
C. Site Underground Environment: U District and Roosevelt Station box excavations, twin running tunnels between the Maple Leaf Portal and University of Washington station, and associated cross passages.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Qualifications.
   1. Identify and provide required documentation for FRL tunnel rescue personnel for all underground work shifts for work in the tunnel.

C. Training Plan and Documentation.

D. Completed MSHA Forms.

E. Rescue Notification Plan

1.05 QUALITY ASSURANCE

A. Qualifications:
   1. FRL Tunnel Rescue Personnel:
      a. Ensure each person has been employed in an underground tunnel construction project for a minimum of one year within the past five years.
      b. Ensure personnel, who are employed on the surface but work regularly underground, meet the experience requirement.

1.06 SCHEDULING

A. Availability of FRL Tunnel Rescue Personnel
   1. Provide FRL tunnel rescue personnel at all times when workers are underground.

   2. The FRL tunnel rescue requirement is applicable during all phases of underground construction operations. See Sections 31 71 19, Tunnel Excavation by Tunnel Boring Machine, and Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.

   3. Completion of the tunnel and cross passage excavation does not preclude the need for the availability of FRL tunnel rescue personnel during subsequent phases of underground construction.

   4. Provide a minimum three FRL tunnel rescuers per underground shift, who are qualified, trained, and equipped for providing emergency tunnel rescue service.

   5. FRL tunnel rescue personnel shall be available at the tunnel entrances or exits after notification of an occurrence that might require their services. Consider tunnel rescue personnel available even if performing regular work duties.

   6. Detailed statement describing the proposed method of compliance with the requirements for FRL tunnel rescue.
      a. Include the names of the FRL tunnel rescue personnel in the statement.
      b. Post a copy of the statement at the tunnel entrance for the workers information.
1.07 TUNNEL RESCUE EQUIPMENT STATION

A. Designate in advance of the start of tunneling the location of the tunnel rescue equipment station serving the tunnel construction site. Each site where tunnel construction is being performed shall have a designated location.

B. Locate equipment at the tunnel construction sites to be served by the work.

C. Tunnel rescue equipment stations are to be centralized, organized storage locations for tunnel rescue equipment designed to ensure readiness for immediate use.

1.08 MAINTENANCE

A. Provide tunnel rescue equipment station with at least the following equipment:

1. Twelve self-contained oxygen breathing apparatus, each with a minimum of two hours capacity (approved by MSHA and NIOSH under 42 CFR 84, subpart H), and any necessary equipment for testing such breathing apparatus.

2. A portable supply of liquid air, liquid oxygen, pressurized oxygen, oxygen generating or carbon dioxide absorbent chemicals, as applicable to the supplied breathing apparatus and sufficient to sustain each team member for 6 hours while using the breathing apparatus during rescue operations.

3. One extra oxygen bottle (fully charged) for every six self-contained compressed oxygen breathing apparatus.

4. One oxygen pump or a cascading system, compatible with the supplied breathing apparatus.

5. Twelve permissible cap lamps and a charging rack.

6. Two gas detectors appropriate for each type of gas which may be encountered at the tunnel(s) served.

7. Two oxygen indicators.

8. One portable tunnel rescue communication system (approved under 30 CFR 23) or a sound-powered communication system. Verify that the wires or cable to the communication system are of sufficient tensile strength to be used as a manual communication system. These communication systems shall be at least 1,000 feet in length.

9. Necessary spare parts and tools for repairing the breathing apparatus and communication system.

B. Coordinate maintenance and inspection of the tunnel rescue equipment with the SFD Tunnel Rescue Team.

1. Review the condition of all equipment on a monthly basis.

2. Establish protocols for transition from FRL tunnel rescue to SFD Tunnel Rescue Team during emergency events.

C. Maintain tunnel rescue apparatus and equipment in a manner that ensures readiness for immediate use.

D. Verify that a person trained in the use and care of breathing apparatus inspect and test the apparatus at intervals not exceeding 30 days and certifies, by signature and date, that the inspections and tests were completed.
E. When the inspection indicates that a corrective action is necessary, make the corrective action and have the trained person record the corrective action taken.

F. Maintain the certification and the record of corrective actions at the tunnel rescue equipment station and make available to the Resident Engineer upon request.

1.09 PHYSICAL REQUIREMENTS FOR FRL TUNNEL RESCUE PERSONNEL

A. Each designated FRL tunnel rescuer shall be examined within 30 days of commencing underground site work and annually thereafter, by an occupational physician who certifies that each person is physically fit to perform tunnel rescue and recovery work for prolonged periods under strenuous conditions.

B. A minimum of two persons per underground shift shall pass the medical examination for compressed air work.

C. Personnel requiring corrective eyeglasses shall not be disqualified from providing FRL tunnel rescue services provided the eyeglasses can be worn securely within an approved facepiece.

D. Complete MSHA Form 5000-3 (certifying medical fitness) completed and signed by the examining physician for each FRL tunnel rescue person. Submit to MSHA and the Resident Engineer.

1.10 RESCUE NOTIFICATION PLAN

A. Each tunnel shall have a Rescue Notification Plan outlining the procedures to follow in notifying the on-site FRL tunnel rescue personnel and the Primary Tunnel Rescue Responder SFD Tunnel Rescue Team and the protocol for communication and responsibility during an emergency, when the SFD Tunnel Rescue Team arrives at the Site.

B. Post a copy of the Rescue Notification Plan at each tunnel entrance for the worker’s information.

1.11 TRAINING REQUIREMENTS

A. Conduct the training courses required by this Section jointly and collaboratively with and under the direction of the SFD Tunnel Rescue Team and instructors

1. FRL tunnel rescuer designated personnel shall complete, at a minimum, an initial 20-hour course of instruction, as prescribed by MSHA’s Office of Educational Policy and Development in the use, care, and maintenance of the type of breathing apparatus which shall be used on-site

B. Upon completion of the initial training, verify that all FRL personnel receive at least 40 hours of refresher training annually jointly and in collaboration with the SFD Tunnel Rescue Team. This joint training shall include at least four hours each month, or for a period of eight hours every two months. Include in this training:

1. Sessions underground at least once each month.

2. The wearing and use of the breathing apparatus.

3. The use, care, capabilities, and limitations of auxiliary tunnel rescue equipment, or a different breathing apparatus.

4. Advanced tunnel rescue training and procedures, as prescribed by MSHA’s Office of Educational Policy and Development.
5. Tunnel map training and ventilation procedures.

C. Personnel shall be ineligible to serve as a FRL tunnel rescuer if more than eight hours of training is missed during 1 year, unless additional training is received to make up for the time missed.

D. Maintain a record of training for each FRL tunnel rescue person on file at the tunnel rescue equipment station for a period of 1 year.

1.12 TRAINING PLAN FOR FRL TUNNEL RESCUE PERSONNEL

A. Verify that each FRL tunnel rescuer receives no less than 20 hours of training as indicated in this Section before such person is assigned to work duties. Ensure such training is conducted in conditions that, as closely as practicable, duplicate actual underground conditions, and approximately eight hours of training shall be given at the tunnel site jointly with the SFD Tunnel Rescue Team.

B. Include the following courses in the training program for FRL tunnel rescuers not previously approved as a FRL tunnel rescuer on this Contract:

1. Self-rescue and respiratory devices:
   a. Instruction and demonstration in the use, care, and maintenance of self-rescue and respiratory devices used at the tunnel.
   b. Training in the use of self-contained self-rescue devices including complete donning procedures in which each person assumes a donning position, opens the device, activates the device, inserts the mouthpiece, or simulates this task while explaining proper insertion of the mouthpiece, and puts on the nose clip.
   c. Given before the new tunnel rescuer goes underground.

2. Entering and leaving the tunnel; transportation; communications:
   a. Instruction on the procedures in effect for entering and leaving the tunnel: The check-in and check-out system in effect at the tunnel; the procedures for riding on and in tunnel conveyances; the controls in effect for the transportation of tunneleers and materials; and the use of the tunnel communication systems, warning signals, and directional signs.

3. Introduction to the work environment:
   a. A visit and tour of the tunnel, or portions of the tunnel, which are representative of the entire tunnel.
   b. The mining methods utilized at the tunnel shall be observed and explained.

4. Tunnel map:
   a. A review of the tunnel map; the escapeway system; the escape, firefighting, and emergency evacuation plans in effect at the tunnel; and the location of abandoned areas.
   b. Introduction to the methods of barricading and the locations of the barricading materials, where applicable.
c. Use the training program for instruction on escapeways and emergency evacuation plans.

5. Ground control and ventilation plans:
   a. Introduction to and instruction on the ground control method in effect at the tunnel; and an introduction to and instruction on the ventilation plan in effect at the tunnel and the procedures for maintaining and controlling ventilation.

6. Health:
   a. Include instruction on the purpose of taking dust, noise, and other health measurements, and any health control plan in effect at the tunnel.
   b. Explain the health provisions of the WISHA and warning labels.

7. Hazard recognition:
   a. Include the recognition and avoidance of hazards present in the tunnel.

8. Electrical hazards:
   a. Recognition and avoidance of electrical hazards.

9. First aid:
   a. Instruction in first aid methods acceptable to MSHA.

10. Tunnel gases:
    a. Instruction in the detection and avoidance of hazards associated with tunnel gases.

11. Health and safety aspects of the tasks to which the new FRL tunnel rescuer will be assigned, including:
    a. Safe work procedures of such tasks.
       1) Mandatory health and safety standards pertinent to such tasks.
       2) Information about the physical and health hazards of chemicals in the tunneler’s work area.
       3) The protective measures a tunneler can take against these hazards.
       4) The contents of the tunnel’s HazCom program.

C. Include within the training plan methods, such as oral, written, or practical demonstration, by which the training is to be considered successfully completed. Administer the methods for determining such completion before assigning tunnel rescue personnel to actual work duties.
PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL

A. Provide FRL tunnel rescue personnel that meet the requirements of this Section, and make them available for service prior to performing any work in a tunnel.

B. Supplement the initial training requirements specified above by assembling the FRL tunnel rescue personnel jointly with the SFD Tunnel Rescue Team as a group on a monthly basis and reviewing access constraints, location of emergency equipment, availability of personal protective equipment, and other necessary information. Additional assembly times to include:

1. Prior to launching and relaunching the TBMs for any reach of tunnel.

2. Prior to beginning cross passage construction.

C. Coordinate all work and responsibilities of the FRL tunnel rescue personnel with the Site Health and Safety Officer.

END OF SECTION
SECTION 31 73 23  
TAIL VOID GROUTING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies requirements for tail void grouting during tunneling including quality control and proof grouting to ensure continuous contact between the extrados of the precast concrete tunnel lining (rings) and the surrounding soil.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 05 15, Portland Cement Concrete.
2. Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.
3. Section 31 74 16, Precast Concrete Tunnel Lining.
4. Section 31 23 01, Excavation Spoils and Muck Disposal.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents:

2. ASTM C150 Standard Specification for Portland Cement
3. ASTM C494 Standard Specification for Chemical Admixtures for Concrete
4. ASTM C827 Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens of Cementitious Mixtures

1.03 DEFINITIONS

A. Extrados: Exterior circumferential surface of the precast segmental lining system.
B. Grout Recess: Optional circular void cast in precast concrete segment to facilitate proof grouting.
C. Inbye: Reference to a position closer to the face.
D. Intrados: Interior circumferential surface of the precast segmental lining system.
E. Lost Ground Void: Space between the outside of the precast concrete segments and the surrounding soils, which may exist in addition to Tail Voids, due to loss of ground.
F. Lost Ground: Refer to Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.
G. Outbye: Reference to a position closer to the tunnel portal.
H. Proof Grout: Cement-based grout injected into the space between the precast segmental lining and the tail void grout to fill any voids and ensure continuous contact of the ring with the surrounding soil.

I. Required Support Pressure: Refer to Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

J. Tail Void: Space between the extrados of the precast concrete segmental lining and the surrounding soil behind the tail shield formed by overcut of TBM cutterhead, thickness of the TBM shield, and clearance between the intrados of the shield and the extrados of the segments.

K. Tail Void Grout: Material used to fill the Tail Void.

1.04 SYSTEM DESCRIPTION

A. General: Design grout mix with appropriate properties to provide intended functions, as defined herein.

B. Use granular cement-based, a two-component grout type, or other types of grout that meet the specified requirements herein.

C. Provide grouting materials with adequate flow properties to enable complete filling of tail void gap simultaneously with TBM advance.

D. Provide grouting material with properties adapted to the grout injection process and encountered ground conditions.

E. Prevent segregation of grouting material during mixing, pumping, and injection.

F. Provide Tail Void Grout with adequate setting characteristics, especially sufficient initial compressive strength, to guarantee bedding of the segmental lining and to prevent uplift and deformations of it due to loading.

G. Compressive strength:
   1. Minimum 15 pounds per square inch (psi) in 1 hour.
   2. Minimum 250 pounds per square inch (psi) in 28 days.
   3. Maximum 500 pounds per square inch (psi) in 28 days.

1.05 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Qualifications for Grouting Manager.

C. Mix Designs:
   1. For each proposed mix of Tail Void Grout provide:
      a. Type and Characteristics
      b. Proportions of each ingredient
      c. Test results from trial mixing and testing.
   2. Lost Ground Void grout.

D. Product Data:
1. Manufacturer’s product data sheets including:
   a. Mixing, handling, storage, and waste disposal requirements.
   b. Source of supply for each grout ingredient.

2. For each type and source of material:
   a. Cement.
   b. Grout components, if not cement-based grout.
   c. Admixtures: Documentation showing that the proposed admixtures have a history of demonstrable satisfactory performance and are compatible with adjacent materials.

E. Working Drawings and Methods Statements:

1. Layout and description of grout mixing, transport, and injection facilities including:
   a. Supply equipment.
   b. Agitators or holding tanks.
   c. Batching and mixing units.
   d. Grout cars.
   e. Pumps.
   f. Grout delivery piping and manifolds.
   g. Calculations of grout pressure range along the tunnel alignment.
   h. Hookup details including valves and gauges.

2. Means and methods for:
   a. Proportioning and mixing of grout.
   b. Transport of grout.
   c. Injection of grout.
   d. Grouting pressures along the alignment.
   e. Measuring grout pressure, quantity, and injection rate.
   f. Maintaining grout pressure within specified limits.
   g. Establishing basis and threshold values for modifying grout mixes.
   h. Minimizing washout and migration of grout into the excavation chamber.
   i. Performing test borings to determine thickness and properties of injected tail void grout.
   j. Injection of proof grout.
   k. Sealing proof grout holes to meet inflow requirements of Section 31 74 16.
l. Calibration of gauges and meters to be used in grouting operations.

m. Collecting and disposing of excess material.

n. Collecting and disposing of water resulting from grouting operations.

3. Integrate means and methods for performing this work with Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine and Section 31 74 16, Precast Concrete Tunnel Lining as related to tunnel excavation and installation of the precast concrete segments.

F. Quality Control:

1. Certifications.

2. Quality Control Plans:

   a. Methods for demonstrating that grout mix meets design criteria.

   b. Methods for assuring uninterrupted grouting at pressures within specified limits.

   c. Methods for demonstrating that injected grout filled completely the tail void gap.

   d. Methods for containing and disposing of excess grout and cleaning of equipment.

   e. Methods for preventing grout migration into the cutterhead from behind the tunnel shield.

   f. Methods for the injection of proof grout.

3. Daily Records:

   a. Shift report, regardless of actual progress, and submitted no later than the beginning of the following working day. Include:

      1) Number and type of equipment used.

      2) List of idle or inoperative equipment and reason for downtime.

      3) Grout injection records for each segment:

         a) Mix type and batch number.

         b) Detailed grout injection records, broken down for each outlet by injected quantity, injection pressure and pumping rate.

4. Weekly Records: Results of testing on grout samples taken during production grouting.

5. Notifications: Immediately if Warning Level or Critical Level specified herein is reached.

6. Tests: Results of trial mixes and tests specified herein.

7. Proof grouting reports as specified herein.
1.06 QUALITY ASSURANCE

A. Qualifications:

1. Grouting Manager: A minimum of three years of related work experience on similar projects to manage the grouting program by designing, testing, and overseeing the injection of grout mixes of the type required through the TBM tail shield injection lines.

B. Certifications:

1. Certificates of compliance for materials listed under Part 2 of this Section.
2. Calibration certificates for gauges and meters to be used in grouting operations.

C. Testing:

1. To demonstrate conformance with the specified requirements as indicated herein, provide the services of an Independent Testing Laboratory (ITL).

2. Perform preliminary grout suitability tests before start of tunneling operations including but not limited to: bleed water, gel strength and pumpability tests.

3. Trial mix: Find and define a suitable grout by testing at least, but not limited to, the unconfined compressive strength at 1 hour and 28 days, as well as characteristics of grout to completely fill annular space. A minimum of 6 tests should be performed on each trial mix.

4. Perform tests during production grouting for unconfined compressive strength.
   a. Test a minimum of 4 samples taken from daily production every 250 feet of tunnel length or once a week, whatever comes first, to verify the grout mix.
   b. Collect grout samples at the injection point.

5. Confirm that Tail Void Grout has been placed and cured by drilling through Segment Rings and inspecting the condition of Tail Void Grout:
   a. Drill through segment and perform Proof Grouting on every 5th ring for the first 100 rings of precast concrete segments for each of the tunnel drives north and southbound from Roosevelt Station and north and southbound from Maple Leaf Portal.
   b. Drill and perform Proof Grouting as required through a segment ring at a maximum interval of 250 feet in each of the tunnels.
   c. Drill and perform Proof Grouting in the area surrounding any ring which requires Proof Grouting due to existence of un-grouted Tail Void.

PART 2 - PRODUCTS

2.01 MATERIALS

A. In accordance with Section 03 05 15, Portland Cement Concrete, for cement-based grouts, except as modified herein.

B. For non-cement based grouts: As required by manufacturers to meet requirements specified herein.
C. Admixtures:


2. Anti-washout agent: in accordance with Contractor as required.

3. Admixtures and fluidifiers that promote steel corrosion are not acceptable.

4. Use admixtures compatible with proposed mixing water and contain no more than 0.1 percent chloride ion by weight of portland cement.

D. Non-Shrink Grout: ASTM C827.

2.02 EQUIPMENT

A. Grouting:

1. General:
   a. In accordance to Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.
   b. Volumetric Measuring Device: Accurate to 1.5 gallons.
   c. Provide scale or measuring device to measure continuously the weight of the grout reservoir or the height difference of the grout in the car.
   d. Pressure gages: Accurate to plus or minus 1 pound per square inch (psi) over allowable grouting pressure range.
   e. Interlink grouting system to the TBM advance.
   f. Provide pressure and volume measurements for each injection line and weight measurements, all continuously to the TBM display and TBM Data Monitoring system.
   g. Provide appropriate grout valves for proof grouting.
   h. Provide coring drill and bits for coring into tail void and retrieving core samples.

2. Pumps:
   a. Use pumps suitable for pumping grout.
   b. Each piston of a double piston pump or each hose pump shall feed no more than one injection line to guarantee continuous grout injection.
   c. Equip with a water or bentonite connection to facilitate flushing the system.
   d. Provide an emergency cutout in case of excessive grouting pressure.
   e. Provide appropriate proof grouting pumping equipment and hoses.

3. Provide batching, mixing, and agitating equipment capable of thoroughly mixing components of Tail Void Grout, for anticipated volumes required to continuously and completely fill the Tail Void during each shove of the TBM.

B. Maintain an adequate supply of spare parts and equipment to support uninterrupted grouting operations.
C. Proof Grouting Equipment:

1. General: Provide for continuous circulation of grout within the system.

2. Mixer:
   a. Use a high-speed colloidal-type mixer with a tangential return flow from the mixer pump capable of providing a homogenized mix.
   b. Size to ensure an uninterrupted supply of grout to the pump.
   c. Provide with a means of accurately measuring and metering grout ingredients, including modifying the water/cement ratio.

3. Agitator:
   a. Equip with:
      1) Baffles to induce turbulence.
      2) Rotating paddles to assure thorough mixing of the grout prior to and during injection.

4. Pumps:
   a. Use an appropriate grout pump for the type volume and pressures specified
   b. Equip with a water connection to facilitate flushing the system.
   c. Equip with a pressure gage.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Perform tail void grouting as an integral part of the requirements of Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine and Section 31 74 16, Precast Concrete Tunnel Lining.

B. Preparation:

1. Prepare calculations to determine required grouting pressure range along the tunnel alignment.
   a. Incorporate Required Support Pressure calculations in accordance with Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine and Section 31 74 16, Precast Concrete Tunnel Lining.
   b. Maintain calculations, in files on Site, and make available upon request of the Resident Engineer.

2. Adapt maximum grouting pressure to meet the capacity of the segment lining and the capacity of the sealing systems.

C. Injection:

1. Performed through grout lines integrated in the shield tail such that complete filling and pressurization of the void is simultaneous with TBM advance.
2. If the main grout line is blocked during grouting, provide the capability to switch over to the spare line to assure continuous filling of the Tail Void. Clean blocked grout lines prior to advancement for subsequent ring.

3. Tail void grouting through precast concrete segments is not permitted.

4. Perform grouting uniformly through all grout lines.

5. Regulate the pressure and monitor volume injected at each grout injection line.

6. Ensure minimum effective grouting pressure at outlets which equals the required support pressure taking into account friction losses and other practical requirements to ensure complete filling of the void.

D. Adapt material properties of grout material during tunneling operation to guarantee required bedding of segmental lining.

E. Do not disturb, displace, or distort the initial lining while performing tail void grouting.

3.02 FIELD QUALITY CONTROL

A. Gages and Meters:

1. Test field gages and meters in the presence of the Resident Engineer no less often than weekly using master gages and meters.

2. Verify accuracy of master gages and meters through the use of an Independent Testing Laboratory no less frequently than every two months.

B. Proof Grouting and Remedial Work: Perform proof grout injection as specified below in case of incomplete backfill of ring gap by tail void grouting:

1. Mix Designs: Use a basic grout design of neat cement mix with water, with a cement ratio in the range by weight of 0.5:1 to 0.6:1. Use a mix compatible with the Tail Void Grout mix design.

2. Drilling equipment: Use a concrete coring drill with appropriately dimensioned coring bit for coring segment concrete and sampling tail void grout. Coordinate location of core with permissible drilling locations identified on segments.

3. Grout recess: If grout recesses in precast segments are used, core out remaining portion of precast segment with appropriately dimensioned coring bit.

4. Other equipment:

   a. Packers: Capable of sealing grout receptacles or holes without leakage when grouting at the maximum specified pressure.

   b. Hoses and piping:

      1) Provide a manifold system of valves and pressure gauges in the line at the collar of the hole to permit accurate control and monitoring of grouting pressure, bleeding, and regulation of flow.

      2) Size: 1-1/2 inches nominal diameter or sized to fit the grout receptacles or holes in segments.

   c. Pressure gages: Accurate to plus or minus 2 pounds per square inch (psi) through the allowable grouting pressure range.
5. Execution general:
   a. Perform drilling and coring on a dedicated platform a maximum of 300 feet outbye of the TBM tail shield.
   b. Perform drilling and grouting through the plastic threaded lifting insert or shear pocket where no lifting insert is present nearest to the crown of the ring. When such a connection is not practicable, perform grouting through a packer placed in a hole cored through the segmental ring.
   c. When a void is discovered, drill out the lower adjacent lifting insert until no voids are found. Then proceed with grouting from lower holes to higher holes except where otherwise indicated.
   d. Grout that has not been placed within two hours of the time of initial mixing, spilled and cured grout and other grouting waste shall be disposed of in accordance with Section 31 23 01, Excavation Spoils and Muck Disposal.

6. Preparation:
   a. Core out lifting inserts or remainder of grout recesses where grouting is to be performed and venting and communication may occur.
   b. Drill out each grout hole from the intrados of the segments until soil is contacted but not greater than 18 inches measured from the intrados.
   c. If non-cohesive saturated soils are detected, carry out core drilling through a grout packer equipped with a valve and back-flow preventer as necessary.
   d. Flush the hole with water except where a back-flow preventer is being used.

7. Placement:
   a. Do not pump grout into more than one hole simultaneously.
   b. Fit each hole drilled with an appropriate packer and valve.
   c. Where multiple holes have been drilled, relieve air and water through an open hole closer to the crown than the one being injected.
   d. Do not close any open un-grouted hole if communication is noted until:
      1) Grout of the same consistency as that being injected issues forth.
      2) Grout issues forth at the volume rate being injected.
   e. If no communication is observed grout each hole to refusal: when the total amount of grout injected into a hole is less than four gallons as measured over a continuous two-minute period at the maximum specified pressure.
   f. Grout the hole closest to the crown to refusal as described above.
g. Remove grout valves after the grout has reached initial set and clean out the hole to a minimum depth for which the grout plug can be inserted. If grout valve is removed prior to the initial set and/or any uncured grout falls out of the hole, replace grout within 24 hours and ensure the hole has been filled to avoid any unnecessary leakage.

h. Install grout plugs at grout ports in the segmental lining and tighten.

i. Repair any holes drilled through the segmental lining after grouting in accordance with Section 31 74 16, Precast Concrete Tunnel Lining.

C. Monitoring

1. Monitor actual volume of Tail Void Grout placed for each ring, and compare with theoretical volume associated with Tail Void.

2. Monitor grouting pressures required to inject Tail Void Grout.

3. When the Warning Levels specified in Table 1 below are reached:
   a. Notify Resident Engineer immediately.
   b. Continue to inject grout until Tail Void is completely filled, or allowable injection pressure is exceeded.
   c. Adjust work routine to ensure adequate grout quantities are injected into the tail void by modifying grout mix, injection pressures, quantities of admixtures, or other factors.
   d. Report effects of work routine modifications to Resident Engineer.

4. When the Critical Levels specified in Table 1 below are reached:
   a. Notify Resident Engineer immediately.
   b. Stop TBM advance provided that this can be done under safe and secure conditions. Continue to inject grout until Tail Void is completely filled, or allowable injection pressure is exceeded.
   c. Restart tunneling procedure by agreement of the Resident Engineer.
   d. Report effects of work routine modifications to the Resident Engineer.

<table>
<thead>
<tr>
<th>WARNING LEVEL</th>
<th>CRITICAL LEVEL</th>
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<tbody>
<tr>
<td>Grout volume less than or equal to 90 percent of total theoretical volume per ring at Required Support Pressure; or Grout volume greater than or equal to 150 percent of total theoretical volume per ring at or below the Required Support Pressure</td>
<td>Grout volume less than or equal to 90 percent of total theoretical volume for the third consecutive ring; or Grout volume greater than or equal to 150 percent of total theoretical volume for the third consecutive ring.</td>
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5. Fill Lost Ground Voids with approved sand and cement mix.
3.03 CLEANING

A. Minimize waste and losses.

B. Collect and dispose of excess materials resulting from grouting operations in accordance with Section 31 23 01, Excavation Spoils and Muck Disposal.

C. Do not allow excess materials to be mixed with other water in the tunnel.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies requirements for bolted, gasketed, precast concrete segments for the final tunnel lining.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 42 00, References.
2. Section 03 05 15, Portland Cement Concrete.
3. Section 03 20 00, Concrete Reinforcing.
4. Section 31 50 00, Excavation Support and Protection.
5. Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.
7. Section 31 73 23, Tail Void Grouting.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Concrete Institute (ACI)
   a. ACI 318 Building Code Requirements for Structural Concrete
   b. ACI 347 Guide to Formwork for Concrete Structures
   c. ACI 517.2 Accelerated Curing of Concrete at Atmospheric Pressure
   d. ACI 533 Guide for Pre-cast Concrete Wall Panels

   a. ASTM A36 Standard Specification for Carbon Structural Steel
   b. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   c. ASTM A108 Standard Specification for Finished Steel Bar, Carbon and Alloy, Cold Finished
   d. ASTM A184 Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement
1.03 DEFINITIONS

A. Circumferential Joints: Joints between adjacent segment rings, perpendicular to the direction of the tunnel.

B. Gap: Distance between segment load-bearing surfaces at joints, dependent in part on the amount of gasket compression and packing thickness.

C. Segmental Lining: Bolted, gasketed, precast concrete segments (also called Precast Concrete Segments) erected as a ring within the TBM tail shield and designed to resist short and long term ground and hydrostatic loads. The segmental lining is also capable of resisting thrusts from the TBM as the tunnel excavation is performed.

D. Groundwater Seepage: Inflow into the tunnel through the tunnel lining.

e. ASTM A185 Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete

f. ASTM A307 Standard Specification for Carbon Steel Bolts and Studs, 60,000 pounds per square inch (psi) Tensile Strength

g. ASTM A325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 kilopounds per square Inch (ksi) Minimum Tensile Strength

h. ASTM A490 Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 kilopounds per square Inch (ksi) Minimum Tensile Strength

i. ASTM A706 Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement

j. ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

k. ASTM C1116 Specification for Fiber-Reinforced Concrete and Shotcrete

l. ASTM C157 Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

m. ASTM C403 Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

n. ASTM D395 Standard Test Methods for Rubber Property - Compression Set

o. ASTM D412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension


q. ASTM D1149 Standard Test Method for Rubber Deterioration Cracking in an Ozone controlled Environment

r. ASTM D2240 Standard Test Method for Rubber Property - Durometer Hardness

s. ASTM E329 Standard Specification for Agencies Engaged in Construction Inspection and/or testing
E. Longitudinal Joints: Joints between adjacent segments, parallel to the direction of the tunnel.

F. Compression Packing: Load-distributing elements cut to the geometries of the longitudinal or circumferential segment joints in which they are placed. The compression packing distributes compressive stresses across the segment joint without affecting the ability of the segment gasket to withstand anticipated hydrostatic pressures.

1.04 SYSTEM DESCRIPTION

A. General:

1. Minimum design of the segmental lining for rebar reinforcement is given in the specifications and as indicated on the Contract Drawings. Augment the minimum design to handle construction loading, as specified herein.

2. Base design on ACI 318 and Sound Transit's Design Criteria Manual, February 2012, as necessary.

3. At a minimum, provide the following:
   a. Segment thickness: 10 inches.
   b. Concrete Mix Designation 6.C.2 in accordance with Section 03 05 15, Portland Cement Concrete
   c. Segments with steel bar reinforcement:
      1) Minimum cover: As indicated on the Contract Drawings.
      2) Minimum steel reinforcement ratio: As indicated on the Contract Drawings, assuming 60,000 psi yield strength for reinforcement.
      3) Minimum bursting steel reinforcement at longitudinal joints: As indicated on the Contract Drawings, assuming 60,000 psi yield strength for reinforcement.
   d. Fire protection requirements: Polypropylene Fibers, per Section 03 05 15, Portland Cement Concrete.

4. A minimum structural design for the segments is shown on the Contract Drawings, as well as in these specifications. Augment or modify this design as necessary to meet anticipated means and methods, modified segment designs shall meet the following requirements:
   a. General design criteria: Per requirements of the Sound Transit Design Criteria Manual, February 2012 (DCM), Section 8.3.1, referenced in Section 01 42 00, References, as well as ACI 318.
   b. Design ground and hydrostatic loads: Design segments at least for the following scenarios, in terms of depth of cover, soil conditions and groundwater pressures. Cover depths and groundwater pressures are measured to the tunnel spring line.
      1) Scenario 1: Maximum Soil Cover Depth and Groundwater Pressures (Station 1230+00)
         a) Soil cover depth and groundwater heads are 140 and 90.1 feet, respectively. Soil conditions within tunnel profile consist of Hard, Cohesive Clays and Silts (CCS)
and Very Dense, Cohesionless Silts and Fine Sands (CSF) deposits.

2) Scenario 2: Minimum Soil Cover Depth (Station 1403+00)
   a) Soil cover depth and groundwater heads are 30.3 and 20 feet, respectively. Soil conditions within tunnel profile consist of Very Stiff to Hard, CCS and CSF deposits.

3) Scenario 3: Maximum Soil Cover Depth in Coarse Grained Soils (Station 1362+00)
   a) Soil cover depth and groundwater heads are 135.6 and 5 feet, respectively. Soil conditions within tunnel profile consist of Very Dense, Cohesionless Sand and Gravel (CSG) deposits.

4) Scenario 4: Minimum Soil Cover Depth in Coarse Grained Soils (Station 1253+00)
   a) Soil cover depth and groundwater heads are 51.4 and 22.4 feet, respectively. Soil conditions within tunnel profile consist of Till and Till-Like (TLD) deposits with CSF layers of varying thickness.

   c. Design ground parameters: In accordance with conditions in the Geotechnical Baseline Report (GBR).
   d. Design earthquake loads: In accordance with requirements of the DCM, Section 8A, with particular focus on Section 8A.6.1.

5. Stagger joints so that longitudinal joints do not align with longitudinal joints in adjacent segment rings.

6. Provide a continuous gasket groove around all joint faces of the segments of a width necessary to accommodate the required gasket with the minimum Contractor-determined clearances, or minimum clearances between:
   a. Segment extrados and the outer edge of the gasket groove to prevent spalling of the concrete due to required gasket line loads.
   b. Joint compression packing and the inside edge of the gasket groove to prevent damage to the gasket when the packing is compressed while maintaining maximum ½-inch eccentricity of the packing with respect to the centerline of the segment joint.
   c. Provide chamfers for tapered longitudinal joints to reduce stress concentrations as necessary to comply with specified requirements.

7. Design segments to support temporary loading due to TBM propulsion, grout pressures, loads due to handling, stacking, demolding, and installation, consistent with selected means and methods.

8. Coordinate design of segments with procedures for constructing cross-passages, in accordance with Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.

B. Gasket:
1. Capable of handling no less than 200 percent (denotes factor of safety = 2.0) of the higher of:
   a. The maximum tail void grouting pressure determined by the Contractor to avoid damage to the precast concrete segments; or
   b. A maximum water pressure of 40 psi above atmospheric.

2. Coordinate design of the gasket system with the following items to achieve the specified performance for the anticipated range of gap widths:
   a. Gasket properties;
   b. Gasket groove depth and geometry;
   c. Anticipated compression packing thickness, if used;

3. Select and configure the gasket and gasket groove geometry to be capable of resisting extrusion into the joint gap due to tail void grout and hydrostatic pressures.

4. Capable of sealing against the maximum pressure when subjected to maximum offsets based upon erection tolerances.

C. Mechanical Joint Connector Systems:

1. Design bolted, dowelled, or other positively interlocking mechanical connections between segment panels. Connect longitudinal joints by bolts only.

2. Provide a minimum of two connections at each joint face for each segment except at circumferential joints for key taper segments, which may utilize a single connection.

3. Design connections to maintain adjacent gaskets sufficiently compressed to perform in accordance with specified requirements.

4. Design connections for all anticipated installation conditions, including loss of TBM thrust ram pressure.

D. Compression Packing:

1. Capable of transferring anticipated design loads across longitudinal or circumferential joints while maintaining at least half of original thickness. Account for given fabrication and installation tolerances in design.

2. Maintain 1/2-inch clearance from segment grooves and edges.

E. Threaded Plastic Inserts:

1. Capable of proof grouting through inserts.

2. Capable of being sealed to same design pressures as gasket using a plug or cap.

3. If used for transportation, handling and installation of segments, design for all anticipated loading conditions with a minimum factor of safety of 2.

F. Insert Drilling Location Indicators:

1. Provide minimum number of indicators as indicated on the Contract Drawings.
2. Provide a minimum of 1.2 inches of clearance between indicator and nearest reinforcement.

G. Groundwater Seepage:
1. Behind the TBM trailing gear after segment erection and tail void grouting, proof grouting and cross passage construction:
   a. Total inflow from each tunnel, between the Maple Leaf Portal and UWS: Less than 18 gallons per minute (gpm).
   b. Maximum inflow at a single point: Less than 0.1 gpm.
   c. No active drips or seeps above springline of the tunnel.

H. Fabrication Tolerances:
1. Fabrication: Cast with such accuracy and uniformity of dimensions that segment panels of the same type are interchangeable from segment ring to segment ring.
2. Reinforcement placement: Cover between reinforcement and forms of – 0 inch, + 1/2 inch.
3. As indicated on the Contract Drawings.

I. Erection Tolerances:
1. Inside diameter of the erected ring: +/- 0.5 percent of the inside diameter.
2. Limit steps on the internal surface between abutting segments to no greater than 3/8 inch.
3. Limit the roll of one ring relative to the adjacent ring to not exceed 1/8 inch.

1.05 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Manufacturer’s product data and performance sheets, including recommendations and requirements for handling, storage, and protection for the following:
1. Gasket materials:
   a. Three samples each of gaskets, plus a sample of the gasket adhesive.
   b. Gasket information, including test data, demonstrating ability to meet specified design and performance criteria.
2. Segment bolts:
   a. Three samples of type proposed for use.
   b. Bolt information, including test data or manufacturer’s certification of compliance with design strengths required.
3. Segment dowel:
   a. Three samples of type proposed for use.
b. Manufacturer’s information, including test data or manufacturer’s certification of compliance with design strengths required.

4. Grout hole/lifting sockets:
   a. Three samples of type proposed for use.
   b. Manufacturer’s information, including test data or manufacturer’s certification of compliance with design strengths required.
   c. Grout caps and grout cap gaskets

5. Compression Packing material: Three samples of type proposed for use.

6. Polypropylene fiber reinforcement:
   a. Half a pound of type proposed for use.
   b. Manufacturer’s product data including product description, chemical and physical properties, and storage and handling instructions.

C. Shop Drawings:

1. Dimensioned details of precast concrete segment geometries and features comprising:
   a. Layout and size of each segment.
   b. Number of segments per ring.
   c. Taper configurations.
   d. Key configuration.
   e. Concrete grade and type.
   f. Reinforcement.
   g. Gaskets and gasket grooves.
   h. Joint details.
   i. Compression packing.
   j. Inserts and insert drilling location indicators.
   k. Mechanical joint connections.
   l. Segment identification information.

2. Details for construction of each type of mold used to cast the precast concrete segments. Include for each type of segment:
   a. The number of molds to be fabricated.
   b. Details for securing embedded items in place during casting.
   c. Form geometry and dimensions.
   d. Fabrication Tolerance for:
1) Circumferential length
2) Width
3) Flatness of segment joint face
4) Width of gasket groove
5) Depth of gasket groove
6) Mismatch of gasket groove at corners
7) Warping
8) Connector locations

D. Working Drawings and Method Statements:

1. Physical description and properties of design elements, including details, dimensions, supporting design calculations demonstrating compliance with specified performance criteria, and list of design criteria. Provide calculations that are stamped, dated and signed by the Segment Designer.

2. Details for compression packing incorporated into the longitudinal and circumferential joint surfaces between segments, including type of material, thickness, compressibility, and calculations and test results demonstrating compliance with minimum design criteria specified herein.

3. Details of segment production, comprising:
   a. Name, address, and contact information for the Segment Manufacturer.
   b. Location of casting and storage yards.
   c. Means and methods for:
      1) Batching concrete with and without fibrous reinforcement.
      2) Casting, curing, and stripping/demolding segments.
      3) Affixing segment gaskets and compression packing.
      4) Handling and storing segments.
   d. Segment production schedule.

4. Refer to Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine, for submittal requirements for transporting segments into the tunnel, erection and fastening of segments.

5. Refer to Section 31 73 23, Tail Void Grouting, for submittal requirements for placing tail void grout.

6. Refer to Section 31 50 00, Excavation Support and Protection for submittal requirements for integrating the segmental lining with other initial support systems at the stations.

7. Refer to Section 31 71 23, Tunnel Excavation by Sequential Excavation Methods, for submittal requirements for integrating the segmental lining with initial support systems at the cross-passages.
8. Segment Repair: Detailed procedure for process of repairing segments during fabrication, during installation, and after installation in the tunnel.

E. Mix Designs: In accordance with Section 03 05 15, Portland Cement Concrete, and as specified herein.

F. Qualifications:
1. Segment Manufacturer.
2. Segment Designer.

G. Certifications:
2. That precast concrete segments meet minimum design and performance criteria specified.
3. Separately by Contractor and Segment Manufacturer that precast concrete segments are capable of supporting storage, transportation, handling, erection, and TBM thrust loads.
4. By Contractor that the circularity tolerance specified is consistent with the Contractor’s proposed segment configuration and geometry.

H. Quality Control Plans:
1. Segment Casting:
   a. Methods for measuring and assuring that tolerances are met with due consideration for thermal, moisture, and ambient temperature influences.
   b. Methods for testing and sampling to verify minimum required compressive strength before stripping, all in accordance with Section 03 05 15, Portland Cement Concrete.
   c. Methods for demolding segments to prevent spalling and other forms of damage to gasket grooves and segment edges.
   d. Methods for controlling shrinkage and temperature cracking.
   e. Methods for assuring even distribution of fibers in concrete mixes during placement in molds.
   f. Record keeping and procedures for resolving quality defects.
   g. Methods for assuring that segment production and storage of segments does not impact tunnel excavation.
2. Segment Protection: Methods for protecting segments and appurtenances from damage while handling, transporting, storing, and installing.
3. Segment ring mockups assuring compliance with indicated tolerances and segment interchangeability requirements.

I. Records:
1. Fabrication
a. Daily and weekly summaries of segments fabricated, including types of segments, mixes used, curing details, strength testing results, storage location, and other information specified herein.

b. Weekly summary of segments transported to the construction sites.

c. Weekly summary of damaged segments at the fabrication plant, including types of repairs if used, and whether repairs were successful.

d. Results of segment and mold dimension checks.

e. Results of mock ups and ring fit-ups.

f. Source Quality Control testing results.

2. Installation: In accordance with Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

1.06 QUALITY ASSURANCE

A. Qualifications:

1. Segment Manufacturer:

   a. Experience with manufacturing bolted, gasketed, precast concrete segments of similar dimensions and tolerances to those specified.

   b. Required to have been in business for at least 5 years and provided precision tunnel rings for two projects comparable to the work of this Contract.

   c. Comparable work includes bolted, gasketed, precast concrete tunnel lining segments installed as tunnel lining below the groundwater table.

2. Segment Designer: Licensed Structural Engineer registered in the State of Washington with a minimum of five years of recent experience in underground construction and in the design of bolted, gasketed, precast concrete segments below the groundwater table.

B. Testing:

1. To demonstrate conformance with the specified requirements as indicated herein, provide the services of an Independent Testing Laboratory (ITL), in accordance with Section 01 45 00.20, Quality Assurance / Quality Control.

C. Acceptance Criteria:

1. Adequacy of Structural Design: Calculations demonstrating that the segments meet the criteria indicated, in conjunction with:

   a. Gasket line loads developed at the expected gaps.

   b. Means and methods to achieve the Groundwater Seepage criteria limits under the given hydrostatic and tail void grouting pressures, adjusted by the factor of safety specified herein.

   c. Temporary construction loads, from handling, transporting, erecting, and TBM jacking, with and without full benefit of tail void grouting, as well as other loads as may be applied during construction of the segmental tunnel lining.
2. Casting of segments to:
   a. Individual panel and collective ring tolerances as indicated.
   b. Meet or surpass all design criteria.

3. Erection of segments:
   a. Meet or surpass specified Groundwater Seepage criteria.
   b. Meet tolerances specified or indicated.

D. Prefabrication Conference
1. Schedule and conduct a prefabrication conference between the Resident Engineer and the Segment Manufacturer within 30 days of the intended start of fabrication of the segments.
2. Discuss issues such as record keeping, testing, inspection logistics, quality assurance and control, and other fabrication-related matters.

1.07 PRODUCT DELIVERY, STORAGE AND HANDLING
A. Transport the required amounts of tapered segment panels in complete ring assemblies and as required to maintain a sufficient number of segment rings available to the tunneling operation.
B. Protect gaskets and compression packings from direct exposure to sunlight and weather as needed based on manufacturer's recommendation. Replace gaskets and compression packings that show signs of deterioration.
C. Transport, store, and handle segments, avoiding damage to surfaces, edges and corners, and avoiding the development of stresses exceeding the capacity of the segment.

PART 2 - PRODUCTS
2.01 MATERIALS
A. Reinforcing Steel:
   1. Welded wire fabric: In accordance with Section 03 20 00, Concrete Reinforcing.
   2. Bar reinforcement:
      a. In accordance with Section 03 20 00, Concrete Reinforcing.
      b. For welded bars for ladder mats at longitudinal joints: ASTM A706.
B. Mechanical Joint Connector Systems:
   1. Structural bolts, nuts and washers:
      a. Bolts: ASTM A325 or ASTM A490.
      b. Washers and Nuts: Consistent with steel used for bolts.
      c. Minimum bolt size: 3/4-inch diameter.
d. Hot-dipped galvanized.
e. Curved bolt systems prohibited.

2. Steel dowels for circumferential joints:
   a. ASTM A108 Grade 1018.
   b. Minimum diameter: 3/4-inch.
   c. Hot-dipped galvanized.

3. Plastic dowels for circumferential joints:
   a. Fiber reinforced engineered thermoplastic.
   b. Ring formed pliable elastic surfaces.
   c. Minimum diameter: 2.5-inches.
   d. Maximum diameter: One-third thickness of segment.
   e. Minimum length: 7 inches.

C. Concrete: Section 03 05 15, Portland Cement Concrete, and as specified herein.

D. Polypropylene Fibers: Section 03 05 15, Portland Cement Concrete.

E. Gaskets:
   1. Continuous over joint surfaces and of uniform gasket thickness along the entire length of mating surfaces, with vulcanized corners.
   2. Material free of imperfections including: Voids, blisters, inclusions, flow marks, porosity, and pitting.
   3. Of such durability that residual contact pressure between the gasket surfaces is capable of resisting the design hydrostatic head specified herein, as well as environmental conditions indicated in the GBR continuously over the 100-year period following erection.
   4. Made of dense elastomeric synthetic rubber.
   6. Tensile Strength: ASTM D412, greater than 1,700 psi.
   7. Elongation: ASTM D412, greater than 300 percent.
   8. Compression Set: ASTM D395, Method B:
      a. Short-Term – Less than 20 percent compression after 25 percent compression at 160 degrees F for 22 hours.
      b. Long-Term – Less than 20 percent compression after 50 percent vertical compression after 70 hours at 212 degrees F.
   9. Ozone Resistance: ASTM D1149, Procedure A, with following stipulation:
a. No surface cracking of untensioned specimen (zero percent elongation) when immersed in a 200 parts per hundred million ozone solution for 100 hours at room temperature and 55 percent humidity.

10. Water-tightness: Provide gaskets that meet the Groundwater Seepage criteria under the conditions specified herein.

11. Fire rating: Use a concrete test rig to demonstrate that gaskets will be unaffected by fire. Install gaskets in grooves in concrete blocks in a manner consistent with conditions in the tunnel, with a gap of 1/8-inch. Via a burner, apply a temperature of 1450 degrees F at the intrados side of the blocks for a period of 30 minutes. Set the distance between the intrados and the gaskets to be consistent with the conditions within the tunnel. Measure the temperature at the gasket, and demonstrate that less than three-quarters of the width of the gasket profile is damaged by the applied heat. Certification by the manufacturer or past test results will be accepted in lieu of specific fire rating testing.

12. Aging: ASTM D573, 70 hours at 210 degrees F. Changes in material properties shall comply with the following parameters:
   a. Hardness: Less than 6 units increase.
   b. Tensile Strength: Less than 15 percent decrease.
   c. Ultimate Elongation: Less than 30 percent decrease.

13. Stress Relaxation: Remaining stress greater than 60 percent of original stress after 100 years, based upon accelerated testing and engineering analysis.

F. Gasket and Compression Packing Primers and Adhesives: As recommended by packing and gasket manufacturers.

G. Compression Packing Material:
   1. Marine grade plywood, composite material, or other approved material. Bituminous fiberboard is prohibited.
   2. Maximum thickness of 1/4 inch.

H. Foam Strips: Compressible material capable of preventing grout from entering joints between segments.

I. Segment Repair Materials: In accordance with Manufacturer’s recommendations, and compatible with concrete mix design.

J. Grout Insert:
   1. Plastic:
      a. Coefficient of thermal expansion similar to concrete.
      b. Hard, durable material compatible with anticipated construction activities.
   2. Option of Steel: In accordance with ASTM A53.
   3. Cap material compatible with grout insert.
   4. Provide with back-flow preventers to permit grouting from the inside while preventing the inflow of grout from the annulus.
5. Provide a hydrophilic ring or other means on outside of insert, to prevent seepage along the outside surface of the insert.

2.02 FABRICATION

A. Utilize molds fabricated from steel in accordance with ACI 347.

B. Cast concrete in accordance with Section 03 05 15, Portland Cement Concrete, and in a controlled environment protected against rain, dust, and direct sunlight.

C. Place reinforcing steel in accordance with Section 03 20 00, Concrete Reinforcing.

D. Provide reinforcement spacers as specified in Section 03 20 00, Concrete Reinforcing.

E. Place fibrous reinforcing in accordance with Section 03 05 15, Portland Cement Concrete.

F. Provide a hard steel trowel finish or similar to the extrados surface.

G. Cure segments and protect during storage in accordance with ACI 533 and ACI 517.2R.

H. If steam curing is used:
   1. Do not apply external heat or steam to segments until concrete preset is achieved in accordance with ASTM C403.
   2. After the segments are cast and attained preset time, place the segment forms in an enclosure or chamber large enough to allow complete circulation of steam.
   3. Do not remove segments from forms until the required stripping strength is attained, as determined by test cylinders.
   4. Provide enclosure or chamber ambient temperature that does not exceed 100 degrees F for the first two hours of curing; maintain temperature between 90 degrees F to 150 degrees F until the required stripping strength is attained. Continuously monitor temperatures during curing.

I. Control cooling rate to limit temperature differential to avoid thermal cracking.

J. Apply an approved curing compound on all surfaces immediately after removal of segments from steam curing.

I. Segment Identification:
   1. Cast the segment type, type of taper, and mold identification directly on the segment intrados.
   2. Paint the casting date adjacent to the above-cast information.

J. Segment alignment: Cast a marker into the intrados of each segment to assist in their alignment.

K. Identify locations where segments can be drilled without interfering with segment reinforcement, as indicated on the Contract Drawings, for use in attaching appurtenances to the lining.

2.03 SOURCE QUALITY CONTROL

A. Segment and Mold Dimension Checks:
1. Check mold dimensions versus tolerances for each mold prior to beginning production. Thereafter, as a minimum, check mold dimensions once for every 200 segments cast.

2. Verify that the first segment cast from any mold meets required tolerances. Thereafter, as a minimum, measure every fiftieth segment from each mold. If variations occur, re-check mold and repair if necessary.

3. For any mold modified or repaired, re-check dimensions of the mold prior to using the mold in production, and check dimensions of the first segment and every 25th segment from this mold.

4. The Resident Engineer may elect to reduce the frequency of ring dimension checks based on consistently meeting the required tolerances.

B. Mockup or Ring Fit-Up:

1. Prior to beginning production of the precast concrete segments, completely assemble and survey two sets of two each pre-production segment rings cast from proposed molds, including compression packing and connections but without gaskets. Circumferential joint dowels may be replaced with temporary steel dowels to aid in ring disassembly. If universal tapered rings are proposed, only one set of two segment rings is required.

   a. Assemble each set of rings separately at the place of manufacture by stacking segment rings one on top of another on a level, flat surface with joints staggered.

   b. Assemble one full set of rings for each type: one left taper, one right taper, or one universal taper.

   c. Survey the rings to verify that the molds and segments as cast meet fabrication tolerances as indicated on the Contract Drawings.

   d. Adjust or replace forms as required to meet specified requirements.

2. The Resident Engineer will select the bottom ring from one of the two sets to be retained as the master ring for the duration of segment casting operations to verify compliance with fabrication tolerances for the production segments using the same 2-ring configuration.

   a. Select segments for the upper trial ring in accordance with the following:

      1) Every 500th segment cast from each mold.

      2) Mold repair or replacement: First segment ring cast and every 250th cast thereafter.

   b. Survey the segment rings to verify that the molds and segments meet fabrication and fit-up tolerances as indicated on the Contract Drawings.

3. The Resident Engineer may elect to reduce the frequency of ring fit-up demonstrations based on consistently meeting the required tolerances.

C. Testing:

1. Perform gasket tests of type required and recommended by manufacturer to demonstrate compliance with design criteria specified herein. As a minimum, perform the following tests:
a. Watertightness tests: Assure no leakage for anticipated combinations of gaps and offsets, and at pressures specified herein. Test both straight gaskets and T-joint configurations.

b. Reaction load tests: Perform sufficient tests to develop correlations, for both no offset and maximum offset, between compression loads on the gasket and gap.

c. Stress relaxation tests: As a minimum, measure reaction loads over a period of three months at 160 degrees F for a no offset condition. Use a load-time plot and engineering analysis to determine stress relaxation at 100 years.

2. Perform trial mix and production concrete testing in accordance with Section 03 05 15, Portland Cement Concrete.

D. Repair of Defects:

1. Segments which exhibit structural damage that will impair the ability of the segment to perform as required, in the opinion of the Resident Engineer, will be rejected. Examples of this type of structural damage include cracks greater than 0.008 inches wide through the full thickness of the segment; multiple cracks at joint bearing areas or inserts; spalling, chipping or cracking that exposes rebar; and honeycombing, cracking or spalling at gasket groove locations that will compromise water sealing capability.

2. For non-structural defects or damage, repair segments per approved repair procedures. Provide repair procedures for patching of blow holes and air voids; chipping and spalling; local protrusions; localized surface cracking; structural cracks less than 0.008 inch; and honeycombing not adjacent to gasket grooves or joint bearing areas.

3. For minor non-structural defects not located at bearing areas or gasket groove locations and less than 3/16 inch in depth, no repairs are required.

4. Do not transport repaired segments to the Site prior to approval of repairs by the Resident Engineer.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Clean the segment erection area to remove water, dirt, debris, and other foreign material prior to erecting each segment ring.

B. Remove foreign material from segments prior to their erection.

C. Set segments to the required joint gap using the TBM segment erector.

D. Do not use the segment bolts or other positively interlocking elements to compress segment gaskets, but only to maintain segment gaskets in the compressed position.

E. Completely erect and fasten segments within the TBM tail shield before thrusting TBM forward.

F. Erect segment rings to stagger longitudinal joints in adjacent rings.
G. Examine segments for structural damage. Repair or replace misaligned or damaged segments to maintain tolerances, to maintain water-tightness, and to ensure stability and safety during construction.

H. Correct improper installation of the segments at any particular location within the tail shield prior to the injection of tail void grout behind the segments at that location, and before the TBM has completed more than 25 percent of the subsequent maximum stroke.

I. Modify construction methods to eliminate future reoccurrence of improper installation and implement additional monitoring of the segment ring to assure compliance with specified Groundwater Seepage and tolerance requirements.

J. Check plane of leading edge of circumferential joint to provide a uniform thrust surface for TBM rams.

K. Perform systematic tail void grouting in accordance with Section 31 73 23, Tail Void Grouting.

3.02 CONSTRUCTION

A. Coordinate tunnel excavation and installation of segmental lining:
   1. To accommodate the cast-in-place invert slab, attachments to the lining, and cross-passage construction.
   2. To accommodate additional requirements as may be required by the Contractor's means and methods for performing tunnel excavation, segmental lining, and ancillary work.

B. Use tapered rings as the exclusive means for negotiating curves and for making alignment corrections.

C. For longitudinal segment joints:
   1. Do not use compression packing of variable thickness.
   2. Use only one compression packing per joint.

D. Regardless of the type of mechanical joint connector, do not remove them subsequent to their installation unless immediately replaced.

E. Protect gasket materials and gaskets on stored segments from UV exposure.

F. Precast Segment Repair or Replacement
   1. Do not install segments which exhibit any of the following damage:
      a. Visible reinforcement.
      b. Cracks in excess of 1/8-inch width at any location.
      c. Spalling in any amount adjacent to or affecting gasket or positively interlocking element seating or confinement.
   2. Replace segments that have been installed against which the TBM has not completed more than 25 percent of the subsequent maximum stroke and which exhibit damage as detailed herein.
   3. Repair segments before TBM has advanced beyond 300 feet of damaged area which exhibit the following:
a. Spalling to a depth in excess of 1-inch.

b. Characteristics specified herein prohibiting installation.

4. Patch holes drilled for cross passage pre-support and dewatering measures after completion of cross passage construction to meet inflow criteria requirements specified herein.

5. Sound Transit will inspect and approve all repaired segments. Do not perform work that would interfere with inspection and acceptance of the segment repair without approval from the Resident Engineer.

3.03 FIELD QUALITY CONTROL

A. Establish a program for measuring the deformation of the segmental lining system under load:

1. Install four anchors at 90-degree spacing at every 25th segment ring under the guidance of the Resident Engineer for tape extensometer measurements.

2. Measure deformations and compare to previously recorded measurements.

B. Inspect the conditions and the competence of segmental lining:

1. Daily, where installed.

2. Immediately after each shove of the TBM.

3. During and upon completion of tail void grouting.

C. Monitor the installation of each segment ring as related to the uniformity of the void space between the segment ring and the tail shield. Record the distance between the inside diameter of the tail shield and the outside diameter of the segment ring. Measure this distance at four locations approximately 90 degrees apart at the leading edge of the ring, at the following times:

1. Take the first set of measurements upon erecting the segment ring, but prior to thrusting against the ring.

2. Take the last set of measurements upon completing the TBM shove, but prior to installing the next segment ring.

3. Resident Engineer may elect to eliminate some or all of these Contractor measurements if it becomes evident to the Resident Engineer, through visual or other means, that the Contractor is consistently erecting the segment rings in accordance with specified requirements.

D. Monitor the installation of each segment ring before and after shove as related to the indicated circularity tolerances.

E. Survey of Completed Lining: In accordance with Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

F. Notifications - Notify the Resident Engineer:

1. 15 days in advance of assembling demonstration segment rings.

2. Within 1 day of removing a segment casting mold from service for repair or replacement:
a. Provide survey results to verify conformance of repaired or replacement mold to tolerance requirements.

b. In cases of repair, submit written report including the nature of the damage and the method of repair.

3. Immediately, upon discovering precast segments that do not conform to the requirements of the Contractor’s design and the minimum design requirements set forth herein, promptly rectify the non-conformance.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for materials, proportioning, and application of shotcrete for both temporary and permanent work. This includes shotcrete used for both the initial and final tunnel linings within the cross passages. Unless indicated otherwise, the requirements specified apply to both temporary and permanent shotcrete.

B. This Section covers both wet-mix and dry-mix shotcrete.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections not referenced below may also be related to the proper performance of this work.

1. Section 03 05 15, Portland Cement Concrete.
2. Section 03 20 00, Concrete Reinforcing.
3. Section 31 23 01, Excavation Spoils and Muck Disposal.
5. Section 31 74 19.10, Initial Shotcrete Tunnel Lining.

1.02 REFERENCES

A. This section incorporates by reference the latest revisions of the following documents:

1. American Concrete Institute (ACI)
   a. ACI 301 Specifications for Structural Concrete.
   b. ACI 506.2 Specification for Shotcrete
   c. CP 60 Craftsman Workbook for ACI Certification of Shotcrete Nozzleman

   a. ASTM A 820 Standard Specifications for Steel Fibers for Fiber-Reinforced Concrete.
   b. ASTM C 39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
   c. ASTM C 42 Standard Test Methods for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
   d. ASTM C 94 Standard Specification for Ready-Mixed Concrete
1.03 DEFINITIONS

Refer to the following Sections:

1. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.
2. Section 31 74 19.10, Initial Shotcrete Tunnel Lining.
3. Section 31 74 19.20, Final Shotcrete Tunnel Lining.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit at least 90 days prior to commencement of shotcrete application the proposed mix characteristics including:

1. All proposed mix design proportions by weight and volume, including tolerances and fiber content (both steel and microsynthetic)
2. Projected strength development vs. time
3. Design slump
4. Water-cement ratio
5. Source of aggregates, gradation ranges, and quantities
6. Mix water source
7. Cement type, brand, and quantity
8. Supplementary cementing material type (silica fume, fly ash) and quantities
9. Chemical admixture types (data sheets) and quantities
10. Test results
C. Submit preconstruction testing results at least 30 days prior to commencement of shotcrete work.

D. Submit resumes for proposed shotcrete nozzlemen and foremen at least 90 days prior to commencement of shotcrete work.

E. Submit details of shotcrete equipment to be used on the Contract, including brand name, model and capacity of pump and air compressor, at least 90 days prior to commencement of shotcrete work.

F. A description of the proposed curing procedures and protection to be provided to shotcrete.

1.05 QUALITY CONTROL

A. Shotcrete Crew Qualifications: Shotcrete crew foremen and nozzlemen shall meet the following requirements.

1. Furnish proof that each shotcrete crew foreman has at least 5 years experience in underground shotcrete application on projects of a similar character to this Contract along with three references from persons responsible for supervision of these projects. Include name, address and telephone number for all references.

2. Furnish proof that all nozzlemen are certified to CP 60 (ACI) for application of shotcrete to vertical and overhead surfaces for both wet- and dry-mix shotcrete. Furnish proof that nozzlemen have successfully completed three projects of similar character to this Contract. All nozzlemen must shoot test panels that fulfill the requirements of Article 1.05B below.

B. Preconstruction testing

1. Test Panels: Prepare preconstruction test panels for examination by the Resident Engineer prior to job shotcrete placement. Preparation and testing shall comply with ASTM C 1140, except as modified below:

   a. Test panel size shall be 24 inches by 24 inches minimum, with a minimum depth of 4-1/2 inches. Panels shall be made with sloped sides.

   b. Coring and testing shall be in compliance with ASTM C 42, except that minimum core size shall be 4-inch diameter by 4-1/2 inches deep, trimmed to 4 inches long. Apply ASTM C 42 length-to-diameter correction factors to the compressive strength results.

   c. Cores shall not be taken closer than 4 inches from any edge of the panel.

2. Concrete or Shotcrete Mix Testing: Produce test panels for each proposed mix.

   a. Provide test panels without reinforcing. Obtain at least six test specimens from each panel.

   b. Test the nonreinforced specimens for compliance with the specified physical properties in accordance with ASTM C 42.

   c. Test admixtures for compatibility with cement in accordance with ASTM C 1141.

   d. Confirm design slump for each wet-mix shotcrete mix.
3. Nozzleman Qualification: Produce test panels for each proposed nozzleman and each anticipated shooting orientation.
   a. Provide test panels with reinforcing that reproduces the thickest and most congested area specified for the structure as identified by the Resident Engineer.
   b. Test panels shall be shot using the same nozzleman, assistant, and equipment that will be used under the Contract, and with each of the approved concrete mix designs and at orientations to be used under the Contract.
   c. Shotcrete used shall be within $\pm 1/2$ inch of the design slump.
   d. Test panels for nozzleman qualification shall not be shot until the shotcrete mix is approved.
   e. Visually grade the reinforced specimens for compliance with specified core grade in accordance with Article 1.05D Shotcrete core grades for test panels and permanent shotcrete.
   f. Extract five cores from locations of reinforcing steel in the test panel. If any one core is graded higher than 3 or with more than two of the five cores having a core grade of 3, the entire test panel is rejected.
   g. When the prequalification test panel is rejected, a second panel may be shot. When the second test panel is rejected, the nozzleman will not be permitted to shoot on the Contract.

4. Steel fiber-reinforced shotcrete (SFRS): Produce three circular test panels for 7-day testing and perform toughness testing in accordance with ASTM C1550.

5. Undertake a full-scale trial of permanent shotcrete application to the membrane waterproofing:
   a. Complete trial at least 60 days prior to commencement of permanent shotcrete work.
   b. Fix waterproofing membrane system, per approved method statement, to an outer form with a 3-inch minimum thick shotcrete initial lining, which is representative of a 10-foot long section of the cross passage geometry.
   c. Apply wire mesh and final lining shotcrete to membrane over the full length to a uniform thickness of 10 inches utilizing the same personnel, equipment, materials and methods as proposed for the works, including finishing.
   d. Extract, evaluate and test six three-core sets in accordance with Articles 1.05B.1.b and c, and 1.05D.
   e. In addition, the outer form shall be carefully removed once the design shotcrete 28-day strength has been achieved. The condition of the waterproofing membrane shall be recorded before the final lining is removed.
   f. The results of this trial shall be approved by the Resident Engineer prior to the commencement of the permanent shotcrete work.
C. Construction testing

1. Produce a material test panel for each mix and each work day. Test panel shall be kept moist and at 70 degrees F +/- 10 degrees F until moved to an Independent Testing Laboratory. Test specimens from test panels in compliance with ASTM C 1140, except as modified below:
   a. Test panel size shall be 24 inches by 24 inches minimum, with a minimum depth of 4-1/2 inches. Panels shall be made with sloped sides.
   b. Test panels shall be shot at the same orientation and in the same manner as the work.
   c. Test panels shall be marked for later identification (mix, location, date, nozzleman).

2. Test specimens from core drilling of in-place shotcrete:
   a. Coring and testing shall be in compliance with ASTM C 42, except that minimum core size shall be 4-inch diameter by 4-1/2 inches deep, trimmed to 4 inches long. Apply ASTM C 42 length-to-diameter correction factors to the compressive strength results.
   b. Perform core sampling and testing at locations determined by the Resident Engineer up to a maximum of fifty 3-core sets.
   c. Fill all core holes with non-shrink grout that has a 28-day compressive strength of 5000 psi minimum. Prepare hole in accordance with grout manufacturer’s instructions and finish flush with the surrounding shotcrete.
   d. In-place coring of permanent shotcrete shall not penetrate nor come within 4 inches of the waterproof membrane.
   e. Cores shall be clearly marked for later identification (mix, location, date, nozzleman).

3. Grade cores that include reinforcement in accordance with Article 1.05D – Shotcrete core grades for test panels and permanent shotcrete.

4. The mean compressive strength of a set of three cores shall equal or exceed 0.85 f’c with no individual core less than 0.75 f’c.

5. Requirements for construction testing of steel fiber reinforced shotcrete (SFRS) are provided in Paragraph 2.05 below.

D. Shotcrete core grades for test panels and permanent shotcrete (Refer to ACI 506.2 for photographs of graded cores):

1. Grade 1: Shotcrete specimens are solid; there are no laminations, sandy areas, or voids. Small air voids with a maximum diameter of 1/8 inch and maximum length of 1/4 inch are normal and acceptable. Sand pockets or voids behind continuous reinforcing steel are unacceptable. The surface against the form or bond plane shall be sound, without a sandy texture, or voids.

2. Grade 2: Shotcrete specimens shall have no more than two laminations or sandy areas with dimensions not to exceed 1/8 inch thick by 1 inch long. The height, width and depth of voids shall not exceed 3/8 inch in any direction. Porous areas behind reinforcing steel shall not exceed 1/2 inch in any direction except along...
the length of the reinforcing steel. The surface against the form or bond plane shall be sound, without a sandy texture or voids.

3. Grade 3: Shotcrete specimens shall have no more than two laminations or sandy areas, with dimensions exceeding 3/16 inch thick by 1-1/4 inches long, or one major void, sand pocket, or lamimation containing loosely bonded sand not to exceed 5/8 inch thick and 1-1/4 inches in width. The surface against the form or bond plane may be sandy with voids containing overspray to a depth of 1/16 inch.

4. Grade 4: The core shall meet in general the requirements of Grade 3 cores, but may have two major flaws such as described for Grade 3 or may have one flaw with a maximum dimension of 1 inch perpendicular to the face of the core with a maximum width of 1-1/2 inches. The end of the core that was shot against the form may be sandy and with voids containing overspray to a depth of 1/8 inch.

5. Grade 5: A core that does not meet the criteria of core grades 1 through 4, by being of poorer quality, shall be classified as Grade 5.

E. Evaluation of in-place shotcrete

1. Remove and replace shotcrete that is delaminated, exhibits laminations, voids, or sand pockets exceeding the limits for the specified grade of shotcrete. Remove and replace shotcrete that does not comply with the specified material properties. Repair core holes in accordance with Chapter 9 of ACI 301 and Article 1.05C.2.c above.

F. Acceptance

1. The Resident Engineer has the authority to accept or reject shotcrete work. Shotcrete which does not conform to these Specifications may be rejected either during the shotcrete application process, or on the basis of tests from either test panels or the completed work.

2. Deficiencies observed during the shotcrete application process such as, but not limited to, the following constitute a cause for shotcrete rejection:
   a. Failure to properly control and remove build-up of overspray and rebound;
   b. Incomplete consolidation of shotcrete behind and around reinforcing steel, mesh and anchors;
   c. Incorporation of sand lenses, excessive voids, delaminations, sags or sloughing;
   d. Failure to apply shotcrete to the required line, grade and tolerance.

3. Wherever possible perform remedial work to correct deficiencies while shotcrete is still plastic.

4. Hardened shotcrete will be examined by the Resident Engineer for any evidence of excessive plastic or shrinkage cracking, tears, feather-edging, sloughs or other deficiencies. Sounding shall be used to check for delaminations.

5. Extract five cores from locations of reinforcing steel in the test panel. If any one core is graded higher than Core Grade 3 or with more than two of the five cores having a Core Grade of 3, the entire test panel is a failure.
6. If the results of compliance tests from shotcrete test panels, or assessment of the plastic or hardened shotcrete indicate non-conformance of the shotcrete, the Resident Engineer will implement a program of evaluation of the in-place shotcrete. Such evaluation shall include, but not be limited to:

   a. Extraction of cores from in-place shotcrete at locations selected by the Resident Engineer and testing of such cores for compliance.

   b. Checking for delaminations using sounding or other appropriate non-destructive testing procedures.

   c. Bond pull-off testing.

   d. Diamond saw cutting or coring to check adequacy of encasement of reinforcing steel and anchors.

7. Rejected shotcrete shall be removed and the lining rebuilt to the satisfaction of the Resident Engineer, or the lining may be strengthened as approved by the Resident Engineer, all at no cost to Sound Transit. Rejected steel fiber reinforced shotcrete may be strengthened by the addition to the intrados of a minimum of one layer of welded wire mesh and 3 inches of plain shotcrete. Additional reinforcing or shotcrete may be required as directed by the Resident Engineer at no cost to Sound Transit.

8. Upon approval of the Resident Engineer, steel fiber reinforced shotcrete (SFRS) in lieu of wire mesh reinforcement may be used for certain underground structures, or certain parts of the shotcrete lining. If the performance of the SFRS is not satisfactory, such approval may be revoked.

PART 2 - MATERIALS

2.01 SHOTCRETE

   A. Shotcrete (including cement, aggregate, water, and admixtures): Refer to Section 03 05 15, Portland Cement Concrete.

2.02 REINFORCEMENT

   A. Reinforcing Steel Bars: See Section 03 20 00, Concrete Reinforcing.

   B. Steel fibers for Initial Shotcrete Lining: ASTM A 820, bent or deformed low-carbon, cold-drawn steel wire, Type 1, with a minimum tensile strength of 160,000 pounds per square inch (psi), 1 to 1.375 inches (25 to 35mm) long, with a minimum aspect ratio of 40.

   C. Polypropylene microfibers for Final Shotcrete Lining: monofilament fibers with a maximum length of 0.5 inches (12mm) and a maximum diameter of 0.0013 inches (32µm) suitable for production of ASTM C1116 Type III synthetic fiber-reinforced shotcrete.

2.03 CURING MATERIALS FOR PERMANENT SHOTCRETE

   A. Curing materials that cause stains on architectural finishes shall not be used.

   B. Sheet materials: ASTM C 171.

   C. Curing compounds: ASTM C 309, apply as recommended by manufacturers.
2.04 PROPORTIONING

A. Select shotcrete proportions to produce the specified material properties.

B. Shotcrete mix proportions for all shotcrete, including preconstruction test mixes, using normal weight aggregate shall produce the following compressive strengths:

<table>
<thead>
<tr>
<th>SHOTCRETE APPLICATION</th>
<th>AGE OF SHOTCRETE</th>
<th>( F'_c, ) PSI</th>
<th>ASTM TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary only</td>
<td>1 hour</td>
<td>100</td>
<td>C 803</td>
</tr>
<tr>
<td>Temporary only</td>
<td>24 hours</td>
<td>2,000</td>
<td>C 1074 or C 39</td>
</tr>
<tr>
<td>Temporary only</td>
<td>7 days</td>
<td>4,000</td>
<td>C 39</td>
</tr>
<tr>
<td>Both temporary and permanent</td>
<td>28 days</td>
<td>5,000</td>
<td>C 39</td>
</tr>
</tbody>
</table>

C. Provide a minimum dosage rate of 3 pounds per cubic yard of polypropylene microfibers for final shotcrete tunnel lining.

2.05 STEEL FIBER-REINFORCED SHOTCRETE (SFRS)

A. SFRS to conform to ASTM C 1116.

B. In addition to the requirements of Articles 2.04B and 2.03C, mix proportions for SFRS shotcrete shall produce the following properties:

<table>
<thead>
<tr>
<th>AGE OF SHOTCRETE FROM TIME OF BATCHING</th>
<th>AVERAGE ENERGY ABSORPTION (ASTM C 1550)</th>
<th>DEFLECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 days</td>
<td>280 Joules</td>
<td>1.5 in (40mm)</td>
</tr>
</tbody>
</table>

C. Toughness Performance Level Testing:

1. Perform toughness performance level testing in accordance with the procedures provided in ASTM C1550.

2. Perform one set of tests as defined in Article 2.08.C for each cross passage at the commencement of excavation.

3. One set of tests shall consist of a minimum of three panels

4. If the specified performance criteria are not met, notify the Resident Engineer immediately.

5. Submit results within 1 day of the testing.

2.06 PRE-BAGGED MATERIALS

A. Pre-bagged materials are allowable with pre-dampening prior to use.

2.07 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, and handle materials to prevent contamination, segregation, corrosion, or damage.

B. Store shotcrete materials in a dry place.

C. Store fibers in a dry, sealed container until ready for batching.
D. Store aggregate materials at a minimum temperature of 40 degrees F.

E. Store liquid admixtures to prevent evaporation and freezing. Store admixtures at all times in clearly marked and labeled containers (including admixture name, type, storage requirements, use-before date, instructions for use, safety precautions, and manufacturer’s recommended dosage range).

2.08 EQUIPMENT

A. Use batching equipment that proportions aggregate and cement mixtures by weight. Batching by volume is not permitted.

B. Use an air supply system that delivers air uncontaminated by oil or any other contaminant and that is capable of maintaining a constant pressure.

C. Shotcrete delivery equipment shall be capable of delivering a steady stream of uniformly mixed material to the discharge nozzle at the proper velocity and rate of discharge.

D. Use positive displacement pumps equipped with hydraulic or mechanically powered pistons, with compressed air added at the discharge nozzle, for wet-mix shotcrete application.

E. Monitor air ring at nozzle for signs of blockage of individual air holes. Stop shooting and clean air ring if non-uniform discharge of shotcrete becomes apparent.

F. Clean shotcrete delivery equipment thoroughly at the end of each shift. Regularly inspect and clean air ring and nozzle; replace if required.

G. Provide a separate air hose and blow pipe, capable of simultaneous operation with shotcreting operation, for removal of rebound and dust.

H. Equipment will be subject to approval of the Resident Engineer. Maintain equipment in proper working order. Provide additional test panels and test cores as required by the Resident Engineer to demonstrate that the equipment is functioning properly during shotcreting operation.

I. Provide standby equipment on site and in good working order at all times during shotcreting operations.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that placement and clearance around reinforcement (including wire mesh) is adequate for complete encasement.

B. Verify that surfaces to receive shotcrete have been properly prepared according to the Contract Documents.

C. Remove rebound and any other foreign material from construction joints prior to continuing shotcrete installation.

D. Rebound shotcrete shall not be reused or incorporated into the work.

E. Sequence of shotcrete installation shall be as shown on the Contract Drawings. Thickness indicated is the minimum thickness at any point. Use thickness indicators to control and verify thickness.
3.02 BATCHING AND MIXING

A. Weight batching shall comply with the accuracy specified in ASTM C 94.

B. Use batching and mixing equipment capable of proportioning and mixing the required materials.

C. Use feed systems for all materials that are interconnected such that if one feed stops, all feeds stop.

D. Shoot dry-mix shotcrete material within 45 minutes after batching or pre-dampening.

E. Shoot wet-mix shotcrete material within 90 minutes after batching.

F. Dosing of admixture by hand is not permitted.

G. Shotcrete delivered to shotcrete pump with a slump that is outside the confirmed design range will be rejected.

3.03 SURFACE PREPARATION

A. Soils: Prepare surfaces to line and grade. Dampen surface immediately prior to shooting.

B. Concrete and Shotcrete: Remove all deteriorated, loose, unsound material or contaminants that may inhibit bonding. Chip areas to be repaired to remove offsets causing abrupt changes in thickness. Taper edges to approximately 45 degrees to eliminate square shoulders at the perimeter of a cavity. Surface shall be saturated surface dry (SSD) immediately prior to placing shotcrete.

C. Structural Reinforcement, including Wire Mesh: The surface shall be free of deleterious materials that inhibit bonding. For new construction, reinforcement laps shall be separated with a clearance of at least three times the diameter of largest aggregate. Reinforcement shall be secured to prevent movement.

D. Forms: Secure forms to minimize the effects of vibration. Construct forms to allow escape of placement air and rebound.

E. Water Leaks: Securely attach drainage pipes, channels or similar prior and during temporary shotcreting.

F. Membrane Waterproofing: Remove loose material, mud, or any other foreign material that will prevent bonding. Clean surface with compressed air. Repair any damage to the membrane prior to shotcrete application. Obtain signed statement for each cross passages from the Resident Engineer and waterproofing installer that membrane waterproofing system is free of defects prior to final shotcrete lining installation.

3.04 JOINTS

A. Construction Joints: Taper construction joints at a 1 to 1 slope where joint is not subject to compression loads. Form square joints where joints are subject to compression loads. Surface preparation of joints shall comply with Article 3.03B. Continue reinforcement through construction joint.

B. Control Joints: Place as shown on Contract Drawings. Discontinue reinforcement and wire mesh at control joints.

3.05 ALIGNMENT CONTROL

A. Install taut ground wires, lattice girders and other means to establish thickness and plane of required surface.
B. Install taut ground wires or other means at corners or offsets not established by forms.

3.06 APPLICATION

A. Shotcrete Placement Technique

1. Provide a platform that permits nozzlemen unobstructed access to the receiving surface. Remove rebound and overspray from previously prepared surfaces prior to shotcrete placement.

2. Apply shotcrete from the bottom and continue upwards to avoid the inclusion of rebound in the lining.

3. For invert lining, use separately controlled air blowpipe during spraying to remove rebound from the lining.

4. Spraying shotcrete through more than one layer of reinforcement or mesh is not permitted.

5. Place shotcrete first in corners, recesses, and other areas where rebound or overspray cannot escape easily. Place shotcrete with nozzle held at approximately 90-degree angle to the receiving surface. In corners, direct nozzle at approximately 45-degree angle or bisect the corner angle.

6. Velocity and spraying distance shall be the optimum for maximum shotcrete adherence and compaction.

7. Apply shotcrete so sags or sloughing do not occur. Where movement of shotcrete has occurred adjacent to a slough-off, the shotcrete in question shall be removed.

8. Discontinue shooting or shield the nozzle stream if wind causes separation of ingredients during shooting.

9. Do not reuse rebound, sprayed fibers, or overspray.

10. Remove laitance and any foreign material from shotcrete surfaces to receive additional shotcrete layers. Surface preparation after final set shall comply with Article 3.03B.

11. Prior of shotcrete application, control groundwater inflow and seepage to prevent dissolution of cement and fine aggregates in the fresh shotcrete. Control groundwater as shown on the Contract Drawings and specified, or by other appropriate and approved methods. Do not apply shotcrete on surfaces with standing water.

12. Remove hardened overspray and rebound from adjacent surfaces, including exposed reinforcement.

B. Encasement of Reinforcement, including Wire Fabric: Place shotcrete to completely encase reinforcing steel. Encase reinforcement by shooting with sufficient velocity and plasticity so material flows around and behind the reinforcement. Front face of reinforcement shall remain clean during encasement. Place shotcrete to provide the cover over reinforcement required by ACI 301.

C. Applying shotcrete against the membrane waterproofing shall be carried out in a manner that prevents damage to the membrane.
D. For permanent shotcrete, apply shotcrete in continuous layer thicknesses between 3 and 6 inches per pass. Test bond strength between layers as directed by the Resident Engineer.

3.07 FINISHING
A. Temporary shotcrete: as specified in Section 31 74 19.10, Initial Shotcrete Tunnel Lining.
B. Permanent shotcrete: as specified in Section 31 74 19.20, Final Shotcrete Tunnel Lining.

3.08 CURING
A. Permanent Shotcrete: Immediately after finishing, cure shotcrete continuously by maintaining in a moist condition for 7 days or until specified strength is attained or until succeeding shotcrete layers are placed. Cure by one of the following methods:
   1. Ponding or continuous sprinkling.
   2. Covering with an absorptive mat or sand that is kept continuously wet.
   3. Covering with impervious sheet material.
   4. Curing compounds: subject to prior approval by the Resident Engineer.
   5. Curing compounds which impair bonds shall not be used where a further layer of shotcrete is to be applied.
B. Temporary Shotcrete: Natural curing is permitted.

3.09 HOT WEATHER SHOTCRETING
A. Do not place shotcrete when shotcrete material temperature is above 90 degrees F for wet-mix; 100 degrees F for dry mix. Lower temperature of reinforcement and receiving surfaces below 100 degrees F prior to placing shotcrete.

3.10 COLD WEATHER SHOTCRETING
A. Placing shotcrete may proceed when ambient temperature is 40 degrees F and rising. Placing shotcrete shall discontinue when ambient temperature is 40 degrees F and falling unless protective measures are taken to protect shotcrete. Shotcrete material temperature, when placed, shall not be less than 50 degrees F. Applicable procedures used for cold weather concreting may be used for cold weather shotcreting. Protection against frost shall be maintained until the shotcrete has developed a compressive strength of 2,000 psi.

3.11 PROTECTION
A. Protect surfaces not intended for shotcrete placement from deposit of rebound and overspray or impact from nozzle stream.
   1. Remove rebound and hardened overspray from final shotcrete surfaces and from areas not intended for shotcrete placement, and dispose in accordance with Section 31 23 01, Excavation Spoils and Muck Disposal.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This section includes specifications for the installation of initial shotcrete linings for the cross passages as shown on the Contract Drawings.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 03 20 00, Concrete Reinforcing.
   2. Section 31 23 01, Excavation Spoils and Muck Disposal.
   4. Section 31 74 19.05 Shotcrete for SEM Tunnels.
   5. Section 31 74 19.20, Final Shotcrete Tunnel Lining.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Concrete Institute (ACI)
      a. ACI 506.2 Specification for Shotcrete
      a. ASTM A36 Standard Specification for Carbon Structural Steel
      b. ASTM A325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
   3. American Welding Society (AWS):
      a. AWS D1.1 Structural Welding Code

1.03 DEFINITIONS

A. Dry-mix Shotcrete: Shotcrete that is supplied in dry form with water added at the nozzle.

B. Flashcrete: Initial layer of steel fiber reinforced shotcrete applied to exposed ground immediately after excavation.

C. Wet-mix Shotcrete: Shotcrete that is supplied from an on-site batch plant or ready-mix concrete supplier, including water in the mix.

D. Lattice Girder: Lightweight, three-dimensional steel frame member shop-fabricated from steel bar stock or reinforcing steel, embedded in the shotcrete lining and used to provide support and dimensional guidance.
E. Splice Bar: Rebar installed to provide mechanical connection of shotcrete in the circumferential direction between the top heading and bench shotcrete linings and at other construction joints.

F. Splice Clip: Rebar installed at the cross passage arch lines to provide longitudinal reinforcement of the shotcrete lining.

G. Waste Shotcrete: Discarded shotcrete and flashcrete materials, including overspray, rebound, loose and broken or otherwise excavated initial shotcrete linings and associated materials (e.g. steel fibers).

H. Wavelength: Distance between two crests used in the determination of the smoothness of the shotcrete surface before installation of the waterproofing membrane.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Samples:
   1. Submit for each lattice girder type to be used:
      a. Two-foot long piece of the full cross-section - two samples.
      b. Butt plate splice mock-up.
      c. Lap splice mock-up.

C. Shop Drawings:
   1. Shotcrete lining shop drawings indicating all structural and construction details and geometry including, but not limited to the following:
      a. Tolerances.
      b. Plan and sequence of excavation and lining installation.
   2. Lattice girder shop drawings, including specifications and fabrication details.

D. Product Information: Lattice girders.

E. Quality Control Plan: Lattice girders.

F. Welders: Certified as described in 05 05 23, Metal Fastenings.

1.05 QUALITY ASSURANCE

A. Shotcrete:
   1. Material and application specified in Section 31 74 19.05, Shotcrete for SEM Tunnels
   2. Visual Inspection:
      a. Smoothness criteria: Do not exceed a depth to wavelength ratio of 1/60 measured with a 10-foot straight edge in the longitudinal direction and deviation from the theoretical curved surface in the circumferential direction.
      b. Thickness indicators: Install appropriate thickness indicators to verify lining thickness.
3. Sample coring and testing: Section 31 74 19.05, Shotcrete for SEM Tunnels.

4. Recording: for every application of shotcrete, record the following information into the daily shift report:
   a. Date, shift, and tunnel temperature.
   b. Nozzleman.
   c. Test cylinders cast and cores drilled, including name of technician and sample identification.
   d. Results of visual inspection.
   e. Locations and volumes applied.

1.06 DELIVERY, STORAGE AND HANDLING

A. General:
   1. Load, transport, unload and store all structural materials so that they remain clean and protected from damage.
   2. Store cementitious materials in dry, protected enclosures and in accordance with manufacturer’s recommendation.
   3. Store materials on platforms, skids or other supports above the ground surface.
   4. Damaged materials to be clearly marked and removed from site immediately.

B. Lattice Girders:
   1. Prevent bending, scraping, or overstressing members at all times.
   2. Protect projecting parts vulnerable to bending or damage during handling.
   3. Replace pieces bent or damaged unless repair is reviewed and accepted by the Resident Engineer.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Flashcrete: Steel fiber reinforced shotcrete as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.

B. Shotcrete: Wet- or dry-mix, as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.

C. Lattice Girders:
   1. For all lattice girders use three primary reinforcing bars connected by stiffening elements of the manufacturer's design.
   2. Design the lattice girder to allow shotcrete to penetrate into and behind the girder without shotcrete shadowing.
   3. Section properties:
a. As indicated on the Contract Drawings.

b. A minimum of 5 percent of the moment of inertia shall be provided by the stiffening elements. This percentage will be calculated as an average along a repeatable length of the girder.

c. The maximum centerline spacing of stiffening elements shall be less than three times the height of the girder to ensure stability against buckling, with a tolerance of plus or minus 1 inch.

4. Material properties:
   a. Minimum physical properties of steel:
      1) Tensile Strength: 80 kilopounds per square inch (ksi) minimum.
      2) Yield Strength: 70 ksi minimum.
   b. Construct the connection elements at the end of the girder of structural angle or plate meeting the minimum properties of ASTM A36.

5. Welding:
   a. Welding process to meet the requirements set forth by AWS for gas metal arc welding (GMAW). Ensure all welders are certified in accordance with AWS D1.1.
   b. Execute all welds parallel to the retaining bars with a minimum length of 1 inch.

D. Lattice Girder Accessories
   2. Splice Clips: Fabricated from No. 4 reinforcing bar in accordance with Section 03 20 00, Concrete Reinforcing.
   3. Splice Bars: Fabricated from No. 4 reinforcing bar in accordance with Section 03 20 00, Concrete Reinforcing.
   4. Butt and end plates: Plate meeting the minimum properties of ASTM A36

E. Steel Fiber: As specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Flashcrete:
   1. Apply minimum 2-inch layer of steel fiber reinforced shotcrete (flashcrete) immediately after excavation on all exposed surfaces to seal and protect the material from deterioration and initial loosening.

B. Lattice Girders:
1. Install to conform to the required shape of the initial lining shape. Consider variability of materials, excavation and erection tolerances, and initial lining deformation to determine actual dimensions.

2. Secure lattice girder segments by means of temporary wood blocking and tie rods or other means to maintain position during shotcreting.

3. Locate butt plates for lattice girder segment as shown on the Contract Drawings. Ensure a tight connection of all elements.

4. Remove temporary blocking prior to continuing shotcrete lining into bench and invert.

5. Remove all foreign material from splices prior to connection of subsequent lattice girder segment.

C. Splice Bars and Splice Clips: Install splice bars and splice clips as shown on the Contract Drawings.

D. Shotcrete:

1. Use steel fiber reinforced shotcrete (SFRS) for the initial lining for the cross passages.

2. Apply shotcrete as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.

3. Install shotcrete linings (including flashcrete layer) to provide thickness shown on the Contract Drawings. Use thickness indicators to ensure design thickness of shotcrete is achieved.

4. Remove and respray shotcrete not meeting specified quality.

5. Finish shotcrete as follows:

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>FLATNESS CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary heading face flashcrete</td>
<td>No criteria</td>
</tr>
<tr>
<td>Tunnel flashcrete</td>
<td>No criteria</td>
</tr>
<tr>
<td>Tunnel initial lining</td>
<td>Article 1.05A.2.a</td>
</tr>
</tbody>
</table>

6. In addition to the initial lining, steel fiber reinforced shotcrete is to be covered with plain shotcrete with a minimum thickness of 2 inches prior to waterproofing installation (smoothing layer).

7. Remove all laitance, loose material, rebound, and Waste Shotcrete and dispose in accordance with Section 31 23 01, Excavation Spoils and Muck Disposal.

8. Shotcrete shall attain its full design strength before waterproofing is installed.

E. Jobsite Production and Safety

1. Maintain supply of steel fibers, lattice girders and admixtures on site equal to five days production on all tunnels under construction, based on a rate of progress equal to the greater of the average rate achieved or the rate assumed in the Construction schedule.

2. Maintain a constant and adequate supply of steel fiber reinforced shotcrete at the tunnel heading during excavation to permit shotcrete to be applied at any time during the construction.
3. Ensure sufficient amount of steel fiber reinforced shotcrete to support one full excavation round is on site at all times during the excavation period. No excavation is permitted without sufficient shotcrete on site.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This section includes specifications for the installation of shotcrete final linings for the cross passages as shown on the Contract Drawings.
B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 03 62 00, Non-shrink Grouting
   2. Section 07 10 00, Waterproofing.
   3. Section 31 23 01, Excavation Spoils and Muck Disposal.
   4. Section 31 74 19.05, Shotcrete for SEM Tunnels.
   5. Section 31 74 19.10, Initial Shotcrete Tunnel Lining.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society for Testing and Materials (ASTM)

1.03 DEFINITIONS
A. Dry-mix Shotcrete: Shotcrete that is supplied in dry form with water added at the nozzle.
B. Wet-mix Shotcrete: Shotcrete that is supplied from an on-site batch plant or ready-mix concrete supplier, including water in the mix.
C. Contact Grouting: Pressure injection of contact grout through grout ports in order to fill voids between the Final Shotcrete Lining and the Initial Shotcrete Lining/Waterproofing System.
D. Contact Grout: Cementitious Grout per Section 03 62 00, Non-shrink Grouting
E. Waste Shotcrete: Refer to Section 31 74 19.10, Initial Shotcrete Tunnel Lining.
F. Wavelength: Distance between two crests used in the determination of the smoothness of the final lining shotcrete surface.

1.04 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Shop Drawings
1. Shotcrete lining shop drawings indicating all structural and construction details and geometry including, but not limited to the following:
   a. Tolerances.
   b. Plan and sequence of lining installation.

C. Product Information for each type of manufactured material and product indicated:
   1. Polypropylene Microfibers.

D. Equipment
   1. Grouting Equipment: Submit product information for equipment and accessories used for contact grouting.

E. Contact Grouting Reports: The Contractor shall submit a contact grouting report for each cross passage addressing as a minimum the following:
   1. Grouting duration, injection pressure, grout flow rate and injected grout quantity for each grout port.
   2. Communication to other grout ports.
   3. Calibration reports for grouting equipment used for grouting operation.
   4. Test results for cement grout according to ASTM C109 for each cross passage.

1.05 QUALITY ASSURANCE

A. Shotcrete:
   1. Material and application specified in Section 31 74 19.05, Shotcrete for SEM Tunnels
   2. Visual Inspection:
      a. Smoothness criteria: Do not exceed a depth to wavelength ratio of 1/100 measured with a 10-foot straight edge in the longitudinal direction and deviation from the theoretical curved surface in the circumferential direction.
      b. Thickness indicators: Install appropriate thickness indicators to verify lining thickness.
   3. Sample coring and testing: Section 31 74 19.05, Shotcrete for SEM Tunnels.
   4. Recording: for every application of shotcrete, record the following information into the daily shift report:
      a. Date, shift, tunnel temperature.
      b. Nozzleman.
      c. Test cylinders cast and cores drilled, including name of technician and sample identification.
      d. Results of visual inspection.
      e. Locations and volumes applied.
1.06 DELIVERY, STORAGE, AND HANDLING

A. General:

1. Load, transport, unload and store all structural materials so as to keep them clean and protected from damage.
2. Store cementitious materials in dry, protected enclosures and in accordance with manufacturer’s recommendation.
3. Store materials on platforms, skids or other supports above the ground surface.
4. Damaged materials to be clearly marked and removed from site immediately.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Shotcrete: Use shotcrete as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.
B. Polypropylene Microfibers: As specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.
C. Membrane Waterproofing: As specified in Section 07 10 00, Waterproofing.
D. Contact Grout: In accordance with Section 03 62 00, Non-shrink Grouting.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Shotcrete

1. Obtain a signed statement for each cross passage from the Resident Engineer and waterproofing installer that membrane waterproofing system is free of defects prior to final shotcrete lining installation.
2. Apply shotcrete as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.
3. Do not use both wet-mix and dry-mix shotcrete in the Final Shotcrete Lining of any cross passage.
4. Install shotcrete linings to provide thickness shown on the Contract Drawings. Use thickness indicators to ensure design thickness of shotcrete is applied.
5. Remove all laitance, loose material, rebound, and Waste Shotcrete, and dispose in accordance with Section 31 23 01, Excavation Spoils and Muck Disposal.
6. Remove and respray shotcrete not meeting specified quality.
7. Trowel all shotcrete final linings to smoothness criteria indicated in Article 1.05 A.2.a, herein.

B. Contact Grouting: Perform contact grouting operation as follows and as indicated on the Contract Drawings:
1. Perform contact grouting through grout pipes in the final shotcrete lining with such quantity and pressure as to fill all voids. Maximum allowable grouting pressure for contact grouting shall not exceed 50 psi.

2. Pump grout until grout comes through adjacent grout pipes.

3. Do not inject grout into more than one hole simultaneously.

4. Any grout not injected within 90 minutes of completion of mixing shall be wasted.

5. Perform contact grouting behind the Final Shotcrete Lining only after it has gained its specified 28 day strength.

6. Perform contact grouting for each cross passage as a continuous operation.

C. Field Quality Control for Contact Grouting:

1. Grout Strength Tests: Take three 3-inch minimum diameter grout cubes and test in accordance with ASTM C109. Test as a minimum once per cross passage.

2. Grouting Equipment: Calibrate gages and meters of equipment used for contact grouting in the presence of the Resident Engineer prior to the start of contact grouting for each cross passage using master gages and meters.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
   A. This Section includes specifications for furnishing, spreading, and compacting aggregate for aggregate base course as indicated.
   B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work:
      1. Section 31 20 00, Earth Moving

1.02 REFERENCES
   A. This Section incorporates by reference the latest revisions of the following documents:
      1. City of Seattle (COS):
         a. Standard Specifications for Road, Bridge and Municipal Construction
         b. Standard Plans for Municipal Construction

1.03 SUBMITTALS
   A. Procedures: Section 01 33 00, Submittal Procedures.
   B. Material source, and all tests and certifications necessary to determine compliance with the specifications.
   C. Test Reports: Submit plant and field test reports as specified in Articles 2.02 and 3.04 herein.

PART 2 - PRODUCTS

2.01 MATERIALS
   1. Mineral Aggregate Type (No.): Type as indicated on the Contract Drawings. Conform to the COS Standard Specifications Section 9-03.

2.02 SOURCE QUALITY CONTROL
   A. Perform sampling and tests of the aggregate base material in accordance with the COS Standard Specifications Section 9-03.15.

PART 3 - EXECUTION

3.01 EXAMINATION
   A. Subgrade Examination
1. Call for an inspection by the Resident Engineer and obtain written acceptance of the prepared subgrade before proceeding with the placement of aggregate base course.

3.02 PREPARATION

A. Perform subgrade preparation in accordance with the Contract Drawings and in close conformity with the lines, grades, and typical cross sections indicated, as referenced in a City of Seattle Standard Plan.

B. Subgrade preparation: Section 31 20 00, Earth Moving.

3.03 CONSTRUCTION

A. Place and compact aggregate base courses in accordance with the lines, grades, and typical cross sections indicated on the Contract Drawings, as referenced in a City of Seattle Standard Plan.

B. Construction requirements: COS Standard Specifications Section 4-04.3.

3.04 FIELD QUALITY CONTROL

A. Test for compliance with specified requirements for compaction of aggregate base in accordance with COS Standard Specifications Section 4-04.3(5). Independently test each material type and/or when a material source changes.

B. Tolerances: Maximum allowable deviation in measured thickness of Aggregate Base Course surfacing is 1/2 inch less than specified depth.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing and placing Hot Mix Asphalt (HMA) on a prepared base in accordance with the lines, grades, thicknesses, and typical cross-sections shown on the Contract Drawings.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 31 20 00, Earth Moving
2. Section 32 11 23, Aggregate Base Courses

1.02 REFERENCES

A. This Section incorporates by references the latest revision of the following documents.

B. City of Seattle (COS):

1. Standard Specifications for Road, Bridge, and Municipal Construction
2. Standard Plans for Municipal Construction

C. Seattle Department of Transportation (SDOT):

1. Seattle Department of Transportation, Director's Rule 5-2009: Street and Sidewalk Pavement Opening and Restoration

1.03 DEFINITIONS

A. Hot Mix Asphalt (HMA): A plant-mixed asphalt concrete pavement composed of asphalt binder and mineral aggregate mixed in specified proportions at a predetermined temperature to provide a homogenous, stable, workable, and compactable mixture.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Mix Design: Comply with the COS Standard Specification Section 5-04.3(6) for mix design submittal requirements.

C. Paving Plan for areas under traffic: COS Standard Specification Section 5-04.3(17).

D. Test Reports: Submit test results of sampling and testing, and inspection records within 24 hours of asphalt concrete placement.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Aggregates for Hot Mix Asphalt: COS Standard Specification Section 9-03.8.
B. Asphalt binder grade: PG 64-22 as defined in COS Standard Specification Section 9-02.1(4).
C. Tack Coat: CSS-1, CSS-1h, or STE-1 emulsified asphalt per COS Standard Specification Section 9-02.1(6).

2.02 MIXES

A. Mix Design for HMA: COS Standard Specification Section 5-04.3(6).
B. The nominal maximum aggregate size is as indicated on the Contract Drawings.
C. Asphalt binder: PG 64-22. The Contractor may propose the substitution of alternate grades of performance grade (PG) asphalt binder at no cost to Sound Transit as specified in COS Standard Specifications Section 5.04.2(1).

2.03 SOURCE QUALITY CONTROL

2. Aggregates for Hot Mix Asphalt: Test Requirements per COS Standard Specification Section 9-03.8(2).

PART 3 - EXECUTION

3.01 PREPARATION

A. Prepare subgrade for surfacing in accordance with Section 31 20 00, Earth Moving.
B. Construct Aggregate Base Course surfacing where indicated in accordance with Section 32 11 23, Aggregate Base Courses.
C. Surface Preparation of Existing Pavements:
   1. When an existing paved surface will be used as a base for one or more courses of asphalt concrete, begin by cleaning the entire existing pavement surface.
   2. Remove all fatty asphalt patches, grease drippings and other objectionable matter from the existing pavement. Sweep existing pavement with a power broom until clean of dust, soil, pavement grindings, and other foreign matter. Fill all holes and small depressions with HMA. Level and compact any patched areas.
   3. Apply tack coat to all paved surfaces on which any course of HMA is to be placed or abutted per COS Standard Specifications Section 5-04.3(4)B4.
D. Surface preparation of aggregate bases or native subgrade: COS Standard Specifications Section 5-04.3(4)C.
3.02 CONSTRUCTION

A. Provide asphalt concrete pavement in accordance with the layout, configurations, and dimensions indicated on the Contract Drawings or in a referenced COS Standard Plan.

B. Construct HMA asphalt concrete pavement in conformance with the COS Standard Specifications Section 5-04.3.

C. For asphalt concrete pavement patching within the City of Seattle right-of-way, comply with the SDOT Director's Rule 05-2009: Street and Sidewalk Pavement Opening and Restoration and the COS Standard Plans.

3.03 FIELD QUALITY CONTROL

A. Compaction Requirements and Test Results for HMA: COS Standard Specifications Section 5-04.3(9). Include thickness of asphalt tested with each compaction report.

B. Surface Smoothness HMA: COS Standard Specification Section 5-04.3(12).

C. Maintenance of Pavement

1. Allow newly compacted asphalt to cool to ambient temperature before any traffic is allowed on it. Do not allow traffic on the newly placed asphalt until approval has been obtained from the Resident Engineer.

2. Maintain finished pavement in finished clean condition until the work is accepted by the Resident Engineer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing Portland cement concrete pavement for roadways, driveways, sidewalks, and concrete patching as indicated.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 31 20 00, Earth Moving
2. Section 32 11 23, Aggregate Base Courses

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge and Municipal Construction
   b. Standard Plans for Municipal Construction
2. Seattle Department of Transportation
   a. SDOT Director’s Rule 5-2009: Street and Sidewalk Pavement Opening and Restoration

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Submit manufacturers’ product data for proposed concrete admixtures.

C. Concrete Mix Designs: Submit mix designs as specified in City of Seattle Standard Specifications Section 5-05. Include Manufacturer’s Certificate of Compliance indicating the batch weights and gradation reports of course and fine aggregates. Submit mix design to the Resident Engineer and include mix proportions per cubic yard, proposed sources, volume of entrained air, test results from flexural strength (beams; roadway concrete only) and compressive strength (cylinders), and water cement ratio.

D. Detectable warning plate for curb ramps: Submit the information required in COS Standard Specification Section 8-14.3(7)B to the Resident Engineer at least 5 Working Days in advance of placement.

E. Shop Drawings:

1. Submit drawings showing the locations of all joints in concrete, including construction joints, expansion joints, isolation joints, and contraction joints.
2. Submit drawings indicating concrete placement method, sequence, location, and boundaries. Include each type and class of concrete, and quantity in cubic yards.

PART 2 - PRODUCTS

2.01 MATERIALS

   A. Use materials in construction of cement concrete pavements, including but not limited to Portland cement, aggregates, reinforcing steel, curing materials and admixtures as specified in the COS Standard Specifications Section 5-05.2.

2.02 MIXES

   A. Concrete mixes are classified as either “Roadway Cement Concrete” or “Non-Roadway Cement Concrete”. Provide the class of concrete as indicated on the Contract Drawings. Provide a mix design for each class of concrete used. Proportion mixes as specified in COS Standard Specification Section 5-05.3(1).

   B. Where class of concrete is not indicated on the Contract Drawings the following will apply in accordance with COS Standard Specification Section 5-05.3:

   C. Roadway Cement Concrete shall be used for construction of cement concrete roadway or cement concrete roadway base with asphalt overlay. Non-Roadway Cement Concrete shall be used for alleys, driveways, sidewalks, curb ramps, curbs, curb and gutters and other cement concrete construction on prepared subgrade or base. Submit concrete mix designs to the Resident Engineer in advance of ordering, leaving sufficient review time as specified in Section 01 33 00, Submittal Procedures.

   D. Concrete placeability, workability, and strength shall be the responsibility of the Contractor.

2.03 SOURCE QUALITY CONTROL

   A. Testing and Analysis:

      1. Perform all testing and analysis of materials used in accordance with COS Standard Specifications Section 5-05 and Section 9.

PART 3 - EXECUTION

3.01 PREPARATION

   A. Prepare subgrade for surfacing in accordance with Section 31 20 00, Earth Moving.

   B. Construct Aggregate Base Course surfacing where indicated in accordance with Section 32 11 23, Aggregate Base Courses.

3.02 CONSTRUCTION

   A. General

      1. Construct Portland cement concrete pavement in accordance with the lines, grades, thicknesses, and typical cross-sections indicated on the Contract Drawings or in a referenced COS Standard Plan. Remove and replace pavement that is not within the allowable tolerances for line, grade, thickness and cross-section.
2. Construct Portland cement concrete pavements for roadways and pavement patching in accordance with the requirements of the COS Standard Specifications Section 5-05.3.

3. Construct Portland cement concrete sidewalks, and curb ramps in accordance with COS Standard Specifications Section 8-14.3.


5. Portland cement concrete pavement and sidewalk patching from trenching activities within the City right-of-way shall also comply with the City of Seattle’s Directors Rule: Street and Sidewalk Pavement Opening and Restoration.

3.03 FIELD QUALITY CONTROL:

A. Concrete Testing: Perform all acceptance testing of concrete pavement for roadways as specified in the COS Standard Specifications, Section 5-05.

B. Opening Pavements to Traffic:

1. Comply with the requirements for pavement opening specified in the COS Standard Specifications Section 5-05.3(17).

2. Do not open newly constructed pavements to traffic until the Resident Engineer has given approval.

END OF SECTION
SECTION 32 16 13
CONCRETE CURBS AND GUTTERS

PART 1 - GENERAL

1.01 SUMMARY
   A. This Section includes specifications for providing cement concrete curbs.

1.02 REFERENCES
   A. This Section incorporates by reference the latest revisions of the following documents.
      1. American Society for Testing and Materials (ASTM)
         a. ASTM A 615, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
         b. ASTM C 143, Standard Test Method for Slump of Hydraulic-Cement Concrete
         c. ASTM C150, Standard Specification for Portland Cement
         d. ASTM C881, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete
      2. City of Seattle (COS):
         a. Standard Specifications for Road, Bridge, and Municipal Construction
         b. Standard Plans for Municipal Construction

1.03 SUBMITTALS
   A. Procedures: Section 01 33 00, Submittal Procedures.
   B. Product Data: Submit manufacturers' product data for all materials being used.
   C. Concrete Mix Design: Submit concrete mix design and test results.

PART 2 - PRODUCTS

2.01 MATERIALS
   A. Concrete for Extruded Concrete Curb: Minimum 28-day compressive strength of 2500 psi. Slump (ASTM C 143) not to exceed 1 inch. Maximum coarse aggregate 3/4 inch. Air-entrainment 5 percent plus or minus 1-1/2 percent.
   B. Concrete for Cast-in-Place Curbs: Class 5 (3/4) in accordance with COS Specification Section 5-05. Slump not to exceed 3-1/2 inches.
   C. Dowels and reinforcing steel: No 3 deformed steel billet bars, ASTM A 615, Grade 60.
   D. Portland cement: Conform to the requirements of ASTM C150.

F. Bonding Material: Epoxy Bonding Agent meeting the requirements of COS Standard Specifications Section 9-26 and ASTM C881 for Type II epoxy resin.

G. Curing Compound: Type 1D, Class B, per COS Standard Specification Section 9-23.2.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General

1. Construct curbs in accordance with the layout, configurations, and dimensions indicated on the Contract Drawings or as referenced in a COS Standard Plan.

B. Extruded Cement Concrete Curbs

1. Place, shape and compact extruded cement concrete curb true to line and grade with an approved extrusion machine. Use an extrusion machine capable of shaping and thoroughly compacting the concrete to the required cross section.

2. Dry and clean pavement of loose or deleterious materials prior to curb placement. Anchor concrete curbs to the existing pavement using epoxy bonding agent. Place according to the recommendations of the bonding agent manufacturer.

3. Load the hopper of the curb machine with the homogenous mix. Run each hopper load of cement concrete through the curb laying machine, adjust it properly to form and compact the cement concrete mix for the curb.

4. Space joints in the extruded cement concrete curb at 15-foot intervals or to match existing transverse joints or cracks in existing pavement. Cut joints vertically.

5. Use Type 1D, Class B liquid curing compound with pigment sufficient to make sprayed compound easily discernible.

6. Protect newly placed extruded cement concrete curb from traffic by barricades or other suitable means until it has attained its required strength of 2500 psi. Leave protection measures in place for at least 72 hours.

C. Cast-in-Place Curbs:


3.02 FIELD QUALITY CONTROL

A. Ensure that when checked with a 10-foot straightedge, grade does not deviate more than 1/8-inch, and alignment does not vary more than 1/4-inch.
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing, installing and removing pavement markings as indicated.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. City of Seattle (COS)
      a. Traffic Control Manual for In-Street Work.
      c. Standard Specifications for Road, Bridge, and Municipal Construction.
   2. Washington State Department of Transportation (WSDOT)
      a. Standard Specifications for Road, Bridge, and Municipal Construction, including applicable provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.
   3. Federal Highway Administration (FHA)
      a. Manual on Uniform Traffic Control Devices (MUTCD)

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Submit to the Resident Engineer for approval, the respective manufacturers' product data for pavement marking materials.
C. Removal: Submit to the Resident Engineer for approval, the method(s) for removing existing and temporary pavement marking(s).

PART 2 - PRODUCTS

2.01 MATERIALS
A. For pavement marking on Sound Transit owned streets, roadways, and parking lots, the materials used in the Work shall be as indicated on the Contract Drawings and conform to the applicable provisions of WSDOT 9-34, unless specified otherwise.

B. For pavement marking on streets, roadways, and parking areas that are to be owned or maintained by jurisdictions other than Sound Transit, the materials used shall conform to the applicable requirements of the jurisdictional agency's standard drawings and specifications.
PART 3 - EXECUTION

3.01 CONSTRUCTION

A. For pavement marking on Sound Transit owned streets, roadways, and parking lots, the work described in this Section shall be performed in accordance with the applicable provisions of WSDOT 8-22 unless specified otherwise.

B. For pavement marking on streets, roadways and parking areas that are to be owned or maintained by jurisdictions other than Sound Transit, the work described in this Section shall be performed in accordance with the applicable requirements of the jurisdictional agency’s standard drawings and specifications.

C. Removal of pavement markings shall be performed by bead-blasting or other method per City of Seattle Standard Specification 2-02.3(3)J and approved by the Resident Engineer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing and installing security fencing, including gates, posts, fittings, hardware, anchors, and concrete footings, as indicated.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents:
   1. City of Seattle (COS):
      a. Standard Specifications for Road, Bridge, and Municipal Construction
      b. Standard Plans for Municipal Construction
   2. Washington State Department of Transportation (WSDOT):
      a. Standard Specifications for Road, Bridge, and Municipal Construction
      b. Standard Plans for Road, Bridge, and Municipal Construction
   3. American Association of State Highway and Transportation Officials
      a. AASHTO T22 Standard Method of Test for Compressive Cylindrical Concrete Specimens
      b. AASHTO T152 Air Content of Freshly Mixed Concrete By the Pressure Method

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Submit manufacturer’s product data and specifications of the specified fencing and gates.
C. Shop Drawings: Submit detailed shop drawings of the fences and gates layout, including installation details of the fencing, posts, gates, hardware, and accessories for review.

PART 2 - PRODUCTS

2.01 MATERIALS
A. General: Supply fencing including fabric covering, framework, concrete footings, hardware, and all appurtenances and accessories as required for a complete installation. Construct fencing to heights indicated.

C. Concrete Footings: Minimum compressive strength at 28-days of 3000 psi in accordance with AASHTO T22. Air-entrain concrete with air content between 4.5-percent and 7.5-percent in accordance with AASHTO T152.

D. Post and Rails: Comply with WSDOT Standard Specification Section 9-16.1(2) and Section 9-16.1(3).


F. Fittings and Hardware: Comply with WSDOT Standard Specification Sections 9-16.1(6), 9-16.1(8), and 9-16.1(9).


PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Construction Requirements

1. Stake locations of fence lines, terminal posts and underground utility locations. Clear and grade with adequate clearance on both sides of the fence line.

2. Install fencing and gates in accordance with COS Standard Plans and Standard Specification Section 8-12.3 (2).

3. Concrete fill: Placed around posts to dimensions indicated and vibrated or tamped for consolidation. Protect above ground portion of posts from concrete splatter.

4. Crown top of footings to shed water.

B. Remove and Reset Fence:

1. Portions of existing chain link fence that are removed to facilitate construction and not otherwise indicated for removal shall be protected from damage during removal and storage and reinstalled to its original locations and condition.

2. Dispose of existing fence and gates, which are damaged by construction operations and replace with new fence and gates of the same or equivalent type at no additional cost to Sound Transit.

END OF SECTION
PART 1 - GENERAL

1.01 DESCRIPTION

A. This work consists of designing and constructing mechanically stabilized earth (MSE) walls, including gabion style facing system as specified herein and in conformity with the lines, grades, design, and dimensions shown on the Contract Drawings. The work shall also include design and construction of the cast-in-place concrete traffic barrier located on top of the MSE walls in conformity with the lines, grades, design, and dimensions shown on the Contract Drawings.

1. The mechanically stabilized earth walls shall be designed and constructed of one of the following three wall types, or approved equal:
   b. Hilfiker Gabion Faced M.S.E. Wall, by Hilfiker Retaining Walls.
   c. Terramesh System, by Maccaferri Inc.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below may also be related to the proper performance of this work.

1. Section 03 05 15, Portland Cement Concrete
2. Section 03 11 00, Concrete Forming.
3. Section 03 20 00, Concrete Reinforcing.
4. Section 03 35 00, Concrete Finishing.
5. Section 31 20 00, Earth Moving.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents

1. American Association of State Highway and Transportation Officials (AASHTO)
   a. LRFD Bridge Design Specifications, 6th Edition
   c. AASHTO M32 Steel Wire, Plain, for Concrete Reinforcement
   d. AASHTO M55 Steel Welded Wire Fabric, Plain, for Concrete Reinforcement
   e. AASHTO M111 Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
f. AASHTO M164 High-Strength Bolts for Structural Steel Joints

7. Washington State Department of Transportation (WSDOT)
   a. Standard Specifications for Road, Bridge and Municipal Construction, (WSDOTSS)
   b. Geotechnical Design Manual, current version (GDM)
   c. Test Method 113 Determination of Degradation Value
   d. Test Method 925 Determination of Long-Term Strength for Geosynthetic Reinforcement

3. Sound Transit Light Link Rail, Design Criteria Manual (DCM)

   a. ASTM A 1011 Standard Specifications for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability and Ultra High Strength
   b. ASTM D 1557 Standard Test Method for Laboratory Compaction Characteristics of soil using Modified Effort (56,000 feet lb/ft³)
   c. ASTM D 4355 Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon Arc Type Apparatus)

5. Geosynthetic Research Institute (GRI)
   a. GRI:GG1 Geogrid Rib Tensile Strength
   b. GRI:GG2 Geogrid Junction Strength

6. Federal Highway Administration (FHWA)
   a. FHWA-NHI-10-024 and FHWA-NHI-10-025 Design and Construction of Mechanically Stabilized Earth Walls – Volumes 1 and 2
   b. FHWA-NHI-11-32 LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations
1.03 SUBMITTALS

A. General: Refer to Section 01 33 00, Submittal Procedures, for submittal requirements and procedures.

B. Certificate of Compliance: Furnish to the Resident Engineer a Certificate of Compliance certifying that the MSE wall materials comply with the applicable Articles of this Section.
   1. Provide a manufacturer's Certificate of Compliance for all concrete admixtures, cement, fly ash, steel reinforcing bars, reinforcing strips, reinforcing mesh, tie strips, fasteners, and joint materials.
   2. The manufacturer’s Certificate of Compliance for wall geogrids shall include the information specified in WSDOTSS Section 9-33.4(4) for each geogrid roll, and shall specify the geogrid polymer types for each geogrid roll.
   3. Provide a manufacturer's Certificate of Compliance for gabion wall assembly including wire mesh baskets, spiral binders, lacing and tie wire.

C. A copy of all test results performed by the Contractor, or the Contractor's supplier, to ensure compliance with this Section.

D. Before fabrication, submit a field construction manual, prepared by the wall manufacturer, for the MSE walls. This manual shall provide step-by-step directions for construction of the wall system.

E. Qualifications of MSE wall manufacturer's representatives and MSE Wall Contractor for approval by the Resident Engineer.

F. Design Calculations and Shop Drawings
   1. Submit detailed design calculations and shop drawings. Wall construction shall not begin without the Resident Engineer's written acceptance of the design calculations and shop plans.
   2. The submittal shall include detailed design calculations and all details, dimensions, quantities, and cross-sections necessary to construct the wall. The calculations shall include a detailed explanation of all symbols and computer programs used in the design of the walls. All computer output submitted shall be accompanied by supporting hand calculations detailing the calculation process.
   3. Design details shall be based on the current WSDOT Geotechnical Design Manual and AASHTO LRFD Bridge Design Specifications, as required by Section 8.0 of the DCM and also based on the following:
      a. Design shall be based on the following documents, listed in order of precedence, with those toward the top of the list having highest precedence:
         1) DCM
         2) WSDOT Geotechnical Design Manual (WSDOT GDM)
         3) AASHTO LRFD Bridge Design Specifications
         4) AASHTO Guide Specifications for LRFD Seismic Bridge Design
         5) FHWA NHI-10-024 Design and Construction of Mechanically Stabilized Earth Walls – Volumes 1 and 2
6) FHWA NHI-00-024 and FHWA NHI-00-025 Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines

7) FHWA NHI-11-32 LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations

b. Seismic design shall be in accordance with the WSDOT Geotechnical Design Manual and AASHTO Guide Specifications for LRFD Seismic Bridge Design, except that the ground acceleration coefficient shall be based on the project specific design earthquakes as stated in the DCM. The stability of the wall against total collapse for the DCM MDE seismic event shall be investigated.

c. The design shall take into consideration application of all dead and live, construction phase and permanent loads, including consideration of loading from the erection truss, traffic barrier, and future phase surcharge loading as shown on the Contract Drawings. Construction phase loads include dynamic loading due to construction equipment and activities. Permanent loads include the track slab and light rail vehicles and passengers (see DCM). Permanent loads may be installed in future contracts.

d. Back-to-back walls shall be designed in accordance with FHWA NHI-00-043, Chapter 5, “Design of MSE Walls with Complex Geometrics”. FHWA NHI-00-043 shall be used only for external stability of the wall. Internal wall design shall be based on AASHTO.

e. The following maximum soil strengths and bearing pressures shall be used. The bearing pressures are based on the minimum embedment depth of 2 feet. Greater embedments may allow higher bearing pressure, and may encounter denser soils. Higher bearing pressures will need to be verified with settlement calculations:

<table>
<thead>
<tr>
<th>Soil Properties</th>
<th>Density (pcf)</th>
<th>Internal Friction Angle (degrees)</th>
<th>Cohesion (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced Soil (WSDOT 9-03.14(1)</td>
<td>130</td>
<td>38</td>
<td>0</td>
</tr>
<tr>
<td>Gravel Borrow)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retained Soil (WSDOT 9-03.14(3)</td>
<td>125</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>Common Borrow)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

f. The face of the wall shall be embedded to a depth of 14 percent of the exposed wall height but not less than 2 feet.

g. The bottom reinforcement shall be located no higher than the final grade elevation, and the minimum length of all reinforcement shall be 100 percent of the wall height, except for back-to-back walls, which shall be designed according to FHWA NHI-00-043.

h. Design shall ensure a design life of 100 years for the integrated wall system.
i. Include drainage provisions in design.

j. Welded wire facing, gabion facing baskets, all connection materials, wire screen, and steel and polymeric reinforcement elements shall be designed to have corrosion resistance-durability to ensure a minimum design life of 100 years in accordance with DCM.

k. Design, fabricate and install corner details including brackets and reinforcement.

l. Include design calculations showing maximum lateral wall displacements that are allowed. These maximum lateral displacements shall be computed for all wall heights. Develop, design, and detail remedial measures that will ensure the structural integrity of the wall in the event that the maximum allowable lateral displacements are exceeded.

m. Include design calculations for the traffic barrier on top of the MSE wall system. The traffic barrier shall be designed for a minimum TL-1 impact load. The MSE wall system supporting the traffic barrier shall be designed for the additional loading induced by the traffic barrier to the MSE wall system as outlined in the WSDOT GDM.

4. Fully detailed shop drawings including the following items:

a. Plan and elevation sheet(s) for each wall, containing:
   1) Elevation view of each wall with: elevation at top of wall, at all horizontal and vertical break points, and at least every 50 feet along the wall; elevations at top of leveling pads and foundations, distance along face of wall to all steps in foundations and leveling pads; designation as to type of panel or module; length, size, and number of geogrids or mesh or strips and distance along face of wall to where changes in length of geogrids or mesh or strips occur; and location of original and final ground line; summary of quantities for all items for each wall, including incidentals.
   2) Plan view of each wall indicating offset from construction centerline to face of wall at all changes in horizontal alignment; limit of widest module, geogrid, mesh, or strip; and centerline of any drainage structure or drainage pipe behind, or passing under or through the wall.
   3) General notes for design and construction of wall.
   4) Horizontal and vertical curve data affecting wall construction.
   5) Cross-sections showing construction limits, and limits and extent of select granular backfill material placed above original ground.
   6) Gabion style facing details and detailed sequencing of gabion face installation.
   7) Limits and extent of reinforced soil volume.
   8) Submit extent and details of finishes for the gabion face for approval by the Resident Engineer.
9) Details of connections and joints between the subgrade geogrid, mesh, or strip and the gabion face materials.

10) Details of supplemental corrosion protection systems such as grounding rods, spiral ties, or coatings.

b. All details, including reinforcing bar bending details. Bar bending details shall be in accordance with WSDOTSS Section 9-07.1.

c. Foundation and leveling pad details, including details for steps in foundations or leveling pads, as well as allowable and actual maximum bearing pressures for DCM Load Groups I and VII.

d. All modules and facing elements shall be detailed. Show all dimensions necessary to construct the element, all reinforcing elements in the element, and the location of reinforcement element attachment devices embedded in the facing.

e. All details for construction of the wall, structural abutments, and foundation elements shall be clearly shown.

f. All details for connections to coping shall be shown.

g. All details for the traffic barrier at the top of the wall, including cross section geometry, construction joints, reinforcement, and attachments. Details shall show the interface of, and the interaction between, the barrier and the top layers of MSE soil reinforcements and gabion facing.

5. The plans shall be prepared under the direction of and signed by a Professional Engineer, licensed in the State of Washington.

6. Provide a schedule for construction of each wall. Include start and finish dates, and duration for major tasks.

7. Provide manufacturer’s product data and details for gabion face system.

8. Samples: Provide the following labeled with supplier’s name, address, and phone number:

a. 5lb sample of gabion fill aggregate showing full range of sizes and colors.

b. 12”x12” sample of gabion wire mesh.

9. Mock-up: Provide minimum 3’x3’ mock-up of gabion face. Mock-up shall be of the required design depth.

1.04 QUALITY ASSURANCE

A. The completed walls shall meet the following tolerances:

1. Deviation from the vertical design batter and horizontal alignment shall not exceed 1/2 inch when measured along a 10-foot straight edge.

2. Deviation from the vertical design batter of the wall shall not exceed 1/2 inch per 10 feet of wall height.

3. Maximum allowable offset in any panel joint shall be 1/2 inch.

4. Base of retaining wall excavation shall be within 3 inches of staked elevations.
5. External wall dimensions shall be placed within 2 inches of staked locations.

6. Minimum structural thickness of concrete facing panels shall be 5.5 inches.

B. At start of wall construction the MSE wall contractor shall provide a qualified and experienced representative to resolve wall construction problems as directed by the Resident Engineer. Qualified representatives shall have a minimum 10 years’ experience in MSE wall construction prior to the start of MSE wall construction under this Contract. The Contractor shall implement recommendations made by the representative, as accepted by the Resident Engineer.

PART 2 - PRODUCTS

2.01 GENERAL

A. Make arrangements to purchase reinforcing strips or reinforcing mesh, gabion face system, attachment devices, joint filler, and all necessary incidentals from one of the following sources or approved alternate. All materials shall be from the same source.

1. Tensar International Corporation.
   Alpharetta, GA 30009

2. Hilfiker Retaining Walls
   Eureka, CA 95503

3. Maccaferri Inc.
   Williamsport, MD 21795

2.02 GEOGRIDS AND GEOSYNTHETICS

A. Wide width tensile strength of geogrid shall be an average roll value (the average test results for any sampled roll in a lot shall meet or exceed the values shown in the table). Strength shall be determined in accordance with ASTM D 4595 or GRI:GG1, modified to address geogrids as follows:

1. Minimum specimen width shall be 8-inches with a minimum gage length of 8-inches. Gage length shall be a minimum of two grid apertures (three junctions) long. Gage length shall be in increments of whole grid apertures. For purpose of calculating tensile strength, specimen width shall be distance between outermost ribs of specimen as measured at midpoint of those ribs plus the average center to center spacing between ribs. When testing under GRI:GG1, conduct test at 10 percent per minute based on the gage length specified above.

B. Geogrid reinforcement shall consist of a regular network of integrally connected polymer tensile elements with an aperture geometry sufficient to permit mechanical interlock with the surrounding backfill. Long chain polymers in the geogrid tensile elements shall consist of at least 95 percent by mass of material of polyolefins. Material shall be free of defects, cuts, and tears.

C. Geogrid joint strength determined in accordance with Geosynthetic Research Institute test method GRI:GG2 in the direction of loading (e.g., perpendicular to the wall face) shall be greater than or equal to 80 percent of the ultimate strength (T_{ult}) of the grid element to which it is attached. For this determination, T_{ult} shall be established using Geosynthetic Research Institute test method GRI:GG1.

D. The ultraviolet (UV) radiation stability, ASTM D 4355, shall be a minimum of 70 percent strength retained after 500 hours in weatherometer.
E. Acceptance Samples and Testing

1. The Resident Engineer will take random samples of the geogrid materials at the job site to be tested by the Contractor. Approval of the geogrid materials will be based on testing of samples from each lot. A lot shall be defined as all geogrid rolls sent to the project site produced by the same manufacturer during a continuous period of production at the same manufacturing plant having the same product name.

2. Geogrid samples will be tested for conformance to the specified material properties. The Contractor shall submit the test results to the Resident Engineer within 14 calendar days of the taking of the samples. If the test results indicate that the geogrid lot does not meet the specified properties, the roll or rolls, which were samples, will be rejected. Two additional rolls for each roll tested, which failed from the lot previously tested, will then be selected at random by the Resident Engineer for sampling and retesting. If the retesting shows that any of the additional rolls tested do not meet the specified properties, the entire lot will be rejected. If the test results from all the rolls retested meet the specified properties, the entire lot minus the roll(s), which failed, will be accepted.

3. All geogrid materials, which have defects, deterioration, or damage, as determined by the Resident Engineer, will be rejected. All rejected geogrid materials shall be removed from the site and replaced at no expense to Sound Transit.

F. Except as otherwise noted, geogrid identification, storage, and handling shall conform to the requirements specified in WSDOTSS Section 2-12.2. The geogrid materials shall not be exposed to temperatures less than –20 degrees F or greater than 122 degrees F.

2.03 REINFORCING STRIPS

A. Shop fabricate from hot rolled steel conforming to the requirements of AASHTO M 223 Grade 65 or approved equal.

B. Steel reinforcing strips of adjacent modules shall not be electrically interconnected. The reinforcing strips shall be coated with a fluidized-bed epoxy resin system or coal-tar epoxy system.

2.04 REINFORCING MESH

A. Shop fabricate of cold drawn steel wire conforming to the minimum requirements of AASHTO M 32 and weld into finished mesh fabric in accordance with AASHTO M 55.

B. The reinforcing mesh shall be coated with a fluidized-bed epoxy resin system or coal-tar epoxy system.

2.05 TIE STRIPS

A. Shop fabricate from hot rolled steel conforming to the requirements of ASTM A1011 Grade 50 or approved equal.

B. Coat with a fluidized-bed epoxy resin system or coal-tar epoxy system prior to module construction.

2.06 CONCRETE LEVELING PAD

A. Class 3000 concrete conforming to WSDOTSS Section 6-02.
2.07 BACKFILL MATERIAL

A. Backfill material used in MSE reinforced zone shall be free draining, free from organic or otherwise deleterious material, and shall conform to the requirements as specified in WSDOTSS Section 9-03.14(1), Gravel Borrow, except that:

1. If geosynthetics or epoxy/PVC-coated steel inclusions are used in the compaction zone, the maximum particle size shall be reduced to 3/4 inch.

2. The Plasticity Index (PI) of the fines passing the No. 200 sieve shall be less than or equal to 6.

B. All backfill material shall be substantially free of shale or other soft, poor durability particles, and shall not contain recycled materials, such as glass, shredded tires, Portland cement concrete rubble, or asphalitic concrete rubble.

C. Backfill material shall conform to the following requirements:

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Allowable Test Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles Wear, 500 rev.</td>
<td>AASHTO T 96</td>
<td>35 percent max.</td>
</tr>
<tr>
<td>Degradation</td>
<td>WSDOT Test Method 113</td>
<td>15 min.</td>
</tr>
<tr>
<td>pH</td>
<td>AASHTO T289 - 91</td>
<td>4.5 to 9</td>
</tr>
<tr>
<td>Resistivity</td>
<td>AASHTO T288 - 91</td>
<td>Greater than 3000 ohm-cm</td>
</tr>
<tr>
<td>Chlorides</td>
<td>AASHTO T291</td>
<td>Less than 100 parts per million</td>
</tr>
<tr>
<td>Sulfates</td>
<td>AASHTO T290</td>
<td>Less than 200 parts per million</td>
</tr>
<tr>
<td>Soil Organic Content</td>
<td>AASHTO T267</td>
<td>Less than 1 percent</td>
</tr>
</tbody>
</table>

D. Wall backfill material satisfying these gradation, durability, and chemical requirements shall be classified as non-aggressive.

E. Embankment Backfill Material used behind the MSE reinforced zone shall meet the Structural Fill requirements of Section 31 20 00, Earth Moving.

F. Backfill Material contained within the gabion facing system shall match the approved submittal sample uniformly throughout the length and height of constructed walls. Supplier shall ensure consistent availability of similar gabion facing backfill material throughout the duration of construction.

2.08 GABION FACING

A. Gabion facing shall be constructed of welded wire mesh basket filled with stone aggregate and closed with spiral binders, stiffeners, lacing wire and ring fasteners.

1. Wire Mesh Basket: Welded steel wire mesh conforming to AASHTO M55, 2"x2"square openings. Welds to have minimum shear strength of 800 lbf (3560 newtons). Wire gauge to be sized for 100 year design lifespan, galvanized after fabrication. per AASHTO M111 minimum coating 2.0 oz/ft². Where the length of the basket exceeds 0.5 times its width, the basket shall be equally divided into cells less than or equal to 0.5 times the basket width using diaphragms of the same type and size mesh as the mattress panels. Each basket shall be prefabricated with the necessary panels and diaphragms, and secured so that they rotate into place. Minimum basket dimensions are as follows:

   a. Basket Width (parallel to wall face): 3'-0"
   b. Basket Depth (perpendicular to wall face): 1'-6"
2. Lacing Wire, Spiral Binders, Connecting Wire: Galvanized steel wire in gauge and strength to match wire mesh basket and per gabion manufacturer’s recommendation.

3. Ring Fasteners: High tensile strength galvanized wire rings sized per manufacturer’s recommendation.

4. Aggregate: Crushed limestone aggregate, washed and free of soil, fines, and debris, with 100% passing an 4” sieve opening and 0% passing a 2” sieve opening.

B. All gabion facing units shall be electrically interconnected.

PART 3 - EXECUTION

3.01 WALL EXCAVATION:
A. Excavation shall be in accordance with the requirements of Section 31 20 00, Earth Moving, and in conformity to the limits required for each stage of construction.

3.02 FOUNDATION PREPARATION
A. Foundation preparation shall be in accordance with the requirements of Section 31 20 00, Earth Moving.

B. The foundation for the MSE wall structure shall be graded level for a width equal to or exceeding the length of reinforcing as shown in the approved shop drawings, and in accordance with WSDOTSS Section 2-12.3.

C. At each gabion basket foundation level, provide an unreinforced concrete leveling pad as required to construct the wall to within the required tolerances. Cure leveling pad a minimum of 12 hours before placement of wall panels. Leveling pad shall be sized to conform with the allowable soil bearing pressure.

3.03 SOIL REINFORCEMENT
A. Bending of soil reinforcement in the horizontal direction (plane of reinforcement) that produces a permanent deformation in its alignment shall not be allowed, unless detailed in the approved shop drawings. Gradual bending that does not produce permanent deformation is allowed; however, design shall consider the effect of bending on pullout resistance and reinforcement stress including any potential uneven stress distribution.

B. Skewing of soil reinforcement by rotating on the horizontal plane at connection to the gabion facing will be allowed within the following limits:
1. The connection shall be structurally designed to rotate without bending and without altering the stress distribution at contact points.
2. The skew angles shall neither exceed 30 degrees nor AASHTO specifications limits.

3.04 WALL ERECTION
A. Geogrid reinforcing shall be placed in accordance with WSDOT’s Section 2-12.3 and as specified in this Section.
1. The Contractor shall stretch out the geogrid in the direction perpendicular to the wall face to remove all slack and wrinkles, and shall hold the geogrid in place with soil piles or other methods as recommended by the geogrid manufacturer, before placing backfill material over the geogrid to the specified cover.

2. The geogrid reinforcement shall be continuous in the direction perpendicular to the wall face from the back face of the concrete panel to the last geogrid node at the end of the specified reinforcement length. Geogrid splices parallel to the wall face will not be allowed.

3.05 BACKFILL PLACEMENT

A. Backfill placement shall closely follow erection of each course of soil reinforcement. Backfill shall be placed in such a manner as to avoid damage or disturbance to the wall materials or misalignment of the gabion face elements.

B. The Contractor shall place wall backfill at geogrid soil reinforcement in accordance with WSDOT Section 2-12.3 and as specified in this Section.

1. The Contractor shall not end dump fill material directly on the geogrid reinforcement.

2. The Contractor shall ensure that 6 inches minimum of backfill shall be between the geogrid reinforcement and construction vehicles or equipment tires or tracks at all times.

C. Backfill placement and compaction methods shall ensure that no voids exist directly beneath the wall reinforcement near the gabion facing panels.

D. Wall materials that become damaged or disturbed during backfill placement shall be either removed and replaced at the Contractor’s expense or repaired and corrected as directed by the Resident Engineer.

E. Any misalignment or distortion of the gabion facing due to placement of backfill outside the limits of this Section shall be corrected as directed by the Resident Engineer.

F. The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer of material:

1. The moisture content of all backfill material shall meet the requirements of WSDOT’s Section 2-03.3(14)C, Method C.

2. The Optimum Moisture Content shall be determined in accordance with ASTM D2216.

G. Backfill shall be compacted within the reinforced backfill and retained backfill zones to a uniform density of at least 90% (based on ASTM D1557) throughout the reinforced soil mass, and to a uniform density of at least 95% within 2 feet of top of wall. Only small, hand operated compaction equipment shall be used within 3 feet of wall facing panels.

H. At the end of each day’s operation, the Contractor shall shape the last level of backfill to permit runoff of rainwater away from the wall face. In addition, the Contractor shall not allow surface runoff from adjacent areas to enter the wall construction site.

3.06 GABION FACE ERECTION

A. Install gabion assembly per manufacturer’s directions and anchor to MSE wall.

B. Erect gabion assembly with vertical wires plumb and horizontal wires level and continuously aligned with adjacent basket. All corners to be 90 degrees.
C. Gabions, fasteners, and wires to be free of sharp or protruding ends.

D. Grounding
   1. All gabions and metal components to be welded together to create continuous conductivity.
   2. Install grounding rods and connections to ground all gabion components against stray current.

E. Aggregate backfilling
   1. Install aggregate and compact in lifts not to exceed 12".
   2. Provide bracing and filling methods as needed to maintain shape and alignment of baskets throughout filling and compacting.
   3. Close gabion top after compaction and settling of aggregate so aggregate maintains contact with top of gabion.

3.07 TRAFFIC BARRIER INSTALLATION

A. The Contractor shall install the traffic barrier where shown on the Contract Drawings and approved shop drawings after completing the wall. The Contractor shall install the barrier in a manner that prevents movement of the gabion facing panels and prevents ripping, tearing, or pulling of the wall reinforcement. The Contractor shall demonstrate to the Resident Engineer prior to beginning traffic barrier installation that the installation method will not rip, tear, or pull the wall reinforcement.

B. Traffic barrier shall be constructed to the dimensional requirements as shown on the Contract Drawings. Dimensions not indicated in the Contract Drawings shall be determined by the MSE wall design Engineer.

C. The moment slab supporting the traffic barrier shall be continuously wet cured for 3 days in accordance with WSDOTSS Section 6-02.3(11).

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for watering of installed restoration planting by means of in-kind restoration of existing irrigation systems or other temporary means accepted by Resident Engineer.

1. Verification of the existing site conditions and preparation of Watering Plan Report accepted by the Resident Engineer.

2. Automatic Irrigation System Restoration:
   a. Bidder-designed fully automatic in-ground irrigation system including supply of all labor, materials, equipment, tools; and transportation and performance of all operations in connection with the design and installation of the irrigation system including piping, valves, fittings, sprinklers, automatic controls, final adjustment to sprinklers heads to ensure complete coverage of planting areas.
   b. Submit design shop drawings

3. Where no automatic irrigation system exists, temporary watering by means other than automatic irrigation system.

4. Coordination of this Work with other trades.

5. Maintain and operate the irrigation and temporary watering systems during the planting Warranty Period of 1 year duration to ensure the health and resumption of growth of planted materials.

6. Warranty Period for the irrigation and watering systems for 1 year.

B. Provide complete coverage with minimum maintenance and without overspray onto walks, pavements, and structures.

C. Related Sections: The Work of the following Sections is related to the Work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this Work.

1. Section 01 31 14, Coordination with Others.

2. Section 01 56 39, Temporary Tree and Plant Protection

3. Section 08 71 00, Door Hardware.

4. Division 26, Electrical.

5. Section 31 20 00, Earth Moving.

6. Section 32 90 00, Planting.
7. Section 32 92 00, Turf and Grasses.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   b. American Society for Testing and Materials (ASTM);
      a. ASTM A53/A53M Pipe, Steel, Black and Hot-Dip Zinc-Coated, Welded and Seamless.
      b. ASTM B3 Soft or Annealed Copper Wire.
      c. ASTM B33 Tinned Soft or Annealed Copper Wire for Electrical Purposes.
      d. ASTM D1785 Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.
      e. ASTM D2464 Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80.
   c. American Water Works Association (AWWA):
      a. ANSI/AWWA C500 Metal Seated Gate Valves for Water Supply Service.
      b. Accepted Procedure and Practice in Cross-Connection Control Manual, published by the Pacific Northwest Section of AWWA.
   d. National Electrical Manufacturers Association (NEMA):
      a. NEMA WC5 Thermoplastic Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.
   e. Washington State Department of Transportation
      a. Standard Specifications for Road, Bridge and Municipal Construction 2012
   f. University of Washington
      a. Facilities Design Manual

1.03 QUALITY ASSURANCE

A. Design Criteria:
   1. Delegated design: The bidder-design irrigation and temporary watering system shall be designed by an irrigation specialist with the technical qualifications and experience for design of irrigation systems.
   2. The Contractor shall verify all site measurements and account for any discrepancies with the Drawings in the design of the irrigation system.

B. Product Criteria:
1. When 2 or more units of the same type or class of material or equipment are required, these units shall be products of 1 manufacturer.

2. Components of the irrigation system shall be compatible with each other and the system as a whole.

C. System Requirements:

1. Complete head to head sprinkler coverage for all planting areas. The Contractor shall achieve full and complete coverage without overspray onto pavements, buildings, or other site elements.

2. Sprinklers shall operate at their optimal operating pressure. Precipitation rates of sprinklers within individual zones shall be matching within a tolerance of plus or minus 10 percent.

3. Divide the irrigation system into zones that provide separate watering volumes and durations based on water needs for plant types and specific micro-climate conditions including soil type, soil moisture conditions, slope, solar exposure, and wind exposure.

4. Provide an irrigation water connection header that includes a gate valve, pressure reducing valve, backflow prevention assembly, master valve and quick coupler valve.

5. Sleeve all pipe installed under pavements.

6. The entire system shall be designed to permit purging of water such that risk of damage due to freezing can be eliminated by draining or blowing out the system for the winter.

7. Provide 1 quick coupler valve for every 200 feet of mainline and at the end of each mainline branch.

8. Provide 2 spare control wires to the ends of each mainline branch.

9. Size pipes to ensure water velocity does not exceed 5 feet per second.

1.04 ADMINISTRATIVE REQUIREMENTS

A. Coordination: Per Section 01 31 14, Coordination with Others. Coordination required with property owners having jurisdiction over Work sites.

1.05 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Watering Plan Report

1. Submit report for acceptance by Resident Engineer prior to any construction activities.

2. Include:

   a. Photo Documentation and Inventory:

      1) Photograph Irrigation systems on proposed project sites immediately following Notice to Proceed to record existing conditions of existing irrigation systems, or lack thereof.
2) Write description of type of irrigation system, condition of system, and other pertinent information to aid in in-kind replacement of system. Indicate jurisdiction of each location, and development standards to be met.

b. Shop Drawings for Automatic Irrigation Systems:

1) Provide scaled plans and details of construction and installation of all proposed irrigation systems for all areas of planting. Show locations, depths, size, and information as applicable, of the following items:
   a) Point of connection and available static water pressure.
   b) Routing of sprinkler mainlines and lateral pipes.
   c) Sprinklers.
   d) Dripline, air/vacuum relief valves, and flush valves.
   e) Gate valves.
   f) Irrigation control valves.
   g) Quick coupling valves.
   h) Routing of control wires.
   i) Other irrigation system component locations necessary to accurately represent authorized changes to the irrigation system.
   j) Include shop drawings for all candidates submitted for equivalency status to specified products.

2) Obtain approval of Resident Engineer for minor variations in detail for the purpose of improving fabrication and installation procedures, but not affecting general design.

c. Watering Systems for Work Areas without Automatic Irrigation Systems

1) Provide report indicating location, jurisdiction, proposed watering methods, source of water, and frequency, and duration of water for all Work areas without Automatic Irrigation Systems.

C. Product Data: Include manufacturer's product literature for all products to be installed in this system. Include material showing manufacturer's name; catalog numbers; catalog cuts; technical data; and the installation, operation, and maintenance instructions for each product.

D. Point of Connection Water Pressure Tests: Test water pressure at each irrigation point of connection. Submit written results of test to the Resident Engineer.

E. Record Drawings:

1. Record accurately in red ink on 1 set of black-line prints all changes in the Work constituting departures from the approved Watering Plan Report.
2. Record the changes and dimensions in a legible manner to the satisfaction of the Resident Engineer. Before Final Inspection of the Work, submit Record Drawings to the Resident Engineer for review.

3. Dimension from 2 permanent points of reference (buildings, monuments, sidewalks, curbs, and pavements). Record data on Record Drawings daily as the Work is being installed.

4. Show locations, depths, size, and information as applicable, of the following items:
   a. Point of connection and available static water pressure.
   b. Routing of sprinkler mainlines and lateral pipes.
   c. Sprinklers.
   d. Dripline, air/vacuum relief valves, and flush valves.
   e. Gate valves.
   f. Irrigation control valves.
   g. Quick coupling valves.
   h. Routing of control wires.
   i. Other irrigation system component locations necessary to accurately represent authorized changes to the irrigation system.

5. Maintain Record Drawings on site.

F. Submit Operation and Maintenance Manuals in accordance with Article 1.05B and Section 01 78 23, Operation and Maintenance Data.

G. Submit controller charts in accordance with Article 1.05B.

H. Submit special tools and spare parts in accordance with Article 1.07C.

1.06 SEQUENCING AND SCHEDULING

A. Schedule a Preconstruction Meeting in conjunction with the Preconstruction Meeting described in Section 32 90 00, Planting.

B. Coordinate installation of irrigation with all other Work.

C. Coordinate layout and installation of irrigation sleeves, conduits, and piping under paved areas and other features prior to their construction.

D. Coordinate installation of irrigation system with excavation of planting beds and backfilling of planting beds with topsoil. Refer to Section 32 90 00, Planting for requirements.

E. Install and test the irrigation system before installation of plant material except as noted herein. Coordinate layout and installation of irrigation system with location and installation of plant material to ensure that there will be complete and full irrigation coverage of planting.
F. Stake tree locations in the field prior to installation of irrigation pipe and sprinklers. Refer to the Planting Plans and Details on the Contract Drawings for plant setbacks and spacing requirements.

G. Trees shall be located and planted prior to the installation of the irrigation system.

1.07 TURNOVER ITEMS

A. Controller Charts:
   1. Record Drawings require approval by Sound Transit before charts are prepared.
   2. Provide 1 irrigation zone location chart, sized to fit inside of controller door, for each automatic controller. Show the area covered by the irrigation controller.
   3. The chart is a reduced copy of the Record Drawing. In the event that the controller sequence is not legible when the print is reduced, enlarge to a readable size.
   4. Mark the chart with a different color to show the area of coverage for each zone.
   5. When completed and accepted, hermetically seal chart between 2 pieces of transparent plastic. Install chart in controller enclosure using Velcro fasteners.
   6. Complete irrigation zone location charts prior to Final Inspection.

B. Operation and Maintenance Manuals: Within 10 days prior to Final Inspection, prepare and deliver to the Resident Engineer the required descriptive materials, properly prepared in 2 individually bound copies of the operation and maintenance manual. Describe the material installed in sufficient detail to permit operating personnel to understand, operate, and maintain equipment. Include spare parts lists and related manufacturer's information for each equipment item installed. Include following information in manual:
   1. Index sheet listing Contractor's address and telephone number, including names and addresses of local manufacturer's representatives.
   2. Complete operating and maintenance instructions on major equipment.
   3. Manuals: As specified in Section 01 78 23, Operations and Maintenance Data.

C. Special Tools and Spare Parts:
   1. Supply the following items as part of Contract:
      a. 4 percent additional sprinklers and nozzles of each type and spray pattern shown on the Contract Drawings.
      b. 2 wrenches for disassembly and adjustment of each type of sprinkler head installed.
      c. 2 keys for each automatic controller.
      d. 1 coupler with 3/4 inch bronze hose bib, bent nose type with hand wheel, and 1 coupler key for each 5 quick couplers installed.
      e. 1 valve box cover key for each 10 valve boxes.
      f. Backflow device valve handles.
2. Deliver tools and spare parts to the Resident Engineer at conclusion of Final Inspection.

D. Provide the following additional documentation at close of Contract:

1. Record Drawings.

1.08 WARRANTY

A. General Warranty: The Special Warranty specified in this Section shall not deprive the Sound Transit of other rights that Sound Transit may have under other provisions of the Contract Documents, and shall be in addition to, and run concurrent with, other warranties made by the Contractor under requirements of the Contract Documents.

B. Make repairs and replacements and guarantee the satisfactory operation of the entire system in every detail for the 1 year Warranty Period. All warranty repairs and replacements are part of the Contract.

C. Fees:

1. Fees for normal inspections or observations by the Resident Engineer will be paid for by the Sound Transit.

2. Additional inspections, travel expenses, administrative costs and tests required because of defective work or ill-timed notices will be made at the Contractor's expense.

D. Additional Requirements:

1. Repair settling of trenches. Restoration of plantings, mulch, grades, pavements or other improvements shall be in accordance with the Contract Documents.

2. Correct irrigation system problems or damage within 24 hours of notice until the Final Inspection of the Work.

3. During the first irrigation season, be available within 1 day for required repairs to the system.

4. Provide a written statement to the Resident Engineer stating that the Contractor shall:

   a. Warrant the satisfactory operation of the entire irrigation system including performance, parts, assemblies and workmanship.

   b. Return to the job site at the beginning of the first winter season to perform a general inspection of the system, test valves and sprinklers, repair leaks and faulty work, check operation of the system, adjust spray patterns for full coverage, drain system, show grounds staff location of drain valves and blow out points, restore areas where trenches have settled, and adjust irrigation controller scheduling if necessary.

   c. Return in spring after the first winter season for a system check and if necessary restore system for spring and summer operation. Explain system and operation methods to grounds staff and have the grounds supervisor furnish a signed statement of compliance with this requirement. Adjust automatic controller scheduling if necessary.
PART 2 - PRODUCTS

2.01 MATERIALS

A. All materials and equipment shall be new and the best grade of its kind. All items of equipment or material shall be as indicated or specified by patent or proprietary name or names of manufacturer, or accepted equal.

B. Proposed substitutions for products listed shall be submitted in accordance with Division 01.

C. All products to meet jurisdictional requirements of property owners where Work occurs. Where jurisdictional requirements do not specify products, refer to materials specified herein, or accepted equal.

2.02 PIPING

A. Pipe for buried irrigation systems shall be PVC except where noted otherwise.

B. PVC Pipe:
   3. Schedule 80 female adapters for transition between PE and PVC Pipe.

C. PVC Threaded Nipples: 6 inches long, 1/2 inch diameter, Schedule 80, complying with ASTM D1785.

D. Sleeves: PVC pipe, Schedule 80. Sized as shown on the Contract Drawings.

E. PE Pipe: Class 160. Continuous run within sleeves.

2.03 PIPE FITTINGS


B. PE Pipe fittings: Fused polyethylene or brass internal barb fittings. For pipe diameter greater than 5/8 inch, use 2 stainless hose clamps and brass barb fittings at each joint, unless noted otherwise in the Contract Drawings.

2.04 PVC PIPE JOINT COMPOUND AND PRIMER

A. Joint compound: Slow drying, heavy-duty PVC solvent cement type, ASTM 2564.

B. Primer: Tinted, compatible with joint compound; as recommended by manufacturer of PVC pipe, ASTM 656.

2.05 IRRIGATION SPRINKLERS

A. Pop-up Bodies: Use sprinkler pop-up bodies constructed of ultraviolet-resistant plastic construction, an integral check valve that holds up to 8 feet of head (3.50 psi), heavy duty retract spring, and pressure regulation capability in either the pop-up stem or under the nozzle. Use pop-up bodies with 12 inch risers, unless otherwise noted on Contract Drawings. Use Rain Bird 1800-SAM series, Hunter PRS series, Toro 570Z-XF series, or accepted equal.
B. Use sprinkler nozzles constructed of high strength, ultraviolet-resistant and impact-resistant plastic with anti-clogging valve adjustment screw for flow and radius adjustment. Use nozzles that have matched precipitation rates for individual irrigation zones. Provide adjustable arc nozzle where noted on Contract Drawings. Use rotary stream sprinkler and bubbler nozzles from Rain Bird, Hunter, Toro, or accepted equal.

C. Provide sprinklers as shown on the Contract Drawings. Use riser nipples for all sprinklers the same size as the threaded opening in the sprinkler body. Sprinklers of the same type shall be by the same manufacturer.

D. Swing Joints: as shown on the Contract Drawings.

2.06 DRIP IRRIGATION

A. Furnish all product materials required for full and efficient drip irrigation operation. All products shall be of 1 manufacturer for parts compatibility and ease of installation. Product components shall be the most current models and equipment available, and shall supersede obsolete models and equipment that may be specified in these specifications.

B. Dripline shall consist of nominal sized 1/2 inch low-density linear polyethylene tubing with internal pressure compensating, continuously self-cleaning, integral drippers spaced at 18 inches on center. Dripline shall have integral check valves. The tubing shall be brown in color and conform to an outside diameter (O.D.) of 0.67 inch and an inside diameter (I.D.) of 0.57 inch. Individual pressure compensating drippers shall be welded to the inside wall of the tubing as an integral part of the tubing assembly. These drippers shall be constructed of plastic with a hard plastic diaphragm retainer and a self-flushing/cleaning elastomer diaphragm extending the full length of the dripper. Space dripline as indicated on accepted Shop Drawings.

C. Header pipe downstream of the irrigation control valves shall consist of nominal sized 1/2 inch low-density linear polyethylene blank tubing. The tubing shall be brown in color and conform to an outside diameter (O.D.) of 0.67 inch and an inside diameter (I.D.) of 0.57 inch.

D. Drip Irrigation Components:

1. Dripline Fittings: All fittings shall be constructed in one of the following end configurations: barbed insert fittings only; male pipe threads (MPT) with barbed insert fittings; or female pipe threads (FPT) with barbed insert fittings. All fittings shall be constructed of molded brown plastic having a nominal inside dimension (I.D.) of 0.57 inch. Female and male threaded ends shall be capable of mating to standard PVC pipe with tapered threads.

2. Soil Staples: Hold dripline in place with 6 inch long steel soil staples.

3. Automatic Flushing Valves: constructed of brown molded plastic with one of the following end configurations: 1/2 inch MPT or insert inlet with collar.

4. Air/Vacuum Relief Valves: constructed of black and/or gray plastic with a 1/2 inch male pipe thread capable of mating with a threaded PVC reduction bushing or 1/2 inch FPT fitting.

2.07 IRRIGATION CONTROL VALVES

A. Irrigation control valves must be compatible with the controller, provided with a straight or angle pattern of either brass or bronze, and manufactured for the purpose. Control valves must meet the following requirements:
1. Normally closed, 24-V ac, 60 Hertz solenoid actuated globe pattern diaphragm type with valve pressure rating not less than 200 psi.


3. Actuated by a low power, 2.0 watt, 24-V ac solenoid actuator.

4. Flow control stem and cross handle for regulating and shutting off water flow and bleed screw for manual operation without electrically energizing solenoid coil.

5. Provide for internal parts to be removable from top of valve without disturbing valve installation.

2.08 DRIP CONTROL VALVE ASSEMBLY

A. Drip valve assemblies must be compatible with the controller, provided with a straight or angle pattern of either brass or bronze, and manufactured for the purpose:

1. Control Valves: Normally closed, 24 VAC, 60 Hertz solenoid actuated globe pattern diaphragm type with valve pressure rating not less than 200 psi. Actuated by a low power, 2.0 watt, 24 VAC solenoid actuator. Size valves as indicated on the Drawings.

2. Control Valve Body and Bonnet: Glass-filled nylon, with nylon reinforced rubber diaphragm. Encapsulate solenoid coil in molded epoxy. Provide for internal parts to be removable from top of valve without disturbing valve installation.

3. Provide control valve with flow control stem and cross handle for regulating and shutting off water flow and bleed screw for manual operation without electrically energizing solenoid coil.

4. Pressure Regulator: The pressure regulator is a spring-operated piston-type regulator with an externally accessible regulation unit. The body is molded black plastic with a combination of male/female pipe threaded inlet and outlet. The pressure regulator will have a built-in indicator that shows when it is operating.

5. Disc Filter: A multiple disc filter equipped with size 120 mesh and constructed of chemical-resistant thermoplastic for corrosion resistance. The body shall be molded of black plastic with male pipe threads for both inlet and outlet. The disc filter shall be capable of periodic servicing by unscrewing a threaded cap or unlatching the band.

2.09 MASTER VALVES

A. Heavy duty, brass or bronze construction, capable of operation from controller, installed underground with unions, equipped with standard cross handle operating wheel. Normally closed, solenoid actuated globe pattern diaphragm type with valve pressure rating not less than 200 psi.

2.10 UNIONS

A. PVC schedule 80 threaded for below-grade locations, and provided on both sides of the master control valves, irrigation control valves, strainers, backflow prevention assembly, and pressure reducing valves.

2.11 IRRIGATION VALVE BOXES AND VALVE KEYS

A. For irrigation control valves, drip control valve assemblies and gate valves: black plastic valve box with snap lock black cover. Minimum size shall be 16 inches by 12 inches by
10-3/4 inches. Size valve boxes to ensure 3" clearance around and between all connections and valves. Multiple valves may be installed in 1 box, provided that clearances are met.

B. For flow sensor: black plastic valve box with snap lock black cover. Minimum size shall be 16 inches by 12 inches by 10-3/4 inches.

C. For automatic flush valves and air relief valves: Provide a 2 inch diameter, Class 160 PVC protective sleeve with locking cap.


E. Quick coupler valves: as shown on accepted Shop Drawings. Color: black.

F. Provide 1 set of keys required for valves, valve box covers and protective sleeve caps.

2.12 IRRIGATION CONTROLLER

A. Irrigation Controller:
   1. Compatible with Maxicom2 irrigation central control systems. Controller shall include Ethernet connectivity to the Building Management System.
   2. Capable of rain delay shut off and flow control leak detection.
   3. Type: Rain Bird ESP-SAT Series, or accepted equal.

B. Provide controller for complete automatic operation of irrigation system: commercial grade, in weatherproof, lockable box or cabinet, UL listed and with adequate number of stations to operate system. Provide stations with independent time controls with 1 minute incremental settings up to 60 minutes maximum per station. Provide controllers to allow easily made changes on station timing and programs start time without tools or disassembling. Stations may be omitted with time setting of zero minutes. Provide rapid advance between stations and override on each station for manual operation. Provide for schedules up to 1 week and permit multicycle operation as often as every hour. Equip controller with manual start switch for activation of semi-automatic watering cycle.

C. Capable of operating 24-V ac irrigation control valves.

D. Provide a UL listed 24-V ac transformer with controller. Color-code station wiring with irrigation zone indicator key visibly imprinted. Include pump start or master valve control with controller and circuit overload protection to prevent damage due to voltage surges.

E. Controller Housing: Heavy-gauge steel coated with rust inhibitor; finish with industrial gray enamel. Weatherproof cabinet, NEMA Type 4. Gasket controller door and provide covered, heavy-duty lock for protection against theft and vandalism. Mount controller components on face panel for easy removal. Print operating instructions on face of controller for easy access when programming.

F. Lock Cylinder and Master Keying: As specified in Contract Specifications Section 08 71 00, Door Hardware.

2.13 RAIN SENSOR

A. Capable of transmitting signal to irrigation system controller to arrest or delay water schedule due to rain events. Manufacturers: Rain Bird, Hunter, Toro, or accepted equal.
2.14 IRRIGATION CONTROL WIRE

A. Provide thermoplastic insulated, solid copper conductor conforming to ASTM B3, suitable for continuous operation at 24-V ac.

B. Direct burial control wires to irrigation control valves: NEC Type UF or G.E. Co. No. SI-58-51 or accepted equal. Size wire to each irrigation control valve to not exceed 5 percent voltage drop from impressed voltage, not less than No. 14 AWG.

C. Common wire: white insulation. Control wire: 1 color other than white or green. Use a different color control wire for each irrigation control valve.

D. Waterproof wire splice connections: 3M DBY, Rain Bird's Penn-Tite, Scotchlok, or accepted equal.

2.15 WIRE SLEEVE (CONDUIT)

A. Conduit below paving: Schedule 40 PVC sized in accordance with irrigation details, or as required to accommodate the number of control wires at each sleeve.

2.16 BACKFLOW PREVENTER

A. Double Check Valve Assembly with the following:
   1. Internally spring-loaded isolation valves, 2 ball valves, and 4 field test cocks.
   2. All check valve internal parts shall be easily accessible from top of device without removing check valve body from line.
   3. Assembly shall be rated to 175 psi working pressure.
   4. After testing, remove and plug test cocks.
   5. Install washed gravel under assembly to provide adequate drainage.
   6. Backflow preventer size shall be same as pipe or larger.
   7. Febco, Watts, or accepted equal.

2.17 GATE VALVES

A. AWWA C500, bronze body, bronze mounted, non-rising stem with solid wedge gates.

B. Pressure rating: 300 psi.

C. Manufacturer: Wilkins, Nibco, Watts, or accepted equal.

2.18 PRESSURE REDUCING VALVE

A. Brass body, pressure rating 300 psi. Pressure range 25 to 75 psi adjustable. Basis of design: Wilkins 600, or accepted equal.

B. Factory pressure set at 50 psi.

2.19 QUICK COUPLING VALVES

A. Quick coupling valves shall be two-piece body type of heavy duty brass or of heavy duty bronze, and watertight both before and after the coupler is inserted. The valve mechanism shall be designed to ensure that the valve seat is closed before the coupler is removed. Each valve shall have the manufacturer's identification cast or stamped on the valve.
2.20 FLOW SENSOR
A. Capable of transmitting signal to irrigation controller to indicate abnormal flow or leak.
B. Manufacturer: Rain Bird, Hunter, Toro, or accepted equal.

2.21 WATER METER
A. Refer to Mechanical Drawings.

PART 3 - EXECUTION

3.01 GENERAL
A. Conduct all irrigation Work within tree protection areas in accordance with 01 56 39, Temporary Tree and Plant Protection.
B. Code Requirements: Before Work of this Section, carefully inspect installed Work of other trades and verify that the Work is complete to the point where watering may commence properly. Verify Work can be installed in accordance with pertinent codes and regulations, original design, referenced standards and manufacturer's recommendations.
   1. Immediately notify the Resident Engineer of conflicts between equipment or methods indicated or specified with local codes, prior to start of installation. If Contractor fails to give notification, assume responsibility for cost of revisions necessary to comply with code.
C. Grades: Before starting Work, carefully review grades to determine if irrigation Work may proceed. Keep within specified material depths with respect to finish grade.
   1. Coordination with Work of other trades: Make necessary measurements in field to ensure precise fit of items in accordance with original design. Coordinate installation of irrigation materials with other Work. Coordinate piping locations with tree and shrub locations to avoid conflicts

3.02 GENERAL - AUTOMATIC IRRIGATION SYSTEM
A. Verify static pressure at point of connection before installing or restoring automatic irrigation system. Report any discrepancy to Resident Engineer.
B. Service connections: As indicated or designated by utility company. Notify the Resident Engineer at least 3 weeks before electrical and water services are required. Furnish labor and materials to connect to service connection.
C. Water Supply: Connect to water supply at locations indicated in accepted Shop Drawings. Make minor changes caused by actual site conditions.

3.03 INSTALLATION OF WATERING METHODS OTHER THAN AUTOMATIC IRRIGATION SYSTEM
A. Install any equipment necessary for watering methods in approved Watering Plan Report.
B. Do not disturb existing planting.
C. Water slowly to avoid runoff onto pavement or overspray onto walls or other site elements.
3.04 INSTALLATION OF AUTOMATIC IRRIGATION SYSTEM

A. Excavating and Backfilling:

1. Perform excavation and backfilling as specified in Section 31 20 00, Earth Moving. Restore existing surfaces to original condition.

2. Provide not less than 12-inch depth of soil cover over lateral pipes, not less than 18 inch depth of soil cover over mainlines.

3. Provide 2-inch depth of soil cover over driplines.

4. Trenching of new mainline and lateral runs shall be straight and without abrupt grade changes.

5. Trenches shall be free from rock, debris or sharp articles, with a minimum depth as shown in the Contract Drawings. Trench width must allow a minimum of 2 inches between parallel pipes. Do not stack pipes. Excavate trench bottoms with uniform slope of 1/2 percent standard minimum grade.

6. Backfill any excess excavation with suitable materials in conformance with Sections 31 20 00, Earth Moving, and 32 90 00, Planting, which is free of rocks, organic material, or other materials that may damage pipe. Thoroughly compact to give full support to pipe. Backfill when pipe is not in an expanded condition due to heat or pressure. Place backfill material in 6 inch lifts and compact each lift. Backfill to ensure no future settlement of the trench. Thoroughly backfill around sprinklers and be especially attentive to the restriction of movement of sprinklers by external force. Repair all trench settlement during the warranty of this Contract. Backfill trenches uniform with the surrounding grade.

7. Backfill irrigation sleeve trenches and mechanically compact in 2 lifts to a dry density equal to 95 percent of adjacent undisturbed soil. Backfill will conform to adjacent grades without dips, sunken areas, humps, or other surface irregularities.

8. If settlement occurs and subsequent adjustments in pipe, valves, sprinkler heads, lawn or planting, or other construction are necessary, the Contractor shall make all required adjustments.

9. Compaction: Use hand-operated, plate-type, vibratory, or other suitable hand tampers in areas not accessible to larger rollers or compactors. Compact initial backfill material surrounding pipes and conduits to 90 percent maximum density. For pipes, conduits, and sleeves under roads or slabs, compact backfill as specified in Section 31 20 00, Earth Moving.

B. PVC Pipe Assembly

1. Handle plastic materials carefully, store under cover and prevent damage to pipe. Provide support beds for full lengths of pipe when transporting and storing pipe. Do not install damaged or dented pipe.

2. Cut PVC pipe square and remove burrs. Clean pipe and fittings using primer and cleaner recommended by PVC pipe manufacturer. Use tinted primer to aid in visual inspection.

3. Apply a thin, even flow coat of slow drying, heavy duty PVC solvent cement to outside of male fitting. Cure joints as recommended by manufacturer and keep pipe and fitting out of service during curing period. Construct watertight joints equal to or greater in strength than pipe. Do not tap pipe and fittings.
4. Wipe off excess solvent cement with a clean rag. Let welded joints cure at least 15 minutes before moving them and at least 24 hours before water is permitted into pipe.

5. Install pipe fittings for sprinkler and quick coupler valve outlets horizontally and facing the exterior of the planting area.

C. Sleeves:
   1. Place pipe to be installed under pavement and through site walls in a pipe sleeve that has an inside diameter not less than 2 inches larger than outside diameter of the pipe or the combined outside diameter of pipes installed.
   2. Sleeves through building walls shall have watertight seals.

D. Backflow Preventer:
   1. Install unit as indicated on accepted Shop Drawings. Verify exact location with the Resident Engineer before installation.
   2. The backflow prevention assemblies will be inspected and tested before use in accordance with the applicable portions of the Washington Administrative Code and other applicable regulations as set forth by the Washington State Department of Health and the City of Seattle. No water is to flow through the assembly until testing and inspection is accepted by the Resident Engineer.
   3. Inspections and tests shall be completed and the results recorded by a licensed Backflow Assembly Tester (BAT) Operator or by a Contracting Agency Certified Water Works Operator with a CCS-1 or CCS-2 Classification. Document that the devices are in good operating condition prior to flushing and testing of any downstream water pipes.
   4. Installations must be according to procedures outlined in the current edition of "Accepted Procedure and Practice in Cross-Connection Control Manual," published by the Pacific Northwest Section, American Water Works Association.

E. Irrigation Control Valves
   1. Before installation of irrigation control valves, thoroughly flush the mainline.
   2. Use valve box extensions by same manufacturer to ensure that box extends completely below the bottom of the valve. Install locking cover bolts.
   3. Install valve boxes perpendicular to walks and curbs.
   4. Stake location of valve boxes for acceptance by Owner’s Representative prior to installation.

F. Sprinklers:
   1. Thoroughly flush lateral pipes and swing joints prior to installation of sprinklers.
   2. Install sprinklers as shown on accepted Shop Drawings.
   3. Install sprinklers flush with finish grade adjacent to walks, and curbs. Lower heads to grade before completion of maintenance period.
   4. Install sprinklers a minimum of 2 inches and a maximum of 4 inches from hard surface edges.
5. Upon completion of installation, adjust sprinklers to properly distribute water flow to all planting areas. Adjust adjustable sprinklers by fully opening sprinkler nozzle farthest from control valve. Open manual adjustment of control valve slightly to obtain a 24 inch high spray at sprinklers noted above. After this condition has been met, adjust other sprinklers in that section for equal height sprays, regulating control valve as required to maintain condition. Adjust control valve to obtain catalog rate pressure for sprinkler installed. Rotate individual heads to keep sprays within areas of planting areas and eliminate overspray onto pavements, walls, site features and the building.

G. Swing Joints: Connect sprinklers to laterals using a swing joint assembly as shown on accepted Shop Drawings.

H. Drip Irrigation:

1. Install all dripline as indicated on accepted Shop Drawings. Use only Teflon tape on all threaded connections. Make adjustments to alignments to accommodate large trees and shrubs. Ensure alignment adjustments do not reduce amount of water supplied to each plant.

2. Install one 6 inch long metal wire staple every 3 linear feet and 2 staples on each change of direction (tee, elbow, or cross).

3. Dripline fittings shall be mated with dripline by pushing the fitting into the tubing while twisting side to side until the tubing abuts to either adjoining tubing or a fitting stop.

4. Cap or plug all openings as soon as pipes have been installed to prevent the entrance of materials that would obstruct the pipe. Leave in place until removal is necessary for completion of installation.

5. Thoroughly flush all water pipes before installing valves and other accessories.

6. Pipe Sleeves:

a. Place supply header pipes and dripline tubing in PVC Schedule 80 sleeving at least twice the pipe diameter under all paved areas, drives and roads.

b. Extend sleeves 1 foot minimum beyond edge of curbs and pavement, cap ends and flag.

7. Dripline Valves and Accessories:

a. Automatic Flushing Valve: Install in valve box with a gravel sump adequate to drain 1 gallon of water.

b. Air/Vacuum Relief Valve: Install on pipe perpendicular to dripline rows at high point of each zone. Install in valve box with gravel sump.

I. Control Wire:

1. Lay wires connecting controller and irrigation control valves in trenches with a minimum cover of 18 inches.

2. Sleeve wire under pavement in Schedule 40 PVC pipe.

3. Provide continuous wire runs without splices between controller and irrigation control valves. Splice only at control valves or junction box locations.
4. Install 2 spare wires to run from the controller to the furthest ends of each branch of the mainline.

5. Tape control wires together at 5 foot intervals with electrical tape. Tape this bundle to the bottom of the mainline at 10 foot intervals with at least 1 full wrap of duct tape. Tie a loose 24 inch loop in all wiring runs at changes of direction greater than 30 degrees. Untie all loops after all connections have been made.

J. Irrigation Controller:

1. Coordinate electrical service to controller location. For interior installation, wall-mount controllers within vandal-resistant enclosure as indicated on accepted Shop Drawings.

2. Program irrigation system is to operate after plants have been installed, without conflict with other Work.

3.05 INSPECTION OF AUTOMATIC IRRIGATION SYSTEM

A. Do not cover installed work before the Resident Engineer has inspected installation. Uncover covered work at no additional cost to Sound Transit.

B. At completion of installation, and before planting of shrubs or groundcover, inspect overall coverage of system. Demonstrate the working system.

C. Completely check system within 5 days before Final Inspection and make necessary corrections. Properly align heads and adjust to ensure full coverage. Clear system of foreign materials. Properly adjust valves. Check sprinkler controller valve chart for accuracy.

D. At end of the Landscape Warranty Period, schedule a Final Inspection of the system with the Resident Engineer. If the Warranty Period ends during the freezing season (see 3.05 SYSTEM PROTECTION), schedule the Final Inspection within 10 days of reactivation of the irrigation system.

3.06 TESTING OF AUTOMATIC IRRIGATION SYSTEM

A. Perform tests on each automatic irrigation systems in the presence of the Resident Engineer. Give at least 48 hours advance notice of tests.

B. Hydrostatically test sprinkler pipes normally under pressure as follows:

1. Leave all system joints, connections, and other fittings exposed until after completion and acceptance of pressure test. All subsequent breaches of integrity of the mainline shall require re-testing.

2. Mainline: 120 psi static pressure for 1 hour. Test will fail if pressure loss occurs during the test. Ensure means of air release at terminations and bleeding of all trapped air.

3. Lateral pipes: 80 psi for 30 minutes. Lateral test will include all swing joint assemblies with temporary threaded caps on the downstream Marlex fitting. Wrap caps with 3 wraps of Teflon tape. Ensure means of air release at terminations and bleeding of all trapped air. Test will fail if pressure loss is greater than 5 psi during the duration of the test.

4. Test the entire system as a complete unit. Do not test in separate completed segments.
5. Center load pipe with small amount of backfill to prevent arching and movement under pressure. Leave joints exposed for inspection during pressure test. No water is permitted in pipe for pressure testing until at least 24 hours has elapsed for solvent weld setting and curing.

6. Test by capping each outlet, filling pipe with water, and applying pressure with a pump. Measure pressure with a pressure gauge. Maintain specified pressure for 1 hour and determine leakage. Immediately correct leaks, and subject system to same test. No pipe, fitting or joint showing leakage will be accepted. After piping has been tested to the satisfaction of the Resident Engineer, backfill pipe trenches before adjustment and testing of sprinklers and valves.

7. Furnish necessary force pump and other test equipment.

C. Irrigation Controller: Test controller for 7 days just before end of establishment period. Operate system automatically in manner indicated.

D. Do not cover installed Work before the Resident Engineer has inspected installation. Uncover covered Work as directed by the Resident Engineer for testing.

E. Drip irrigation: The Contractor must make a full inspection with the Resident Engineer of all components of the system, including the visual inspection of each emitter under operating conditions. Adjustments, flushing, cleaning of filters, replacements to the system must be made immediately to ensure the proper operation of each emitter. Once drip irrigation is successfully tested, cover the dripline as shown on the Contract Drawings.

3.07 SYSTEM PROTECTION OF AUTOMATIC IRRIGATION SYSTEM

A. Deactivate and drain (winterize) the system prior to the onset of the freezing season (no later than Nov. 15) and reactivate at the onset of the spring season (no earlier than April 15). Accomplish each as often as required during the construction, acceptance, and warranty period. If construction is completed when the system is not in use, winterize after testing. Certify by letter the dates of each winterization and activation. Repair damage from failure to comply.

B. When using compressed air to winterize the system, do so in short cycles at no more than 40 psi air pressure. Do not allow pipe close to the compressor to get hot to the touch.

3.08 CLEAN UP

A. Upon completion of Work, clean up excess materials, equipment, and rubbish resulting from Work. Leave premises in a clean, neat and orderly condition.

3.09 TRAINING OF AUTOMATIC IRRIGATION SYSTEM

A. Thirty days prior to completion of the plant Warranty Period, the Contractor shall provide a course on the use, adjustment, and maintenance of the automatic controller and irrigation heads. The instructions shall include an on-Site review/walk through of the irrigation system(s) as well as an office session to review the O&M Manual documentation. If the Warranty Period ends during the freezing season, schedule the training within 10 days of the Final Inspection after reactivation of the irrigation system.

B. Approximately 10 maintenance persons will attend the course. The Contractor shall schedule the course through the Resident Engineer at a time convenient to Sound Transit. The Contractor must notify the Resident Engineer of the proposed course dates at least 6 weeks before those scheduled dates.
3.10 EXHIBITS

A. Not Used.

END OF SECTION
SECTION 32 90 00
PLANTING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for:
   1. Verification of the existing site conditions.
   2. Preparation of accepted Shop Drawing of Planting Plans and Details.
   3. Soil preparation of all planting areas to include discing, amending, incorporation, and mixing to prepare soils for planting.
   4. Testing prepared planting soil, and incorporating soil additions as required by test results.
   5. Fine grading.
   6. Furnishing, installation, maintenance of planting until Substantial Completion.
   7. Repair and restoration of existing vegetation and lawn.
   8. Staking and guying of trees.
   9. Mulching of all plant bed.
  10. Fertilization of all plant material.
  11. Cleanup.

B. Planting areas include properties under the jurisdiction of the City of Seattle, Washington State Department of Transportation, and The University of Washington. Standards of each property owner must be met or exceeded.

C. This section includes a Warranty and Establishment Period of 1 year duration from Substantial Completion to ensure the health and establishment of plant materials.

1.02 RELATED SECTIONS

A. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 31 14, Coordination with Others.
2. Section 31 20 00, Earth Moving.
3. Section 32 84 00, Planting Irrigation.
4. Section 32 90 00, Turf and Grasses.
1.03 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. City of Seattle:
   a. Standard Plans for Road, Bridge and Municipal Construction.

2. National Arborist Association (NAA)

3. a. Standards for Tree Care Operations, ANSI A300

4. American Association of Nurserymen (AAN)
   a. American Standard for Nursery Stock, ANSI Z60.1 (ASNS)

5. American Joint Committee on Horticultural Nomenclature
   a. Standardized Plant Names (SPN)

6. Soil Science Society of America
   a. North American Proficiency Testing Program (NAPT)

7. Washington State Department of Transportation
   a. Standard Specifications for Road, Bridge and Municipal Construction 2012

8. University of Washington
   a. Facilities Design Manual

B. Definitions

1. COS: City of Seattle.

2. Integrated Pest Management (IPM).
   a. IPM is an approach to pest control that requires regular monitoring to determine if and when treatments are needed and employs physical, mechanical, cultural, biological, and educational tactics to keep weeds and pest numbers low enough to prevent unacceptable damage or annoyance.
   b. Additional treatments, such as pesticide applications, are made only when and where monitoring has indicated that the pest will cause unacceptable economic, medical, or aesthetic damage. Treatments are not made according to a predetermined schedule. Treatments are chosen and timed to be most effective and least-hazardous to non-target organisms and the general environment.

3. Soils
   a. Topsoil: Imported soil used as a component of prepared planting soil for non-rain garden planting area.
   b. Prepared Planting Soil: Topsoil incorporated and mixed with site soils per soil preparation procedures. See 3.03 Preparation herein.
c. Native Soil: Existing, undisturbed soil suitable for sustaining plant growth as determined by soil test.

d. Planting Backfill: Mixture of accepted native soil and topsoil (or topsoil if no accepted native soil is present) for tree and shrub planting pits that exceed the prepared planting soil depth for the planting areas.

e. Tree pit: excavated hole in which tree is planted.

4. WSDOT: Washington State Department of Transportation.

5. UW: University of Washington.

1.04 SEQUENCING AND SCHEDULING

A. Coordinate Work of this Section with other Work.

B. Planting Time: Plant during seasons conducive to plant and soil health: from September 15 to October 31 and from February 1 to July 1.

1. Plant during November 1 to January 31 only by approval of Resident Engineer.

C. Coordinate earthwork and soil preparation. Do not expose soil piles for longer than 15 days without temporary or permanent vegetative, or other, cover. Test any soil piles exposed longer than 15 days in accordance with on-site testing requirements identified below. Do not expose soil piles to rainfall that will saturate materials.

1.05 ADMINISTRATIVE REQUIREMENTS

A. Coordination: Per Section 01 31 14, Coordination with Others. Coordination required with property owners having jurisdiction over Work sites.

1.06 SUBMITTALS

A. Shop Drawings

1. Submit scaled plans and details of construction and installation of all proposed trees, shrubs, groundcover and lawn planting. Indicate location and size of plant material and quantities. Indicate property owner and standards met.

2. Include typical planting details for street trees, deciduous trees, evergreen trees, shrubs, groundcovers, plant spacing.

3. Include list of all materials to be used.

4. Provide a comprehensive plant schedule including all trees, shrubs, groundcovers and lawn. Indicate quantity totals, common and scientific names, typical spacing, size and condition.

5. Obtain approval of Resident Engineer for all shop drawings.

B. Source of Supply Plan

1. Submit plan for the procurement of plant material within 90 days prior to Contractor’s scheduled start of planting. Include:

   a. Plant List.

   b. Documentation that plants are being contract grown or deposits have been provided to nurseries to ensure availability.
c. Name and contact information of growers.

d. Representative photographs of supplier’s stock.

e. Document plant materials are not stored in or grown in standing water unless the plants are hydrophilic species.

2. Should at any time the nursery stock be lost or compromised due to weather or other natural occurrences, notify the Resident Engineer immediately of the need to locate new material.

C. Samples: Submit at least one month prior to landscape preconstruction meeting.

1. Composted Material: Two (2) one-pound bags

2. Topsoil: Two (2) one-pound bags.

3. Sand: Two (2) one-pound bags.

4. Mulch: Two (2) one-pound bags.

5. Wood Chips (if used): Two (2) one-pound bags.


7. Crushed Rock (if used): Two (2) one-pound bags.

D. Certifications for Testing Lab, Plants and Materials: Submit at least one month prior to landscape preconstruction meeting with certificate names of materials and manufacturer.

1. Agricultural Testing Laboratory to perform on-site soil testing. Furnish documents confirming testing lab is a member of the Soil Science Society of America’s North American Proficiency Testing Program (NAPT). The soil testing laboratory must be accepted by the Resident Engineer in advance of any testing.

2. Commercial Fertilizers: Include guaranteed analyses.

3. Plant Material: Furnish certificates of inspection as may be required by Federal, State or other authorities indicating that plant material is free of disease or hazardous insects.

4. Soil Analysis Report: Submit a certified soil analysis report made in accordance with methods established by the Association of Official Agricultural Chemists for the proposed topsoil, planting soils, and organic amendments (compost) from a recognized soil testing laboratory. All test reports shall be dated within 90 calendar days of the submittal. For organic amendments, include the list of feed stocks by volume. Topsoil and amendments shall not be incorporated in the landscape planting work until the Soils Reports are approved by the Resident Engineer. The Soil Analysis report shall include:


   c. Particle Size/Appraisal: pH, salinity, organic percent, and USDA Particle size.
d. The reports shall include a statement that the laboratory has reviewed the planting plan and the specifications, and that its recommendations meet the needs of the Contract.

5. Ground Dolomitic Limestone: Include guaranteed analysis and weight of packaged material.

6. Organic Amendment: Include acid reaction, content of woody material, water absorbing capacity and moisture content by weight.

E. Delivery, Storage, and Handling Plan

1. Submit at least one month prior to the landscape preconstruction meeting.

2. Indicate:
   a. Proposed locations for on-site plant holding.
   b. Water source.
   c. Protection measures during various seasonal conditions and transportation to site.
   d. Schedule and Work Plan.

3. Submit one month prior to landscape preconstruction meeting the proposed planting schedule.

4. Indicate:
   a. Name and phone number of the forepersons.
   b. Dates for each type of landscape work, and for Substantial Completion.
   c. Proposed watering schedule and rates to establish planting areas until Substantial Completion.
   d. Proposed equipment and layout, if applicable.
   e. Proposed weed management plan for planting areas through Substantial Completion.

5. Once accepted, revise dates only as approved in writing, after documentation of reasons for delays.

F. Weed and Pest Control Plan (pesticides, herbicides, insecticides and fungicides) if determined through the Integrated Pest Management Plan that they are necessary.

1. Submit Sound Transit Herbicide Request Form. If application is granted, then:
   a. Submit proof of applicators’ State of Washington license and that pesticide is registered in the State of Washington.
   b. Provide manufacturer’s literature, including toxicity levels, for each pesticide and herbicide proposed. Include all Material Safety Data Sheets (MSDS).

G. Product Data: Submit at least one month prior to landscape preconstruction meeting product literature or cut sheets giving name of product, manufacturer’s name and compliance with these Specifications.
1. Commercial fertilizer.
2. Anti-desiccant.
3. Root barrier.
4. Coir fabric, if used.
5. Mycorrhizae.

H. On Site Soil Testing of Prepared Soil

1. Employ, at Contractor's expense, an approved agricultural testing laboratory to perform on-site soil testing.

2. Submittal for On-Site Soil Testing: Test on-site prepared planting soils when fully installed as specified. Test to include, but not be limited to, standard plant nutrient levels and pH. The test shall provide the following: particle size analysis, pH and Buffer pH; percent organic content by oven dried weight; nutrient levels by parts per million including nitrogen, phosphorus, potassium magnesium, manganese, iron, zinc and calcium; soluble salt by electrical conductivity of a 1:2 soil water sample measured in milliohm per centimeter; and the Cation Exchange Capacity (CEC).

I. If prepared soil does not meet approved submittals and specifications, replace material with approved product or submit a program of additional amendments based on recommendations of an agricultural chemist for approval by Resident Engineer prior to incorporating on site. Retest amended material to assure it meets specifications.

1. Testing Locations and Frequency:
   a. Initial tests shall be conducted at prepared planting soil in three locations: one sample tree planting pit and two other areas as selected by the Resident Engineer.
   b. Contractor shall conduct on-going on-site prepared soil sampling of one pound of material for every 100 cubic yards of material placed. Resident Engineer will select locations.

J. Settlement Test: Install 20 square feet of prepared planting soil at specified depth and apply irrigation to induce settlement to determine percent of additional soil required to achieve specified grade conditions of soil after settling. Supplement specified depth of soil in all plant beds with additional topsoil as needed to achieve specified grade conditions.

K. Submit experience of Landscape Contractor meeting requirements of 1.06.B.

L. Warranty and Establishment Plan: Submit a minimum of fourteen (14) days prior to Substantial Completion inspection.

1. Watering Plan
2. Weed Control Plan
3. Integrated Pest Management Plan

M. Tree Pit Drainage Test Report: Submit a report on the drainage of standing water in all tree pits. Fill each tree pit with four inches of water. Monitor tree pit four hours later and record water level. Tree Pit Drainage Test is to be monitored by Resident Engineer.
Photographs of Plants: Submit representative photograph of each plant species being held at a nursery 60 days prior to planting, or 30 days prior to final digging deadline for the planting season (whichever is sooner).

Plant Substitutions: Plant substitutions will not be permitted unless the Contractor furnishes the Resident Engineer with written evidence from no less than three nurseries that the plants specified are not obtainable.

1.07 MEETINGS AND INSPECTIONS

A. Preconstruction Meeting: Arrange a preconstruction meeting no less than fourteen (14) days prior to start of work between the Resident Engineer, Landscape Architect, Contractor, Planting and Irrigation Subcontractor(s), and any other subcontractors involved in the excavation or importation of soil affecting the planting areas. Review the proposed landscape locations, schedule, source of soils and plants, consideration of substitutions, review of specifications, and planting and irrigation procedures.

1. Inspections shall occur at various milestones throughout the project. Notify the Resident Engineer four (4) working days prior to inspections.

2. These inspections will occur:
   a. Subgrade inspection prior to soil placement.
   b. When Imported Soil Material is brought on site.
   c. When Tree Pit Drainage tests are occurring.
   d. When Plant Material arrives on site, prior to planting.
   e. Plant layout inspection
      1) When Contractor lays out plant material per Contract Drawings and prior to planting.
   f. Throughout soil preparation, irrigation, and planting activities.

B. Substantial Completion.

C. Final Acceptance at the end of the Warranty Period. Submit notice to Resident Engineer requesting inspection at least 7 days prior to the anticipated inspection date.

1.08 QUALITY ASSURANCE

A. Regulatory Requirements

1. Ship landscape materials with certificates of inspection required by governing authorities. Conform to all governmental regulations regarding the transportation of materials.

2. Investigate the conditions of public thoroughfares and roads as to availability, clearances, loads, limits, restrictions, and other limitations affecting transportation to and ingress and egress at the site.

B. Landscape Contractor Qualifications: Installer shall be a specialist in installing and planting landscape products and documented experience in performing work of comparable size, scope and quality. Licensed in the state of Washington with at least 5 years’ experience on projects of similar scope, and experienced in landscape work of the highest professional quality. Firm shall have equipment and personnel adequate to perform the work specified.
C. Supervision: Provide full supervision with at least one qualified person who shall be present at all times during execution of the work of this Section, and who is hereinafter referred to as the Landscape Planting Supervisor. That individual, who shall direct the work, shall be thoroughly familiar with the types of materials being installed and the proper methods for their installation.

D. Underground Utilities: Clearly identify utilities. Protect. Repair any damage to original condition by professionals licensed to repair utilities.

E. Permits, Codes and Regulations: Assure all work is in compliance with all applicable codes, regulations, and all related documents including but not limited to, Authority Having Jurisdiction and adopted International Building Code.

F. Measurement: Caliper, Branching, Grading, Quality, Balling and Burlapping: Follow the American Standard for Nursery Stock (ASNS), ANSI Z60.1.

1.09 RESTORE VEGETATION IN AREAS TO REMAIN:

A. Restore all lawn, planting, trees and irrigation in surrounding areas damaged during construction according to accepted horticultural practice and in compliance with property owner’s jurisdictional standards and this Section, Section 01 56 39, Temporary Tree and Plant Protection, and Section 32 84 00, Planting Irrigation. Restored areas are to be approved by Resident Engineer.

1.10 REGULATORY REQUIREMENTS

1.11 DELIVERY, STORAGE AND HANDLING

A. Packaged Materials: Deliver chemicals, fertilizer and soil conditioner to the site in original unopened containers showing weight, manufacturer’s guaranteed chemical analysis, trademark and conformance with state law, and name of manufacturer. Specified requirements for packaged materials also apply to bulk shipments. Protect materials from deterioration during delivery, and while stored at the site.

B. Plant Delivery: Exercise care in transporting, handling, loading and unloading plant material. Cover plant materials to protect from wind, sun, heat damage and drying out during transport. Plant materials damaged in any way shall be removed from the site and replaced.

C. Plant Selection and Inspection

1. Tagging Plant Material: Attach legible labels to each individual plant, or container containing one or more plants. Provide the necessary detailed information as to horticultural name, size, or other data required to identify as conforming to specifications on the label. When the label is attached to a container containing more than one plant, mark quantity as well as other required information on the label. Refer to American Standards for Nursery Stock regarding labeling of plant material. The Resident Engineer will reject plant material with illegible or missing tags.

2. Inspection of Plant Material: Allow the Resident Engineer opportunity to inspect plant material at nursery or offsite holding area prior to arrival on site. All plant materials will be inspected by Resident Engineer after arrival on site. Notify the Resident Engineer four (4) working days prior to the proposed arrival of plant materials on site and submit an itemized list of plants in each delivery. Arrange for adequate manpower and equipment on site at the time of plant material inspection and to unload, open, and handle plant material during inspection. Immediately remove plants not meeting the requirements herein specified from
the project or matching approved representative photographs, and replaced at no additional cost to Sound Transit.

3. Any plant stored in standing water will be rejected and removed from the site.

4. Do not prune plants prior to delivery.

D. Temporary Storage

1. Plant all materials within 24 hours of being delivered. If planting is delayed more than 24 hours after delivery, set plants on the ground well protected by covering root ball with soil, wet peat, or other material acceptable to the Resident Engineer. Protect balls, burlapped roots, and container grown material from freezing, sun, drying winds, and mechanical damage.

2. Water as necessary until planted.

3. Plants stored under temporary conditions, whether accepted by the Resident Engineer or not, are the sole responsibility of the Contractor.

4. Plants temporarily stored are subject to inspection and approval prior to planting. Immediately remove rejected plant material from the site.

5. Do not heel in plants for more than 1 week.

6. Do not store fertilizer, lime or other chemicals (herbicides or pesticides) with any planting material.

7. Protect packaged materials from deterioration during storage.

8. Do not remove container-grown stock from containers until planting time.

9. Do not prune plants prior to planting.

1.12 FIELD CONDITIONS

A. Environmental Requirements: Do not plant when the ground is frozen, saturated, or the soil is otherwise in an unsatisfactory condition for planting. Do not plant during periods of freezing temperatures, excessive heat, drought, moisture, and cold.

B. Environmental Requirements: Work soil only during suitable weather conditions. Do not disc, rototill, or work soil when ground is frozen, excessively wet, or in otherwise unsatisfactory condition.

C. Project Conditions

1. Landscape work shall not begin until structures, utilities, paving and other improvements, which require access to or through planting areas, have been installed and accepted by the Resident Engineer. Planting work shall not begin until the landscape irrigation system is installed in place, tested and accepted by the Resident Engineer.

2. Be informed as to the nature and location of the Work, general and local conditions including climate, adjacent properties and utilities, confirmation of the ground, the nature of subsurface conditions, and the character of equipment and facilities needed prior to and during execution of the Work.

3. Excavation: When conditions detrimental to plant growth are encountered, such as rubble fill, adverse drainage conditions, inadequate soil depth, or obstructions,
notify the Resident Engineer in writing for clarification. Suspend planting until conditions have been rectified or other direction given by the Resident Engineer.

4. Proceed with and complete landscape work as rapidly as portions of the site become available, and working within seasonal limitations for each kind of landscape work required.

5. Utilities: Determine location of underground utilities and perform work to avoid possible damage. Hand excavate, as required. Maintain grade stakes set by others until parties concerned mutually agree upon removal.

6. Should the Contractor, in the course of Work, find discrepancies between Contract Drawings and physical conditions or omissions or errors in Contract Drawings, or in layout as furnished by the Resident Engineer, inform the Resident Engineer immediately in writing for clarification. Work done after such discovery, unless authorized by the Resident Engineer, is at the Contractor's risk.

1.13 TEMPORARY MAINTENANCE PRIOR TO SUBSTANTIAL COMPLETION

A. Begin maintenance immediately after each plant is planted. Water, mulch, weed, prune, spray, fertilize, cultivate, and otherwise maintain and protect plants until Substantial Completion. Tighten and repair tree ties and stakes as required. Correct defective work as soon as possible after it becomes apparent and weather and season permit. Reset settled plants to proper grade and position, and remove dead material.

B. Upon completion of planting, and prior to receipt of certificate of Substantial Completion, remove from site excess soil and debris and repair all damage resulting from planting operations.

C. As part of maintenance, provide protection measures against gophers, rabbits, or other rodents, and repair damage caused by their activities.

D. Do not prune without approval of the Resident Engineer.

1.14 SUBSTANTIAL COMPLETION

A. The Resident Engineer will make an inspection for Substantial Completion.

B. The Contractor shall submit a written request for Substantial Completion inspection at least fourteen (14) days prior to the day on which the inspection is requested.

C. The Contractor will furnish full and complete written submittals for the Warranty and Landscape Establishment of the planting, including weeding, watering and IPM plans for review by the Resident Engineer at the time of the request for acceptance. See Article 1.04 Submittals.

D. All planting shall be alive, healthy, growing and installed as specified to be accepted.

E. The Contractor is to prepare a list of items to be completed or corrected for review by the Resident Engineer.

F. Upon completion of the inspection, the Resident Engineer will amend the list of items to be completed or corrected, and indicate the time period for their completion or correction. Additional inspections will be conducted to back-check the correction list. The Warranty and Establishment Period shall not begin until all items have been completed or corrected.
1.15 WARRANTY AND ESTABLISHMENT PERIOD

A. Warranty and Establishment Period shall consist of providing adequate and proper care for plant materials and landscape areas within the Contract limits for a minimum period of one year (365 days) to ensure healthy, vigorous growth of planted material. The contractor is responsible to maintain the irrigation system for the entire planting establishment period. The Warranty and Establishment Period shall begin immediately upon written notification by Resident Engineer of the acceptance of the planting materials at Substantial Completion, including the acceptance of the automatic irrigation system.

B. Inspections:

1. Planting areas will be inspected quarterly by the Resident Engineer during the Warranty and Establishment Period. Plants to be replaced shall be flagged during the inspection. Corrective work lists will be prepared by the Resident Engineer based on those inspections.

2. The Contractor shall correct the deficiencies within fourteen days (14) of receiving the list, unless other scheduling arrangements have been agreed upon with the Resident Engineer. Replacement plants shall be flagged after planting.

3. In addition, the Resident Engineer may make periodic inspections at other times during the Warranty and Establishment Period. Should the Resident Engineer determine at any time that the Contractor is not providing adequate and proper care of plant materials or is performing substandard work, the Resident Engineer will order the Contractor in writing to make necessary corrections.

4. The Contractor shall make corrections within seven (7) days immediately following receipt of such notice.

5. Inspections shall continue until the acceptance of all areas, including any extended warranty areas due to plant replacement during the initial Warranty and Establishment Period.

C. Warranty for Plants

1. Warranty plants, materials and work for one year from the start of the Warranty and Landscape Establishment period against all defects of material and workmanship.

2. The Contractor is responsible for the loss of any plant material, whether unhealthy, dead, damaged due to vandalism or missing, through the Establishment Period. Replace at no additional cost during the Establishment Period, any trees, shrubs, grass areas or groundcovers that have died or that are, in the opinion of the Resident Engineer, in unhealthy or unsightly condition, or that have lost their natural shape due to dead branches, excessive pruning, or excessive defoliation.

3. Any tree and shrub material that is 25 percent or more dead or disfigured shall be considered dead and shall be replaced. A tree is considered dead when the main leader has died back or there is 25 percent of the crown dead. Plants are considered disfigured when excessive dead wood had been removed or when the symmetry, typical habit of growth, or sculptured form has been impaired by the removal of dead wood.

4. Complete replacement during the periods set out as planting periods subject to the same conditions and made in the same manner as specified for the original planting. Make replacement within fourteen (14) days of notification from the Resident Engineer. Remove dead plants within two days of notification and mark.
planting plan showing the exact location of replaced plants. If plants cannot be replaced within 14 days of notification due to seasonal conditions, replace plants no later than the next succeeding planting season with agreement from Resident Engineer.

5. Replace unacceptable plants in accordance with original Specification. Warranty all replaced material during the Warranty and Establishment Period for an additional one year period from date of replacement. Tree tie stakes shall be tightened and repaired as necessary during the Warranty period.

6. The above warranty is applicable to any growing conditions through which plants of like kind could be expected to survive and any deformity or cause of death which could be attributed to, or affected by, the physiological conditions of the plant. The warranty would not apply to plant losses due to abnormal weather conditions such as floods, excessive wind damage, drought, severe freezing, or abnormal rain, as determined by the National Weather Service.

**PART 2 - PRODUCTS**

### 2.01 MATERIALS

A. General: All materials used to be approved by Resident Engineer and meet or exceed the requirements of the property owner’s jurisdictional standards.

B. Composted Material

1. Contractor shall use only compost that has been tested within 90 calendar days of submittal and meets the requirements in this Section. Compost not conforming to the above requirements or taken from a source other than those tested and accepted shall not be used.

2. Composted material shall be the result of biological degradation and transformation of organic materials under controlled conditions designed to promote aerobic decomposition. Compost shall be stable with regard to oxygen consumption and carbon dioxide generation. Compost shall be mature with regard to its suitability for serving as a soil amendment. The compost must have a moisture content that has no visible free water or dust produced when handling the material. Compost production and quality must be in compliance with WA Department of Ecology’s specifications, which appear in WAC Chapter 173-350 Section 220; plus the following additional requirements.

3. Additional requirements:
   a. The carbon to nitrogen ratio of coarse compost shall be below 25:1 or below 35:1 if the proposed plantings are composed entirely of plants native to the Puget Sound Lowlands region.

4. The compost shall have a minimum organic matter content of 40% dry weight as determined by U.S. Composting Council TMECC 05.07A “Loss-On-Ignition Organic Matter Method (LOI)”

5. Soluble salt content shall be less than 4.0 mmhos/cm when tested in accordance with U.S. Composting Council TMECC 04.10 “Electrical Conductivity”.

6. Maturity shall be greater than 80 percent in accordance with U.S. Composting Council TMECC 05.05-A, “Germination and Root Elongation”.
7. Pure composted plant waste, a well decomposed, humus-like material derived from the decomposition of grass clippings, leaves, branches, wood and other organic materials, as supplied by Cedar Grove, Inc., or Sawdust Supply Co., or approved equal.

8. Compost shall be produced at a permitted solid waste handling site for composting facility (Health Permit, Department of Ecology Storm Water Permit, PSCAA Facility and Equipment Registration).

9. The material shall be certified free of all plant parasitic organisms, viable weed seeds, heavy metals or parasitic residues.

10. Composted plant waste physical criteria:

   a. Fine compost shall meet the following gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
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<tbody>
<tr>
<td>2&quot;</td>
<td>100</td>
</tr>
<tr>
<td>1&quot;</td>
<td>95</td>
</tr>
<tr>
<td>5/8&quot;</td>
<td>90</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>75</td>
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</tbody>
</table>

   b. Medium compost shall meet the following gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
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</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>100</td>
</tr>
<tr>
<td>1&quot;</td>
<td>95</td>
</tr>
<tr>
<td>5/8&quot;</td>
<td>90</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>75</td>
</tr>
</tbody>
</table>

   c. Coarse compost shall meet the following gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3&quot;</td>
<td>100</td>
</tr>
<tr>
<td>1&quot;</td>
<td>90</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>70</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>40</td>
</tr>
</tbody>
</table>

1) The pH range shall be between 6.0 and 8.8 when tested in accordance with U.S. Composting Council TMECC 04.11-A, “1:5 Slurry pH”.

2) No more than 1 percent foreign material (plastic, concrete, ceramics, metal, etc.) on a dry weight basis as determined by U.S. Composting Council TMECC 03.08-A “Classification of Inerts by Sieve Size”.

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**NORTHGATE LINK EXTENSION**  
**TUNNELS, PORTAL, AND STATION EXCAVATIONS**  
**SECTION 32 90 00**  
**PLANTING**  
**RTA/LR 0177-09**  
**LINK CONTRACT N125**  
**PAGE 13 OF 26**
3) Stability shall be 7-mg CO2-C/g OM/day or below in accordance with the U.S. Composting Council TMECC 05.08-B “Carbon Dioxide Evolution Rate”.

C. Topsoil for Planting Beds: 3-way top soil composed, by volume, as 50 percent sandy loam, 35-40 percent compost amendment and 10-15 percent peat with 100 percent passing through a 1/2 inch screen as supplied by Cedar Grove or approved equal.

D. Planting Backfill: For all planting areas.

1. Planting mixture for backfill where excavated planting areas exceed the depth of required topsoil as specified herein, shall be 50 percent native topsoil dug from planting pit and 50 percent topsoil for planting beds as defined herein. Where no native topsoil is available, backfill with 100% topsoil per Section 3.03.

E. Sand: Natural, medium to coarse grained in texture, free from salt and decomposed organic matter like roots, sticks, leaves, paper and of any other undesirable trash like glass, plastic or metal fragments that could interfere with soil drainage and planting operations. 100 percent passing No. 4, Zero – 2 percent passing No. 270 – All US Standard Sieve. ASTM E11.

F. Dolomitic Limestone: Fine ground dolomite with minimum of 88 percent of No 20 sieve retaining 0 percent, No 100 sieve retaining 25 percent and packaged in new, waterproof, non-overlain bags, clearly labeled.

G. Water: Potable, clean, fresh and free from harmful materials. Furnish all hoses and other irrigation equipment required for the Work.

H. Temporary Irrigation Equipment: provide equipment in accordance with approved temporary irrigation plan.

I. Plants

1. Trees and Shrubs:
   a. Provide trees and shrubs that are nursery grown in accordance with good horticultural practice for at least two years under climatic conditions and soils similar to those at job site. Trees shall be freshly dug.
      1) Trees: Straight trunks with a single, intact leader, undamaged and uncut. Evenly branched on all sides.
   b. Appearance shall be typical of species or variety with normal growth habit, in accordance with ASNS.
      1) Sound, healthy and vigorous; well-branched and densely foliated when in leaf with healthy root systems, free from disease, insect pests, eggs or larvae, disfiguring knots, sun-scalds, abrasions of the bark, broken tops, torn roots, and any other objectionable feature.
      2) Nomenclature: Agree with SPN as accepted in the nursery trade for varieties not listed therein. Clonal types shall be true.
      3) Measure height or spread and quality in accordance with standards specified in ASNS.
   c. Conform to measurements specified on Plant List. Dimension plants in their natural position. Plants larger than specified may be used, without
increasing Contract Price, if approved by the Resident Engineer. Large plants cut back to sizes specified will not be accepted.

d. Provide freshly dug, balled and burlapped stock (B&B) with a compact natural ball of earth firmly wrapped and tied in burlap so that upon delivery the soil in the ball is still firm and compact about the small feeding roots. Root ball sizes: in accordance with standards specified in ASNS.

e. Provide container grown stock that is healthy, vigorous, and has a well-established root system reaching the sides of container and maintaining a firm ball when removed from the container. The container shall be rigid enough to hold the ball shape and protect root mass during shipping, and be sized according to ANSI Z60.1 for type and size of plant required.

2. Groundcover: Furnish in size(s) indicated on the Plant List and conform to ASNS standards for species and size(s).

1. Seed: Seed shall be fresh, clean, new crop seed. Seed mixes shall be Washington or Oregon certified. All other crop shall be identified. The Contractor shall furnish to the Resident Engineer the dealer’s guaranteed statement of the composition of the mixture and the percentage of purity and germination of each variety. Seed shall not contain in excess of 1.0 percent weed seed. Seed containing prohibited or restricted noxious weeds. The following noxious weeds are prohibited from any mix: Bindweed, Canada Thistle, quackgrass, sedge kind weed, horse nettle, wild garlic, Bermuda grass, cheat, wild onion, corn cockle, dodder, Johnsongrass, perennial sweet Sudan grass, sorghum hybrids.

**Drought Tolerant Lawn Mix**

<table>
<thead>
<tr>
<th>Name</th>
<th>Percent by Weight</th>
<th>Percent Purity</th>
<th>Percent Germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magic Chewings Fescue</td>
<td>30</td>
<td>98</td>
<td>92</td>
</tr>
<tr>
<td>Hard Fescue</td>
<td>20</td>
<td>98</td>
<td>91</td>
</tr>
<tr>
<td>Durby Perennial Ryegrass</td>
<td>50</td>
<td>98</td>
<td>98.25</td>
</tr>
</tbody>
</table>

J. Staking, Guying and Grate

1. Stakes: Wood: 2 inch diameter with chamfered tops.
2. Ties: Recycled polypropylene, chainlock guys.
3. Twine: 3-ply jute.

K. Mulch

1. Organic Mulch: Mulch, fine fir or hemlock bark of uniform color for use in planting areas. Size range of 1/2 inch to 1-1/4 inch with a maximum of 20 percent passing a 1/2 inch screen. Free from weed seed, sawdust and splinters; not containing resin, tannin, wood fiber or other compounds detrimental to plant life. (Other bark mulch is not permitted.)
   a. Bagged mulch: Moisture content not in excess of 22 percent.
2. Wood Chip Mulch: chipped wood mulch which has been composted for a minimum of one year.
3. Wood chips salvaged from clearing and grubbing of on-site activity may be approved as a substitute for organic mulch, if found acceptable by the Resident Engineer prior to application. Arborist Wood Chip Mulch may also be used as a substitute for organic mulch when approved by the Resident Engineer.

4. Arborists Wood Chip Mulch: Shall be coarse ground wood chips (1/2-inch to 6-inch long) derived from the mechanical grinding or shredding of the above-ground portions of trees. It may contain wood, wood fiber, bark, branches, and leaves, but may not contain visible amounts of soil. It shall be free of weeds and weed seeds including but not limited to plants on the local noxious weed list and invasive plant portions capable of sprouting, including but not limited to horsetail, ivy, clematis, knotweed, etc. It may not contain more than ½ percent by weight of manufactured inert material (plastic, concrete, ceramic, metal, etc.).

L. Fertilizers
   1. General: Packaged in new, waterproof, non-overlaid 80 lb. bags clearly labeled as to weight.
   2. Fertilizer: commercial grade, containing not less than 10 percent Nitrogen, 6 percent phosphorous and 4 percent potash by weight of ingredients.

M. Tree Watering Bags: “Gator Bags” or approved equal.

N. Plant Protection Fence

O. Root Barrier

P. Plant Treatment Materials
   2. Mycorrhizae: Mycogrow Gel as manufactured by Fungi Perfecti, Olympia, WA, 1-800-780-9126, Mycorrhizal Landscape Inoculant as manufactured by BioOrganics, Santa Monica, CA, or Biovam as manufactured by Brock Probiotics and available through T&J Enterprises, Spokane, WA (509) 327-7670.

2.02 SOURCE QUALITY CONTROL

A. Plant Material: Provide plants of quantity, size, genus, species and variety as indicated in the Construction Documents for landscaping work and complying with recommendations and requirements of ASNS. Provide healthy, vigorous stock, grown in recognized nurseries in accordance with horticultural practice and free of disease, insects, eggs, larva, and defects such as knots, sun-scald, injuries, abrasions, or disfigurement.

B. Plant List: In accordance with Submitted Source of Supply Plan.

C. Substitutions: Substitutions will not be permitted unless substantiated written proof is supplied that a specified plant is not obtainable from three or more nurseries. See 1.04.N.

D. Contractor: Perform work with personnel familiar with planting techniques under the supervision of experienced landscape forepersons at all times. Notify the Resident Engineer of the name and phone number of the on-site supervisor fourteen (14) days in advance of the first day of planting operations.
2.03 INTEGRATED PEST MANAGEMENT AND PESTICIDE APPLICATIONS

A. Integrated Pest Management Plan (IPM)

1. The principles of integrated pest management (IPM) shall be employed. The intent is to limit any pesticide, including herbicide, applications through healthy landscape management practices.

2. Contractor shall consider pesticide and herbicide applications only as a last resort and only after other methods of control are proven ineffective.

B. Pest Monitoring

1. Pest monitoring and inspections shall include the following:
   a. Contractor shall visually inspect all landscape zones quarterly, or as determined by the Resident Engineer to identify potential pest problems. Pest problems include insect, disease, and weed infestations. The presence of a pest does not necessarily mean there is a problem. Contractor shall keep written records of pests identified and zones where problems may be developing.

   b. Contractor to identify areas where non-chemical IPM control methods should begin. Resident Engineer shall review and approve all IPM areas.

2. Pest Monitoring Report:
   a. When pests are identified on site, Contractor shall provide written pest monitoring reports and include status of infestation, description of controls implemented (e.g. “applied wood chip mulch”, “mechanically pulled weeds”, “adjusted watering”).

C. PESTICIDE APPLICATION

1. Pesticides: Pesticides include all herbicides, insecticides, fungicides, and various other substances used to control pests and weeds. All pesticide applications shall be preceded by monitoring and positive pest identification. Submit these findings to the Resident Engineer prior to any pesticide application.

2. Weed and Pest Control Plan: A Weed and Pest Control plan shall be prepared and signed by a licensed Commercial Pest Control Consultant when chemicals are proposed. The plan shall include methods of Weed and Pest Control; dates of Weed and Pest Control operations; and the name, application rate, and Material Safety Data sheets of all proposed chemicals. In addition, the Contractor shall furnish a copy of the current product label for each pesticide and spray adjuvant to be used. These product labels shall be submitted with the Weed and Pest Control plan for approval.

3. Combination Products: Under no circumstances will combination products be allowed (such as “weed and feed”, weed control plus fertilizer, or insect control plus fertilizer).

4. Blanket Applications: Under no circumstances will regularly scheduled calendar-based or “blanket” applications of pesticides be allowed without written prior approval of the Resident Engineer.

5. Pre-emergent herbicides are not allowed.
6. Application Approval: If Contractor determines that applications may be needed, Contractor shall fill out Sound Transit’s Pesticide Use Request form. Pesticides use must be reviewed and approved by Resident Engineer prior to use.

7. Product recommendation and information on health and environmental hazard of that product. City of Seattle and King County Pesticide Tier Tables, and “Grow Smart Grow Safe” may be helpful in locating this information:

8. Weather: All pesticides shall be EPA approved and applied during dry weather by a licensed Washington State Pesticide Applicator or Operator in accordance with the label directions. All applications shall be posted in accordance with WSDA regulations for 24 hours after application. All chemicals used shall have a Material Safety Data Sheet (MSDS) filed with Sound Transit.

9. Appropriate Pesticides: Contractor is responsible to verify that pesticides are appropriate for use with the respective plant materials. Contractor is responsible for damages incurred as a result of applications and shall repair or replace such damage at no cost to Sound Transit.

10. Notification: After approval, Contractor shall notify the Resident Engineer or designee a minimum of 48 hours prior to all pesticide applications.

11. Regularly monitor all plant material and immediately notify Sound Transit of any need for such control. Contractor may be responsible for damage to plant material incurred as a result of failure to immediately notify the Resident Engineer of correctable disease and insect problems, and Contractor shall replace such damaged plant material at no additional cost to Sound Transit.

D. NOXIOUS WEED CONTROL

1. Mandate: Noxious Weed and Pest Control is mandated by state weed control law, Chapter 17.10 RCW. Assistance and weed lists (Class A, B, C, Non-designate, and Weeds of concern) are available from the County Noxious Weed Control Programs.

2. Weed Lists: Contractor shall be responsible for being current on all State, county, and local noxious weed lists and provide these to Sound Transit as requested.

3. IPM Requirements: Contractor shall identify and control Class A, B, or C Weeds upon identification and as indicated by the County (King, Pierce, and Snohomish) Noxious Weed Control Board and approved Landscape Maintenance Work Plan. Sound Transit has a zero tolerance for the presence of Class A noxious weeds. The control work plan shall be developed by the Contractor and approved by the Resident Engineer. Control will follow nonchemical IPM control techniques outlined in the County’s Best Management Practices, Alerts, and other documents posted on the Noxious Weed websites. Pesticide applications can only be considered as a last resort when non-chemical methods have proved ineffective.

4. Weeds of Concern and Pest Vegetation: Non-designate, shall be controlled with ongoing IPM and healthy landscape management techniques.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Prior to soil preparation, ascertain the location of all electric cables, conduits, under-drainage systems and utility lines. Take proper precautions to not disturb or damage
sub-surface elements. If sub-surface elements are uncovered, promptly notify the Resident Engineer. Contractor is responsible for making requisite repairs to damaged utilities at his own expense.

1. Verify that required underground utilities are available, in proper location and ready for use. Coordinate with other trades.

2. Verify that subgrades are at lines and grades appropriate to provide specified depth of soil before beginning work.

3. Verify and confirm drainage of landscape areas prior to placing any topsoil

3.02 COORDINATION

A. Do not begin work until shop drawings as specified herein have been approved and coordination with property owners has occurred per Section 01 31 14, Coordination with Others.

B. Coordinate layout and installation of plant material with installation of irrigation system to ensure that there will be complete and full coverage of the planted areas. Irrigation systems shall be installed, tested and accepted before planting begins.

3.03 PREPARATION

A. Protection of Existing Conditions

1. Use every possible precaution to prevent damage to existing conditions to remain, such as structures, utilities, plant materials, walks and paving on or adjacent to the site of the Work.

2. Provide barricades, fences or other barriers to protect existing conditions to remain from damage during construction.

3. Do not store materials or equipment, permit burning, or operate or park equipment under the branches or on the root zones of existing plants to remain.

4. Submit written notification of damaged plants and structures to the Resident Engineer immediately.

B. Preparation of On-site Soil in Planting Beds

1. Subgrade preparation:
   a. Completely remove and dispose of all structural fill, gravel, quarry spall, constructions debris, and other obstructions in the area to receive planting to depths required to install topsoil, including areas where native soils have been removed and replaced with structural materials adjacent to buildings and paved areas. Remove debris and rocks over three inches in size to required topsoil depths in all areas to receive planting. Remove debris and rocks over three inches in size that were unearthed during scarification.
   
   b. Protect and maintain the integrity of the compacted base and subgrade materials under pavements and curbs, and protect all other structures in areas of the soil preparation and/or excavation.
   
   c. If native soil in areas to receive planting is free from engineered structural fill, gravel, quarry spall, construction debris, and other deleterious materials, establish subgrade lines and grades appropriate to provide for specified depth of prepared planting soil.
d. If subgrades need to be raised to establish lines and grades appropriate to provide for specified depth of prepared planting soil, use Planting Backfill specified herein.

e. After subgrade lines and grades are established, scarify exposed soils to a depth of at least 24 inches. Moisture condition if necessary. Compact to 85 percent maximum of dry weight density.

f. Shape subgrades to lines and grades indicated. After subgrade grade is reached, scarify exposed soils to a depth of at least 10 inches; moisture conditioned if necessary, and then compact to 85 percent maximum of dry weight density.

g. Finish subgrades will be inspected and approved by Resident Engineer before placement of any topsoil or plants.

2. Soils in Planting and Lawn Areas

a. Perform Settlement Test for prepared planting soil as specified in Article 1.04.I of the Section.

b. Prepare subgrade soil in accordance with Article 3.03 B-1, herein.

c. In planting areas provide a minimum of 18 inch depth of topsoil. Where trees are planted, depth of topsoil to be increased to provide 24 inches to 36 inches of topsoil depending on size of root ball so that topsoil is available to the full depth of the root ball.

d. In lawn areas provide 6 inches of topsoil in two 3 inch lifts. Place first lift and rototill soil to incorporate into top 12 inches of subgrade soil. Place second lift and rototill into top 12 of soil and subgrade

e. Place topsoil in 6 inch lifts. Place first lift and rototill soil to incorporate into top 12 inches of subgrade soil. Place second and additional lifts separately and rototill each lift into the next 12 inches of soil.

f. In areas that are protected by vegetation protection fencing or are beneath the canopies of existing trees and shrubs, whichever area is greater, perform soil protection under the direction of the Resident Engineer. Loosen soil by hand using a shovel or fork. Loosen soil with care to avoid loosening or damaging the root systems of existing trees and shrubs. Spread a 2-inch layer of topsoil over soil. Incorporate topsoil into soil using a shovel or fork. Feather soil grades into adjacent grades outside existing tree and plant canopies.

g. In areas where dense clay soil material is encountered, spread a two-inch layer of topsoil over subgrade soil and rototill into the top 12 inches of subgrade prior to placement of topsoil.

h. Prepare the top four inches of topsoil in all cultivated areas free of stones, clods of earth larger than one inch in diameter and other deleterious matter which might be a hindrance to mixing of soil amendments, planting and maintenance.

i. Test prepared planting soil as specified in Article 1.04J of this Section.

j. Apply soil additives to planting areas as required to obtain a pH range of 6.0 to 6.5, except for ericaceous and coniferous planting areas. Ericaceous and coniferous planting areas shall have a pH range of 5.0 to
5.5. Do not apply more than 60 lbs. of lime per 1,000 sq. ft. at one time. Verify pH by test of each major planting area.

k. Roll or hand compact soil to achieve compaction of 85 percent of dry weight density.

l. Incorporate all amendments thoroughly into the soil to assure uniform distribution. Mix additional amendments into the soil as recommended by the testing laboratory as specified in Article 1.04.C and H. of this Section, and as accepted by the Resident Engineer.

3. Obstructions Below Grade: In the event that roots, rocks, underground construction work, utilities or obstructions are encountered during discing, scarification, and tilling operations under this Contract, continue Work by hand with shovel or fork. Notify Resident Engineer immediately of any root obstructions encountered that may be from trees that are being protected and are to remain.

C. Finish Grading

1. After natural settlement and light rolling, prepare complete work to conform strictly to the lines, grades and elevations indicated. Grading shall be provided for natural runoff of water without low spots or pockets. Flow line grades shall be accurately set and shall not be less than two percent gradient unless otherwise indicated or approved by the Resident Engineer.

2. Finish grade of planting soil in landscaped areas shall be 3-3/4 inches below the top of adjacent pavement, curbs, headers, utility boxes or structures to allow for 3 1/2 inches of mulch as top dressing. Adjust utility boxes or structures if necessary to conform to grading requirements. For lawn areas, finish grade of planting soil shall be 1-1/2 inches below the top of adjacent pavement and utilities.

3. Remove all rocks three inches or greater from planting areas.

4. Elevations and landform configuration is critical to project design intent. Supply additional topsoil as needed to give the specified depths and grade under the Contract.

5. Toes and tops of slopes shall be rounded to produce a gradual and natural appearing transition.

6. Protect all planting areas against compaction by construction activities and equipment.

D. Planting Layout

1. Lay out new planting where shown on Contract Documents except where obstructions exist below ground, overhead, or where changes have been made during construction.

2. On slopes greater than 20 percent, trees and shrubs may be staked to indicate layout.

3. Location layout and staking shall be the responsibility of the Contractor, subject to approval by the Resident Engineer, before planting or construction of each area begins.
4. Locate trees. Place plants starting from the perimeter of the bed and progressing to the center so that odd dimensions are adjusted at the centers of planting beds.

5. Coordinate layout and timing of installation of plant material with installation of the irrigation system per 32 84 00 Planting Irrigation to ensure that there will be complete and full irrigation coverage of the planting areas.

3.04 PLANTING INSTALLATION OF TREES, SHRUBS, AND GROUNDCOVERS

A. Excavation

1. Excavate all plant pits in accordance with the Planting Details after acceptance of staked locations by the Resident Engineer. Excavate plant pits after soil testing, analysis, amendments, and acceptance by the Resident Engineer.

   a. Excavate pits and beds with sloping sides and with the pit bottom’s center raised for holding root ball of large shrubs and trees. Compact the raised center to achieve compaction of 85 percent of dry weight density. Loosen sides and bottoms surrounding raised center by scarifying.

2. Excavate pits and beds within branch spread of existing trees and shrubs by hand. Notify Resident Engineer immediately if dense root mats or structural or feeder roots are encountered. Resident Engineer will make adjustments to planting locations if new planting excavation will potentially adversely impact existing plant material.

3. After completion of Tree Pit Drainage Test specified in 1.04.L, allow pits to completely drain. Do not plant in saturated soils. If Resident Engineer determines that drainage is not satisfactory to healthy plant growth, additional excavation and drainage efforts must be made at direction of Resident Engineer.

4. Obstructions Below Ground: In the event that rock, underground construction work, utilities or obstructions are encountered in any plant pit excavation work under this Contract, notify the Resident Engineer and alternate locations may be selected by the Resident Engineer.

5. Where locations cannot be changed, remove the obstruction, subject to the Resident Engineer approval, to a depth of not less than 3 feet below grade and no less than 6 inches below bottom of ball or roots when plant is properly set at the required grade.

B. Subsurface Drainage: When subsurface drainage is required, the subsurface drainage shall be installed, inspected and approved by the Resident Engineer before proceeding with topsoil installation and planting in that area.

C. Inoculation

1. Prior to installation and under supervision of Resident Engineer, inoculate balled and burlapped plants and container plants with mycorrhizae in accordance with the manufacturer’s recommendations.

D. Placement and Planting of Balled and Burlapped and Container Plants

1. Do not plant until the Resident Engineer at site has reviewed and accepted the plant layout and plant material.

2. Do not plant until all soil testing, settlement testing, and prescribed amendments have been successfully implemented.
3. Dig hole according to the contract drawings.
   a. Groundcover, grasses, shrubs and vines: Planting hole to be a minimum of 3 times the width of the root ball.
   b. Trees: Unless noted otherwise on the Contract Documents, excavate tree planting holes to the depth of the root ball over a minimum surface area of 24 square feet, or an area large enough to provide a 2-foot clear horizontal space between the root ball and the sides of the excavation, whichever is larger. Tree pit excavation next to a curb or sidewalk shall allow a horizontal topsoil clearance of at least 3 inches from the back of the curb or sidewalk.

4. Check top of root ball for root flare. If roots are not found, scrape away excess soil until root flare is exposed. This shall be the finish grade level.

5. Set plants in centers of pits plumb and straight, in accordance with the planting details, and faced to give best appearance and relationship to adjacent plants and structures.

6. Plant to such depth that the finished grade level of the plant, after settlement, will be the same as that at which the plant was grown.
   a. Groundcover, grasses, shrubs and vines: Place plants so that the soil level of the plant soil is flush with the soil level of the planting bed.
   b. Trees: Place trees with the root crown 2 inches above the surrounding finish grade. Take care not to over-excavate.

7. Clip and remove wire basket from top and sides of root ball. Once in position, remove platforms, wire, twine, surplus binding, burlap or wire basket from the top two-thirds of the root ball. Backfill operations, watering and mulching shall be as described for balled and burlapped, and container plants.

8. Do not pull burlap out from under balls, but peel back 2/3 of burlap covering, cut along base, and remove. If root ball wrap is non-biodegradable, including burlap treated with copper, remove completely.

9. Remove plants from containers by cutting or inverting the container. Loosen roots.

10. Cleanly cut off all broken or frayed roots. Tease out existing roots on perimeter of root ball without disturbing structure of root ball. Cut all girdling roots.

11. Place bare root plants in the planting hole with roots spread out in a natural position and not bunched, curled, twisted or bent. Cleanly cut any broken roots.

12. Backfilling
   a. Do not backfill tree pits until the Resident Engineer has accepted them.
   b. Under no circumstances shall water-saturated topsoil be used for backfill.
   c. Compact topsoil for backfill around bases of balls to fill all voids. Remove all non-biodegradable materials from the plant pit.
   d. Backfill topsoil in layers of not more than six inches and each layer thoroughly compacted by hand and free of voids before next layer is put in place.
e. Work the backfill topsoil around and beneath the ball leaving no air pockets. Continue adding and tamping topsoil until the hole is half full.

f. Do not bury the base, or bole, of the tree with soil, mulch, or other material.

g. Finish backfilling and tamp thoroughly. Water thoroughly until the root ball and planting pit is saturated. If settling occurs after watering, add enough topsoil to bring the grade to correct level. Do not rework the topsoil.

13. Upon completion of backfilling, build a 3 inch high berm around the root zone of plants to allow slow percolation of water. Construct a 3 inch high by 4 foot diameter berm around the root zone of trees for slow percolation of water.

E. Stake trees per Article 3.06.

F. Mulch: Furnish all equipment and labor to load, haul, and place mulch. Mulch all planting areas within two days of planting each area. Cover tree and shrub beds with a continuous 3 1/2-inch layer of mulch. Keep mulch three inches away from tree and shrub trunks.

G. Install "Gator bags" on trees without permanent irrigation.

3.05 PLANTING OF LAWN

B. Hydroseeding: Section 32 92 00, Turf and Grasses.

3.06 REPAIR AND RESTORATION

A. Protection: Protect adjoining property from damage, construction debris, topsoil, run-off, and mulch.

B. Restoration to Existing Vegetation to Remain: Restore all lawn, planting, trees, mulch, and irrigation in surrounding areas damaged during construction according to accepted horticultural practice and in compliance with this Section.

C. Pruning

1. Do not prune plants without acceptance of the Resident Engineer.

2. Remove dead or broken branches with a clean cut, in a manner appropriate to the particular requirements of each plant, and at the time designated by, and to the satisfaction of, the Resident Engineer. Perform pruning with clean, sharp tools. Pruning of limbs over ½” diameter or pruning of more than 10% of the tree to be performed by a certified arborist.

3. Promptly trace and treat accidental damage to trees and shrubs occurring during the course of planting operations which is not so great as to require removal of a branch or the replacement of the plant in accordance with recognized horticultural practices, as directed by the Resident Engineer.

D. Watering

1. Thoroughly water plants, upon completion of planting operation. Continue temporary water until Substantial Completion when Warranty and Landscape Establishment period begins.

2. Apply water slowly to penetrate and saturate the entire root system while avoiding runoff.
E. Wood Chip Installation: Where required to mulch existing landscape areas and to match existing plant bed dressing if damaged.

3.07 PROTECTION

A. Guying and Staking

1. Stake or guy trees as detailed immediately after planting. Stake or guy trees to stand plumb. Any tree or shrub thrown out of plumb by wind or other causes shall be replanted by loosening the soil around the root system and righting the tree or shrub by adjusting the position of the root system. Adjustment shall not be made by pushing or restraining the trunk or stem. If, in the opinion of the Resident Engineer, damage to the root system has occurred as a result of righting a tree or shrub, the tree or shrub shall be replaced by the Contractor.

2. Remove and replace damaged stakes as needed until completion of the Warranty and Establishment Period.

B. Plant Protection Fence

1. For protection of new plantings and lawns from work by other trades or from use by the public, provide fences in areas not already protected by temporary tree and landscape fencing.

2. Prior to installation, stake location of fence and obtain approval by Resident Engineer. Coordinate location and type of fence with planting work so that planting will not be damaged by installation or removal of fence. Install posts plumb and tie taut. Coordinate removal of fence with Resident Engineer.

3. Remove protection fence at end of Warranty and Establishment Period unless directed otherwise by Resident Engineer.

3.08 ADJUSTING AND CLEANING

A. Maintain the site in an orderly condition during the progress of Work. Continuously and promptly remove excess and waste materials; keep adjacent lawn areas, walks and roads clear. Store materials and equipment per manufacturer's recommendations. Immediately remove rejected materials from the property. Promptly remove equipment, surplus material, and debris and trash resulting from operations under this Contract upon completion and prior to initial acceptance of Work. Leave the site in a neat, orderly condition, broom clean.

B. Protect landscape work and materials from damage due to landscape operations, operations by other contractors and trades and trespassers. Provide adequate and proper care of all plant material and lawn and work done, and maintain protection during installation and Warranty and Establishment periods. Adequate and proper care means keeping all plant material in a healthy, vigorous growing condition and includes removing the weeds, litter and other debris along with retaining the finished grades in a neat uniform condition.

END OF SECTION
PART 1 - GENERAL

1.01  SUMMARY

A. This Section includes specifications for:

1. Furnishing all materials, equipment, and labor necessary for restoration and establishment of lawn including preparation, seeding, fertilizing, mulching, and protection of hydroseeded areas of lawn.

2. For type of seed and requirements for planting soil see Section 32 90 00, Planting.

3. Areas include properties under the jurisdiction of the City of Seattle, Washington State Department of Transportation, and The University of Washington. Standards of each property owner must be met or exceeded.

1.02  ADMINISTRATIVE REQUIREMENTS

A. Coordination: Per Section 01 31 14, Coordination with Others. Coordination required with property owners having jurisdiction over Work sites.

1.03  RELATED SECTIONS

A. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 31 14, Coordination with Others.

2. Section 31 20 00, Earth Moving.

3. Section 32 84 00, Planting Irrigation.

4. Section 32 90 00, Planting.

1.04  SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data

C. Certifications

1. Submit seed vendor's certification for required grass seed mixture, indicating percentage by weight and percentages of purity, germination and weed seed for each grass species.

1.05  QUALITY ASSURANCE

A. Landscape Contractor: A single firm licensed in the state of Washington with at least five years' experience on projects of similar scope and experienced in landscape work of the
highest professional quality. Firm must have equipment and personnel adequate to perform the work specified.

B. It shall be the Contractor's responsibility to provide qualified personnel experienced in all phases of the seeding and fertilizing operation, equipment and methods as herein specified.

C. Furnish seed in containers that show the following information: seed name, lot number, net weight, percentage of purity, germination, weed seed and inert material. Seed that has become wet, moldy, or otherwise damaged will not be accepted. Use seed that conforms to the requirements of the Washington State seed law and, when applicable, the Federal Seed Act, and is "certified" grade or better.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver seed and fertilizer materials in original unopened containers showing weight, analysis, and name of manufacturer. Store seed in such a manner that will prevent wetting and deterioration.

1.07 FIELD QUALITY CONTROL

A. Grading Inspection

1. Subgrades: Inspected and approved by the Resident Engineer prior to placing topsoil.

2. Finish grading: Inspected and approved by the Resident Engineer prior to seed application.

B. Inspections

1. Request a provisional inspection by the Resident Engineer upon completion of the work. Upon completion of the punch list, the Resident Engineer will make provisional acceptance in writing.

2. Final acceptance will be at the end of the one-year warranty period, and after all required repairs have been made.

1.08 WARRANTY AND REPLACEMENT

A. Seeded areas shall have a relatively uniform stand of grass with no bare spots over 12" square at the time of provisional acceptance. Reseed at the original rate and fertilize with 10-20-20 at the rate of 9 kg per 1000 square feet of blended materials. All areas failing to vigorously establish within 90 days after germination or one growing season (whichever is longest), for any reason whatsoever, shall be redone at the Contractor's expense.

1.09 JOB CONDITIONS

A. Environmental Requirements: Do not plant when the ground is frozen, or the soil is otherwise in an unsatisfactory condition for planting and hydroteeding. Do not plant during periods of excessive heat, drought, moisture and cold.

PART 2 - PRODUCTS

2.01 SOIL AMENDMENTS, LIME AND FERTILIZERS

A. Provide the following:

1. Organic Amendment
2. Dolomite Lime

3. Fertilizers

2.02 HYDROMULCH
A. Wood cellulose fiber from Alder; containing a soil-binding agent (tackifier); dyed a suitable color to facilitate placement; containing no growth or germination inhibiting substances.

2.03 SOIL BINDING AGENT
A. Non-toxic, biodegradable materials that are environmentally safe such as ESI - TAK or approved equal. Materials must be manufactured in such a manner that after addition and agitation in slurry tanks with fertilizers, grass seeds, water and other improved additives, the fibers in the material will become uniformly impregnated with grass seed, and which after application, will allow the absorption and percolation of moisture. Each package of the cellulose fiber shall be marked by the manufacturer to show the air-dry weight content. Wood cellulose fiber shall be utilized as a mulch and applied with seed and fertilizer in one operation by approved hydraulic equipment.

2.04 SEED MIXES
A. Fresh, clean, new crop seed, state certified and as specified in Contract Specification 32 90 00, Planting.

2.05 TOPSOILS
A. Specified in Contract Specification 32 90 00, Planting.

PART 3 - EXECUTION

3.01 SOIL PREPARATION
A. Perform all soil preparation operations per section 32 90 00, Planting.

3.02 CULTIVATION
A. Perform cultivation in conjunction with the requirements of Section 32 90 00, Planting. Cultivation may be done by farm disc, harrow or other suitable equipment approved by the Resident Engineer. Prior to cultivation, apply dolomite limestone at the rate of 8 lbs. per 1000 square feet and cultivate to a depth of four inches.

3.03 SOIL PLACEMENT
A. Place soil placement in conjunction with the requirements of Contract Specification 32 90 00, Planting. Spread amendments or prepared soils evenly in the locations and to the depths indicated. After soil has been spread, remove all large clods, rocks and debris greater than one inch in any dimension. Do not be place soil when the ground is frozen, wet or in a condition detrimental to the work.

3.04 COMPACTION
A. Compact with sheep’s foot roller, cleated crawler tractor, vibratory roller, or equipment approved by the Resident Engineer. Use equipment to produce 150-300 lb per square foot of ground pressure.

B. Compact to produce a uniform rough textured surface free of tire ruts, depressions and low spots, and be ready for seeding and mulching. Make a minimum of four passes.
After compaction, finish grade to be flush with the top of curbs, catch basins and other structures. If, in the opinion of the Resident Engineer, water is required to condition the soil for compaction, it shall be immediately furnished and applied by the Contractor, utilizing water supplies on the site or by watering truck if necessary.

3.05 WATERING

A. If required by the Resident Engineer, provide water to condition the soil for compaction or to provide dust control.

B. Provide temporary irrigation to all hydroteched areas as indicated in the Contract Documents and as specified herein and per temporary irrigation plan required by Contract Specification 32 84 00, Planting Irrigation.

3.06 SEEDING

A. Apply fertilizer, seed and mulch in one operation with approved hydraulic equipment. Apply materials at the following rates:

1. Hydromulch, at 50 lbs per 1,000 square feet.
2. Seed, at nine pounds per 1,000 square feet.
3. Lawn Starter Fertilizer, at 20 lbs per 1,000 square feet.
4. Soil Binding Agent, at one pound per 1,000 square feet.

B. Do not perform seeding during windy weather (above 40 kph) or when the ground is overly wet (saturated) or frozen. Give the Resident Engineer 48 hours’ notice of seeding operations. Perform seeding, fertilizing, and mulching of prepared areas during the following time frames:

1. Seeding: from April 1 to June 15 or from September 1 to October 31.
2. Do not perform seeding before or after these dates without the written approval of the Resident Engineer. Written permission to seed from June 1 to August 31 may be granted only if automatic irrigation is available and operational at the site. Permission to seed from November 1 to March 31 will only be given when completion of the Project is imminent and the environmental conditions are conducive to acceptable growth. Do not perform seeding on weekends or legal holidays without written approval of the Resident Engineer.
3. Application of pre-germinated seed, moisture retention agents and/or provision for supplemental watering may be required by the Resident Engineer should the Contractor schedule this portion of the Work outside the time frames listed in item 1 immediately above.
4. All areas must be prepared and seeded during the first available planting period and shall not be allowed to sit idle for long periods of time without receiving the erosion control specified in the Contract.
5. When environmental conditions are not conducive to acceptable results from seeding operations, the Resident Engineer may order the Work suspended. Resume Work only when the desired results are likely to be obtained.
6. Areas inaccessible to above methods of application shall be seeded and fertilized by approved hand methods. Distribution of the material shall be uniform and at the rates specified.
7. The Contractor shall notify the Resident Engineer not less than forty eight (48) hours in advance of any seeding operation and the Contractor shall not begin the work until areas prepared or designated for seeding have been accepted. Following acceptance, seeding and fertilizing of the approved areas shall begin immediately.

8. Reseed and fertilize all areas failing to show a uniform stand of grass after germination of seed, or damage through any cause before final inspection. After the seeded plants have been established, all areas which fail to show a uniformly thick and well-developed stand and all scattered base or dead spots shall be reseeded repeatedly until all areas are covered with a satisfactory growth of grass. Hydroseeded areas shall show no dead spots at Substantial Completion and shall be anchored to topsoil bed with vigorous, healthy root growth. Prior to Substantial Completion, damage resulting from erosion, gullies, washouts or other causes shall be repaired by filling with topsoil, tamping, re-fertilizing.

C. Equipment: use water as the carrying agent utilizing a continuous built-in agitation system. Equipment with a gear pump is not acceptable.

D. Pump a continuous, non-fluctuating supply of homogenous slurry to provide a uniform distribution of material over designated areas.

3.07 MAINTENANCE

A. Water to be provided as specified in Contract Specification 32 84 00, Planting Irrigation.

B. Maintenance shall begin immediately after each portion is installed and continue for 60 growing season days after Substantial Completion of all Work. Growing Season is defined as April 15 to November 15. Maintenance includes re-seeding, repair of ruts and erosion, repair of protective devices, watering, weeding, cutting and the repeating of any or all phase of seeding construction that may be required to obtain a uniform thick and well developed stand.

C. After the first mowing, fertilize turf with specified (16-16-16) Maintenance Fertilizer for lawns and athletic fields, at the rate of two pounds per 1,000 square feet of blended materials.

D. Remove all grass clippings from the site if requested by the Resident Engineer.

3.08 SUBSTANTIAL COMPLETION

A. Inspection to determine Substantial Completion of seeded areas will be made by the Resident Engineer upon the Contractor's request. Provide notification at least five working days before requested inspection date.

1. Seeded areas shall be accepted provided all requirements, including maintenance, have been complied with and grass is well established and exhibits a vigorous growing condition.

2. Reseed areas failing to show a uniform stand of grass at the Contractor's expense.

B. Maintain Lawn following Substantial Completion through the Warranty Period.

3.09 CLEANING

A. Perform cleaning during installation of the work and upon completion of the work. Remove from the site all excess materials, soil, debris, and equipment. Repair the damage resulting from seeding operations.
END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for maintenance, support, and protection of existing underground utilities as indicated.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work

1. Section 01 45 00.20, Quality Assurance/Quality Control.

1.02 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit to Resident Engineer a schedule of estimated shut-down times coordinated with utilities.

1. Obtain permission for shut-downs from utility owners and notify all interested parties, neighbors, utilities, and municipal and county authorities.

C. Submit plan or schematic of temporary water or sewer services to the Resident Engineer for review and coordination with the utility owners.

D. Submit to Resident Engineer a protection and access plan for existing 360 Networks, Comcast, and CenturyLink fiber optic and co-axial telecommunications facilities, and Seattle City Light electrical duct banks to be protected in place.

1. Obtain approval from utility owners or authorized agent and all interested parties within shared system(s) affected by Work. Approval shall be in the form of a written letter from the utility owner(s) representative indicating that the proposed protection and access methods have been reviewed and design and construction methods are acceptable.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 EXAMINATION

A. Field-locate existing utilities by contacting at the Utilities Underground Location Center at 811.

1. For utility owners not covered by this telephone number, such as owners of non-pressure sewer lines, Seattle Public Utilities, call the affected utility owners directly.
B. Ensure underground utilities are marked for identification by the affected utility companies before performing any excavation or other work close to any underground pipeline, conduit, duct, wire, or other structure.

1. Compare the field located utilities with the Contract Drawings. Notify Resident Engineer of discrepancies.

C. Renew field-locates over 360 Networks and Comcast fiber optic and co-axial telecommunications facilities within the U District Station Construction Limits periodically or as required for the duration of work to show location of buried facilities being protected in place and adjacent to excavation and staging areas.

D. Renew field locates over Comcast and CenturyLink fiber optic and co-axial telecommunications facilities, and Seattle City Light electrical facilities within Roosevelt Station Construction Limits periodically or as required for the duration of work to show location of buried facilities being protected in place and adjacent to excavation and staging areas.

3.02 CONSTRUCTION

A. Do not operate, disconnect, or shut down any part of the existing utilities and services, except by permission of authorities having jurisdiction.

B. Notify Resident Engineer and affected utilities a minimum of 2 and a maximum of 10 working days before digging.

C. Do not remove utilities until shut-down time can be kept to a minimum.

D. Do not remove an existing utility line or service until the replacement line, crossover, or capping is ready to be performed.

E. Record locations of cuts, caps and utility abandonment on as-built drawing.

3.03 PROTECTION

A. Maintain existing utilities not indicated for removal or abandonment and protect from damage.

B. Maintain sewer manholes, water valves, meters, fire hydrants, and utility vaults accessible and keep clear of blockages from equipment, debris or construction material.

C. When existing utility services occupy the same trench space as a new utility, excavate to fully expose such services. Protect such services and work around them during excavation and new utility installation operations.

1. In the event of conflict with other underground utilities, immediately notify the Resident Engineer.

D. Provide shoring, underpinning, and structural support for existing utility lines and structures that become suspended or otherwise unsupported because of adjacent excavation operations.

E. If underground utilities are damaged in any way, notify the Resident Engineer and affected utility owners immediately for corrective action. Document in Utility Strike Log in accordance with Section 01 45 00.20, Quality Assurance/Quality Control.

F. Contractor is responsible for all damage to existing utilities due to his operation and shall bear the cost to repair or replace the damaged utility.
G. Loading over 360 Networks, Comcast and CenturyLink fiber optic and co-axial telecommunications facilities and Seattle City Light electrical facilities within the U District Station Construction Limits, and Comcast and CenturyLink fiber optic and co-axial telecommunications facilities and Seattle City Light electrical facilities within the Roosevelt Station Construction Limits is limited to H20 load rating. Determine and design protection methods and requirements necessary to maintain integrity of system to remain in place. Maintain structural integrity of existing vaults, handholes, or other access structures associated with system. Access constraints will need to be confirmed with utility owner(s) representative.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing water service supply mains, modifications to existing water mains, and services in City of Seattle Right-of-Way as indicated.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 45 00.20, Quality Assurance/Quality Control
2. Section 01 77 00, Closeout Procedures
3. Section 01 78 23, Operation and Maintenance Data
4. Section 02 41 00, Demolition
5. Section 31 23 19, Dewatering
6. Section 31 23 33, Trenching and Backfilling
7. Section 33 01 00, Operation and Maintenance of Utilities

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Water Works Association (AWWA):
   a. AWWA M41, Ductile Iron Pipe and Fittings
   b. AWWA M44, Distribution Valves: Selection, Installation, Field Testing, and Maintenance
   c. AWWA C104, Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
   d. AWWA C110, Ductile-Iron and Gray-Iron Fittings for Water
   e. AWWA C111, Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
   f. AWWA C115, Standard for Flanged Ductile-Iron Pipe with Threaded Flanges
   g. AWWA C151, Ductile-Iron Pipe, Centrifugally Cast, for Water
   h. AWWA C153, Ductile-Iron Compact Fittings for Water Service
   i. AWWA C509, Resilient Seated Gate Valves for Water Service
j. AWWA C600, Installation of Ductile-Iron Water Mains and Their Appurtenances

k. AWWA C651, Disinfecting Water Mains

l. AWWA C901, Polyethylene Pressure Pipe and Tubing

m. AWWA C906, Polyethylene Pipe and Fittings

   b. ASTM D2774, Standard Practice for Underground Installation of Thermoplastic Pressure Piping.
   e. ASTM F714, Standard Specifications for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.
   g. ASTM F1290, Standard Practice of Electrofusion Joining of Polyethylene Pipe and Fittings.
   h. ASTM F2620, Standard Practice for Heat Fusion of Polyethylene Pipe and Fittings.

3. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge and Municipal Construction
   b. Standard Plans for Road, Bridge and Municipal Construction

   a. NFPA 24, Standard for the Installation of Private Fire Service Mains and their Appurtenances

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Include data on pipe, fittings, appurtenances, and insulation including manufacturer’s recommendations for pipe and insulation installation.

C. Lay plans for the pipeline construction. Include details for each connection to an existing main and services to be maintained or installed, including temporary water services and hydrants.

1. The review of this submittal by the Resident Engineer and municipal and county authorities does not relieve the Contractor of his responsibilities to any damage
on existing utilities due to his operation in accordance with Section 33 01 00, Operation and Maintenance of Utilities.

2. Apply for and obtain approval for temporary water service(s) at U District Station site prior to submittal of High-Density Polyethylene (HDPE) water main lay plans. Include necessary fittings, tees, valves, and other associated appurtenances with temporary water service(s) into lay plan developed and submitted. Coordinate with SPU Customer Service team 90 days minimum prior to lay plan development.

D. General: Refer to Section 01 77 00, Closeout Procedures, and 01 78 23, Operation and Maintenance Data, for submittal requirements and procedures.

E. Record Documents: Show actual locations of piping mains, valves, connections, and depths of burial on the as-built drawings in accordance with Section 01 78 39, Project Record Documents for review.

F. Construction Work Plan: Submit a construction work plan in accordance with requirements of Section 01 45 00.20, Quality Assurance/Quality Control. An approved Construction Work Plan is a precondition for the Readiness Review Meeting.

1.04 QUALITY ASSURANCE

A. Regulatory Requirements:

1. Private Property: Comply with City of Seattle Fire Department standards for water service piping, appurtenances, installation, and testing.

2. City Right-of-Way: Comply with City of Seattle, Seattle Public Utilities standards for water service piping, appurtenances, installation, and testing.

B. Provide piping materials that have been stamped or marked with the specified testing agency.


D. NFPA Compliance: Comply with NFPA 24 for materials, installations, test, flushing, and valve and hydrant supervision for fire-service-main piping for fire suppression.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver piping with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe-end damage and to prevent entrance of dirt, debris, and moisture.

B. Maintain inventory of repair sleeves for the various HDPE pipe diameters, extra HDPE pipe and restrained connections at the site in case of an emergency.

C. Inspection: Inspect pipe before it is installed. Remove defective products from the Project Site.

1.06 PROJECT CONDITIONS

A. Sequencing and Scheduling: Include sequencing and scheduling information in the Construction Work Plan, refer to Article 1.03F, herein.

A. Operation of Seattle Public Utility (SPU) water system facilities by the Contractor is prohibited. In the event of an emergency contact the SPU Emergency Dispatch Center at 206-386-1800.
B. SPU limits the shutdowns to a maximum of three per main.

C. Supply all Work and material unless noted to be completed or provided by SPU. SPU will perform only the work as specified in these Contract Specifications and Contract Drawings.

D. SPU attendance at the Readiness Review Meeting is required.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General: Install only new materials for water distribution and transmission. Materials used for temporary Water Main and for temporary service connection purposes may be either new or previously used materials and are subject to the Resident Engineer’s inspection and approval prior to installation. Verify all direct and indirect drinking water system components which come in contact with potable water have National Sanitation Foundation certification.


F. Pipe type and class is as indicated on the Contract Drawings.

B. High-Density Polyethylene Pipe and Fittings: PE 4710 with a standard dimension ratio (DR) 11 conforming to AWWA C906.


D. Gate Valves: Resilient seated gate valves in accordance with AWWA C509. Valves to have name or mark of the manufacturer, year valve casting was made, size, and working pressure plainly cast in raised and legible letters on the valve body. Valves to be NSF approved and have ductile iron bodies. Valves to be stamped with “NSF APPROVED” and “DI”.

E. Butterfly Valves: COS Standard Specification Section 9-30.3(4). Valves to have name or mark of the manufacturer, year valve casting was made, size, and working pressure plainly cast in raised and legible letters on the valve body.

F. Valve Boxes: COS Standard Specification Section 9-30.3(5).

G. Concrete Thrust Blocking: Constructed of Non-Roadway cement concrete per COS Specification Section 5-05.3.

H. Steel Casing Pipe: In accordance with the COS Standard Specifications Section 9-30.2(14).

I. Seals and Insulators for Steel Casing Pipe: In accordance with the COS Standard Specifications Section 9-30.2(15).

J. Pipe Insulation: Micro-Lok fiberglass insulation, 2-inch thickness with jacketing as manufactured by Johns Manville, or approved equal.

K. Precast Concrete Vaults: Construct in accordance with the Contract Drawing requirements.
L. Flexible Expansion Joints and Double Ball Expansion Joints: Ex-Tend Expansion Joint and Flex-Tend Flexible Expansion Joint as manufactured by EBAA Iron Inc., or approved equal.

2.02 SOURCE QUALITY CONTROL

A. Water Main material to be used in City of Seattle Right-of-Way is subject to pre-installation taste and odor testing requirements in accordance with COS Standard Specification Section 7-11.2(2).

PART 3 - EXECUTION

3.01 PREPARATION

A. Coordinate the installation of the water distribution system with other utilities to avoid conflicts.

B. Trench, Bed and Backfill as specified in Section 31 23 33, Trenching and Backfilling.

C. Provide safety systems for trench excavation as specified in Section 31 23 33, Trenching and Backfilling.

D. Trench dewatering as specified in Section 31 23 19 Dewatering. Continue trench dewatering until the ends of the pipe are sealed and provisions are made to prevent floating of the pipe. Prevent trench water or other deleterious materials from entering the pipe at any time.

E. Support and protect existing utilities as specified in Section 33 01 00, Operation and Maintenance of Utilities.

F. Abandon and remove existing water mains indicated for removal or abandonment as specified in Section 02 41 00, Demolition.

G. Salvage existing 20-inch gate valve located in existing vault at the northeast corner of NE 63rd St. and 12th Ave, NE to SPU.

H. Pipe handling requirements in accordance with COS Standard Specification Section 7-11.3(2) and in accordance with manufacturer’s requirements.

I. Protection:

1. Prevent water from entering trenches and excavations.

2. Other than chlorination chemicals and clean water, place nothing inside pipes and fittings.

3. Fit expansion plug into open end of pipe joints being laid. Allow plug to remain in-place when pipe laying is not in progress; remove plug when pipe laying is resumed. Protect mouth of pipe being laid in rock.

4. Protect exposed, installed pipe from damage and flooding.

5. Keep installed pipe clean until work has been accepted.

6. Protect pipe coatings from damage during storage and installation.
A. Construct private water lines and appurtenances in accordance with AWWA C600, AWWA M41, and ASTM D2774.

B. Construct and test private fire-service mains, hydrants and appurtenances in accordance with NFPA 24.

C. Construct City of Seattle owned water mains and appurtenances in accordance with COS Standard Specification Section 7-11.3.

G. If coated pipe is being used, provide a certified coating repair specialist to repair Contractor caused coating damage during construction of utilities and station. SPU will only repair damage to coating at time of SPU installation.

D. Connections for City of Seattle owned Water Mains: Comply with all paragraphs of COS Standard Specifications Section 7-11.3(9).

H. Support construction tasks performed by SPU as specified in Article 3.02I, herein, by providing shoring, dewatering, trenching, bedding, backfilling, thrust restraint and traffic control as necessary.

I. SPU crews will complete the following tasks associated with water mains:

1. Operate existing valves.
2. Drain, cut and cap water mains.
3. SPU may install 4-inch to 6-inch taps at the caps for flushing the existing main depending on service location. These taps can then be used by the Contractor for flushing the new main, but the Contractor shall anticipate providing alternate methods for flushing the main.
4. SPU will make all connections to existing active mains. When connecting new mains to existing mains, SPU will perform the work using Contractor furnished materials except where insulating couplings will be used. Insulating couplings will be furnished by SPU.
5. Inspect the pipe material. Acceptance by the Resident Engineer shall be received prior to laying pipe.
6. Perform quality assurance for the installations, and joint bonding welds to insure proper isolation and continuity. SPU will perform electrical continuity tests prior to pipe activation.
7. Measure outside diameter of existing water mains at connection points on mains greater than 12-inches.
8. Install or remove new water services.

E. Minimum depth of cover over the pipe is 36 inches unless otherwise shown on the Contract Drawings.

F. Concrete Thrust Blocking: City of Seattle Specification Section 7-11.3(13).

G. After all tests, flushing, and disinfection have been successfully completed and the installed water main and appurtenances have been approved by the Resident Engineer, make requests for shutdowns for connections at least 5 Working Days in advance of the desired shutdown.
H. Construct vaults in accordance with the manufacturer's instructions and in accordance with the Contract Drawings. Dewater the vault excavation as specified in Section 31 23 19 Dewatering to prevent vault floatation.

I. Pipe Insulation: Install pipe insulation and jacketing in accordance with the manufacturer’s recommendations. Submit the manufacturer’s recommendations to the Resident Engineer at least 5 working days prior to installation.

J. Flexible Expansion Joints and Double Ball Expansion Joints: Install flexible and double ball expansion joints in accordance with the manufacturer's recommendations. Submit manufacturer’s recommendations to the Resident Engineer at least 5 working days prior to installation. Wrap assembly in polyethylene wrap provided by manufacturer to promote reduction in soil resistance. Seal with appropriate tape as to keep debris, moisture, or other foreign material from contacting expansion joint fittings.

K. Joining of High-Density Polyethylene Pipe and Fittings: in accordance with ASTM D2657, D 3261, F1290, and F2620.

3.03 FIELD QUALITY CONTROL

A. Testing of City of Seattle owned Water Mains and appurtenances shall be in accordance with the COS Standard Specifications.


END OF SECTION
SECTION 33 11 14
WATER TRANSMISSION MAIN PIPING

PART 1 - GENERAL

1.01 DESCRIPTION
A. This Section covers the work for furnishing, installing, and testing welded steel pipe, specials, fittings, and appurtenances, complete for the 42-inch water transmission main replacement along 12th Avenue NE adjacent to the Roosevelt Station site.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
1. Section 01 45 00.20, Quality Assurance/Quality Control.
2. Section 01 77 00, Closeout Procedures.
3. Section 01 78 23, Operation and Maintenance Data.
4. Section 01 78 39, Project Record Documents.
5. Section 02 41 00, Demolition.
6. Section 02 80 00, Removal and Handling of Coal Tar-Containing Materials.
7. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.
8. Section 31 23 19, Dewatering.
9. Section 31 23 33, Trenching and Backfilling.
10. Section 33 01 00, Operation and Maintenance of Utilities.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
1. American National Standards Institute (ANSI):
   a. ANSI B16.5, Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
   b. Steel ANSI B16.11, Forged Steel Fittings Standards
   a. ASTM A20, Standard Specification for General Requirements for Steel Plates for Pressure Vessels
   b. ASTM A53, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
c. ASTM A139, Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)

d. ASTM A181, Standard Specification for Carbon Steel Forgings, for General-Purpose Piping

e. ASTM A234, Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

f. ASTM A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products

g. ASTM A572, Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

h. ASTM A1018, Standard Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Carbon, Commercial, Drawing, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength

3. American Society of Mechanical Engineers (ASME):

a. ASME Boiler and Pressure Vessel Code

4. American Water Works Association (AWWA):

a. AWWA C200, Steel Water Pipe


c. AWWA C206, Field Welding of Steel Water Pipe.

d. AWWA C207, Steel Pipe Flanges for Waterworks Service – Sizes 4 in. Through 144 in.

e. AWWA C208, Dimensions for Fabricated Steel Water Pipe Fittings.


g. AWWA C222, Polyurethane Coatings for the Interior and Exterior of Steel Water Pipe and Fittings

h. AWWA C509, Resilient Seated Gate Valves for Water Service.

i. AWWA C602, Cement – Mortar Lining of Water Pipelines – 4 in. (100 mm) and Larger – In Place.

j. AWWA C651, Disinfecting Water Mains.


5. American Welding Society (AWS):

a. AWS D1.1, Structural Welding Code

6. City of Seattle (CoS):
1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittals,

B. General: Refer to Section 01 77 00, Closeout Procedures and 01 78 23, Operation and Maintenance Data for submittal requirements and procedures.

C. Record Documents: Show actual locations of piping mains, valves, connections, and depths of burial on the as-built drawings in accordance with 01 78 39, Project Record Documents for review.

D. Construction Work Plan: Submit a construction work plan in accordance with the requirements of Section 01 45 00.20, Quality Assurance/Quality Control. An approved Construction Work Plan is a precondition for the Readiness Review Meeting.

E. Shop Drawings and Data:

1. Secure Shop Drawings approval before fabrication of any pipe, specials, or fittings. Base Shop Drawings on 12th Avenue NE roadway stationing and elevations. Include a Pipe Laying Plan showing proposed sequence of pipe, specials, and fittings installation. Submit Pipe Laying Plan similar to Table 13-1, in AWWA Manual M11.

2. Submit a method for complying with AWWA C206, Section 2.5 for minimizing temperature stresses at joints. Include calculations showing the anticipated movement at the joints.

3. Pipe, specials, or fittings fabricated before approval of the Shop Drawings are fabricated at Contractor risk. Resident Engineer has the right to make any changes in the design of pipe, specials, or fittings that may be necessary, in the opinion of Resident Engineer, to obtain conformance with the requirements of these Specifications.

4. Approval of Shop Drawings does not relieve Contractor of responsibility for accuracy of dimensions and details, nor does mutual agreement of dimensions or details relieve Contractor of responsibility for agreement and conformity of its Shop Drawings with Contract, or constitute acceptance by Sound Transit or Seattle Public Utilities of correctness or adequacy of such drawings or that they will meet requirements of Contract.

5. Allow 20 calendar days for review of all shop drawings. If shop drawing is rejected, review submittal and timing repeats.

6. Submit documentation indicating doubler plates, wrapper plates, crotch plates, thrust lugs, and other steel pipe details meet the requirements of AWWA M11.

7. Submit proposed method of joining new pipe to existing riveted steel pipe following field exploration of existing pipe conditions. Include pipe roundness, outside diameter, slope, existing joint interface, method on connecting, and other interface features.
8. Geotechnical information is available from Sound Transit.

F. Shop Welding and Nondestructive Testing of Shop Welds
   1. Conform all Shop Welding and Nondestructive Testing of Shop Welds to ASME Boiler and Pressure Vessel Codes, AWWA C200 and C208, AWWA/ASW D1.1 and Article 9.1.

G. Field Welding and Nondestructive Testing (NDT) of Field Welds
   1. Conform all field welding procedures and nondestructive testing of field welds shall to Article II, Section IX of the ASME Boiler and Pressure Vessel Code, ANSI/AWS D1.1, AWWA C200 and C206.

H. Disinfection and Flushing Procedures Plan
   1. Submit a plan for disinfecting and flushing the installed water main for approval before installing pipe.

I. Mortar Samples
   1. Submit a 1-pound sample of the mortar materials proposed for shop-lining pipe interior and a 1-pound sample of the materials proposed for field lining joints 2 weeks before placement. Provide instructions for mixing and curing. Resident Engineer will test the materials for taste and odor and will notify Contractor within 2 weeks of receipt if the materials pass the taste and odor test. If the material does not pass the test, submit an alternative material for testing 1-week minimum before placement. No material, which fails the taste and odor test, shall be used for lining the pipe or joints.

J. Polyurethane Coating and Heat Shrink Sleeves:
   1. Submit quality control program and proposed record-keeping form(s) for approval before beginning the work.
   2. Provide manufacturer’s recommended shrink sleeve model, thickness, length, and size of sleeve required for the specific type of joint and pipe.
   3. Provide manufacturer’s written repair procedure for review and approval before making field-coating repairs.

K. Flexible Joint Coupling
   1. Submit manufacturer’s shop drawing illustrating coupling dimensions, coupling material and thickness, gasket material, and protective coatings.
   2. Provide dimensions and criteria for restraint ring placement and welding details.

1.04 SUBMIT INSTALLATION AND TESTING PROCEDURES. QUALITY ASSURANCE

A. General:
   1. Except as specified herein, fabricate, inspect and test pipe, specials and fittings in accordance with AWWA C200 and C206. Produce all pipe, specials, and fittings larger than 16 inches O.D. by certified manufacturers of large diameter steel pipe as determined by ISO 9000 and the Steel Tank Institute/Steel Plate Fabricators Association; 944 Donata Ct., Lake Zurich, IL 60047, phone 847-438-8265, www.steeltank.com. If the pipe supplier is not certified by the Steel Tank Institute/ Steel Plate Fabricators Association, they must have 10 years'
experience in manufacturing steel pipe, 42 inches or larger in diameter, in accordance with AWWA standards.

B. Inspection:

1. Seattle Public Utilities may elect to inspect pipe, specials, and fittings both onsite and at fabrication shop and monitor welding and nondestructive testing (NDT) of welds. Coordinate welding and NDT activities with Resident Engineer so that Seattle Public Utilities is notified at least 24 hours in advance of any welding or NDT activities. The presence of Seattle Public Utilities does not relieve Contractor of its responsibility to have a certified welding inspector on site whenever shop or field welding is occurring.

2. Provide Resident Engineer and Seattle Public Utilities reasonable access and facilities to allow verification that the material is being fabricated and installed in accordance with these Specifications.

3. Seattle Public Utilities may make tests at the place of manufacture before shipment. Seattle Public Utilities reserves the right to make chemical and physical tests of materials before and after delivery, and to reject material at any time, either finished or unfinished, that does not conform to these Specifications.

C. Testing:

1. Nondestructive Testing Organization Credentials: Submit the credentials of the testing organization for nondestructive testing (NDT) of shop and field welds for approval before beginning welding.

2. Shop Nondestructive Testing: Perform nondestructive testing for various weld categories as specified below.
   a. Butt Joint Welds: 100 percent radioscopic examination
   b. Fillet Welds and Groove Welds: Welding inspection and acceptance:
      1) Visual Inspection (VT): Perform 100 percent VT of all welds in accordance with AWS D1.1, paragraph 6.9, Visual Inspection, Statically Loaded Nontubular Connections.
      2) Magnetic Particle (MT): Perform 100 percent MT on all fillet and partial penetration groove welds in accordance with AWS D1.1, paragraph 6.10; verify weld acceptance: in accordance with VT standards as indicated above.
   c. Doubler pads: air-tested in accordance with AWWA standards.

3. Field Nondestructive Testing:
   a. Requirements for field nondestructive testing: See Part 3–EXECUTION.
   b. Dye penetrant: Not allowed on pipe, specials, and fittings.

D. Affidavit:

1. Submit an affidavit that the pipe, specials, fittings, and other products furnished under this Contract comply with these Specifications.
1.05 PROJECT CONDITIONS

A. Scheduling and Sequencing: Include sequencing and scheduling information in the Construction Work Plan, refer to the Contract Drawings.

PART 2 - PRODUCTS

2.01 GENERAL

A. Use only new unused materials meeting U.S. Environmental Protection Agency and National Sanitation Foundation standard requirements for contact with potable water.

2.02 STEEL PIPE, SPECIALS, AND FITTINGS

A. Unless otherwise specified, provide steel pipe, specials, and fittings larger than 16 inches O.D. as electrically welded steel, fabricated in accordance with the latest revisions of AWWA C200. Provide steel plate or coil meeting the chemical and mechanical properties of either ASTM A1018, Grade 42 or ASTM A139, Grade C modified to 0.25 maximum carbon, fully kilned, fine grain, continuous cast process. Provide materials with the following: carbon equivalency for the ASTM A139 product 0.43 maximum as computed using the formula in ASTM A20, aluminum no less than 0.020, and silicon 0.20 maximum.

B. Produce steel coils used in the manufacture of spiral-welded pipe d from continuous cast slabs exhibiting consistent chemical and mechanical properties throughout the coil as required by the ASTM A20 standard. Submit certified chemical analysis of each heat of steel for both plates and coils. The physical tests may be taken from the coils or from the completed pipe. Decoiling and flattening of steel to provide plates before manufacture of the pipe, as required in ASTM A20 will not be required in this Contract.

C. Fabricate pipe sections d by either of the following methods:

1. Pipe sections may be spirally welded or fabricated from short cylindrical courses joined circumferentially by full-penetration butt joint welds with not more than two longitudinal seams per course. Stagger longitudinal seams on both sides of the pipe.

2. Pipe sections may be rolled or pressed from either one or two sheets the full length of the pipe and welded with no more than two longitudinal seams.

D. Patching inserts, overlays, or pounding out of dents is not permitted. Repair of notches or laminations on section ends is not permitted. Remove damaged ends as a cylinder and repair the section end. Distorted or flattened lengths will be rejected. Replace a buckled section as a cylinder. If pipe is damaged, submit a repair plan for approval.

E. Pipe Inside Diameter: The pipe diameter is 42 inches as measured after the cement mortar lining is placed.

F. Pipe Wall Thickness: The nominal pipe wall thickness is 5/16 inch. Steel of greater thickness may be used.

2.03 STEEL TESTING

A. Tension Test: Test each coil used for pipe manufacture by taking tension test coupons from the outside wrap and from the inner wrap of the coil. Cut sample coupons so that the longitudinal axes of the test specimens are oriented transverse to the final rolling direction of the coil. Conduct tension tests in accordance with ASTM A370.
B. Conduct Charpy V-Notch tests. Take the Charpy impact test specimens from coupons located adjacent to the tension test coupons. Orient and provide frequency of testing of the Charpy impact specimens to match that of the tension test specimens indicated above. Conduct the Charpy V-notch tests in accordance with ASTM A370. Determine the degree of heat treatment required to meet the Charpy impact test. The impact test temperature: 30 degrees Fahrenheit; impact specimens minimum energy: 15 ft-lbs. Charpy testing is only required on all steel greater than ½" thickness.

C. Steel not meeting the physical tests specified shall be rejected.

2.04 STANDARD WEIGHT AND EXTRA STRONG STEEL PIPE, AND FITTINGS

A. Unless otherwise shown, conform steel pipe 16-inch and larger to the requirements of ASTM A53, Type S or Type E, Grade A or B, black, standard weight.

B. Conform elbows and tees to ASTM A181 and ASTM A234 for standard weight, forged steel.

2.05 FLANGES

A. Conform flanges shall the requirements of AWWA C207, slip-on ring type, unless otherwise shown or specified, and rated for a minimum working pressure of 250 psi. Drill steel flanges mating to ductile or cast iron flanges to match bolt pattern of ductile/cast iron flanges. Use flat face flanges if the adjoining flange is flat faced.

B. In locations where flat face flanges will connect to raised face flanges, use materials conforming to the approved flange submittal.

2.06 THREADED COUPLINGS

A. Threaded couplings: black, forged steel, Class 3000, and conform to ANSI B16.11.

2.07 JOINTS

A. Provide butt strap joint closures at connections to existing pipe as shown on Contract Drawings or as required by the Pipe Laying Plan.

2.08 BOLTING MATERIALS

Provide manufacturer’s standard bolts and nuts for non-buried applications.

A. Provide Type 316 stainless steel bolts and nuts for buried flanges and couplings. Apply anti-seize compound when installing.

B. Apply a wax-tape-wrapped with a fiberglass outer wrap to buried bolts, nuts, and flanges, immediately after installation. Provide wax tape as#1 Wax-Tape by The Trenton Corporation www.trentoncorp.com or approved equal.

2.09 GASKETS

A. Provide 1/8 inch thick gaskets, conforming to ANSI B16.5 or AWWA C207, ring type or full face as required to match flanges.

2.10 DISHEDED HEADS

A. Provide semi-ellipsoidal dished heads fabricated from ASTM A572, Grade 42 steel plate or approved equal and include weld ring for connection to a flexible joint coupling. Include fittings as required for testing, filling pipe, flushing pipe, and as required for construction. Dished heads become the property of Contractor after use on Contract.
2.11 BALL VALVES, 2-INCH AND SMALLER
A. Conform to Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.

2.12 PIPE INTERIOR LINING:
A. Provide ½-inch thick cement mortar lining. Shop apply the lining in accordance with AWWA C205. Mortar at field joints shall be field placed in accordance with AWWA C602.

2.13 PIPE EXTERIOR COATING
A. Shop coat buried pipe with an aromatic polyurethane coating consisting of a 100 percent solid, fast-cure, two-component, and shall be Lifelast Durashield 210, or approved equal. Provide fully trained, certified, and authorized polyurethane coating applicators to install coating manufacturer’s products.

1. Environmental Conditions: Do not apply coatings in temperatures outside the recommended minimum or maximum values, in dust or smoke-laden atmosphere, or in damp or humid weather.

2. Perform abrasive blast cleaning only when relative humidity is below 85 percent and when the pipe surface temperature is more than 5 degrees F above the dew point and rising.

3. Coating Applicator: Trained and approved by the coating manufacturer. Provide certification letter from coating manufacturer indicating that applicator-training requirements have been met.

4. Apply coating indoors with controlled environment and protection from moisture, wind, dust, and other contaminants.

5. Surface Preparation: Grind all weld irregularities, splatter, and other surface irregularities to smooth the surface in preparation for coating. Blast clean to Near White Metal, SSPC SP-10 with a minimum 2.5-mil angular profile.

6. Primer: As recommended by the coating manufacturer, subject to approval.

7. Coating Adhesion: Minimum 750 psi in accordance with AWWA C222.

8. Coating: One coat, 40 mils minimum dry film thickness.

9. Pipe End Coating: One coat, 10 mils minimum dry film thickness from pipe end to 1 inch beyond restraint weld ring.

10. Holdback: Hold coating back 6 inches from the field-welded butt-strap connections to existing pipe end, as recommended by the pipe and coating manufacturer. Holdbacks in the coating shall be straight and cut through the full thickness of the pipe and completed in a manner that allows the application of the specified field joint coatings.

11. Quality Assurance:
   a. Minimum requirements for Pipe Applicator Quality Control Program test procedures, testing frequency, and record keeping: As recommended by the coating manufacturer and specified herein.
   b. Submit quality control program testing procedures and proposed recordkeeping form(s) for approval before beginning the work.
c. All quality control test data shall be recorded and filed in a manner that allows copies to be submitted to the coating manufacturer or Resident Engineer when requested.

1) Test and record the following environmental conditions a minimum of once every 4 hours during sandblasting and coating:
   2) Date and time.
   3) Weather conditions.
   4) Precipitation.
   5) Ambient temperature.
   6) Relative humidity.
   7) Dew point.

d. Provide the following pipe and coating test parameters a minimum of once each 4 hours:

1) Pipe temperature at time of surface preparation.
2) Results of visual inspection of blasted pipe surface.
3) Blasted pipe anchor pattern, depth, and profile.
4) Pipe temperature at time of coating application.
5) Adhesion pull tests.

e. Provide the following test parameters for each pipe length:

1) Dry film coating thickness.
2) Electrical holiday testing.
3) Final visual coating observations.

12. Holiday Testing and Repairs: Required for 100 percent of the coated surfaces, using the holiday detector and voltage as recommended by the coating manufacturer. Conduct holiday testing after shop coating is complete. Mark all holidays with permanent marker. Repair holidays with approved, compatible repair material of color sufficient to identify repairs in accordance with the coating manufacturer's instructions. Retest all repairs.

13. Coating Manufacturer’s Services: The coating manufacturer to provide a factory-trained, qualified representative onsite at the start of shop-coating procedures for 1 day, minimum, to inspect surface preparation, coating application procedures, repair procedures, and quality control testing. The coating manufacturer also to provide a factory-trained qualified representative onsite in the field as required during surface preparation and application of coating to resolve problems that may arise in association with the coating products.

2.14 HEAT SHRINK SLEEVES AT FIELD WELDS

A. Heat shrink sleeve: Provide high recovery material conforming to requirements of AWWA C216. Provide sleeve length to extend a minimum of 3 inches onto adjacent pipe coating. Provide 100 mils minimum sleeve thickness. Provide manufacturer's
recommended sleeve model, thickness, length, and size required for the specific type of joint and pipe. Provide Aqua-Shield as manufactured by Canusa-CPS, shrink sleeves, or approved equal.

2.15 WELD LEAD OUTLETs
A. If used, provide outlets for welding leads, as shown on the Contract Drawings. Provide additional welding leads outlets at Contractor option. Show all welding leads on the Shop Drawings.
B. Provide plugs used for closing the weld lead outlets suitable for the internal pressure and shall allow zero leakage. Provide joint compound as recommended by the plug manufacturer and approved by Resident Engineer.

2.16 THREDOLETS
A. Provide thredolets used for 3/4-inch taps, weld lead outlets, and at other locations shown on the Contract Drawings as3000# as manufactured by Bonney Forge, Inc., Allentown, PA.

PART 3 - EXECUTION

3.01 TOLERANCES - WATER MAIN ALIGNMENT
A. Ensure Tolerances for horizontal and vertical lines do not exceed 1/16-inch per foot of pipe but not more than 0.1 foot horizontal and 0.05 foot vertical at any point in the line.

3.02 QUALITY ASSURANCE
A. Shop and Field Welding:
   1. Ensure all pipe, specials and fittings welding is by qualified welders or welding operators and shall conform to AWWA C200 or AWWA C206.
   2. Repaired or redo and retest rejectable weld defects until sound weld metal has been deposited in accordance with appropriate welding codes.
   3. Patching inserts, overlays, or pounding out of dents in steel pipe is not permitted. Remove damaged ends as a cylinder and properly prepare the section end.

3.03 SHOP TESTING
A. Hydrostatic Shop Testing: In addition to nondestructive testing of welds specified herein, hydrostatically test all pipe, specials, and fittings as specified in AWWA C200. Specials manufactured from previously hydrostatically tested pipe sections require NTD testing of welds only. Maintain test pressure for a minimum of 5 minutes. Submit certified copies of hydrostatic shop test for each pipe. Notify Resident Engineer 48 hours before testing.

3.04 HYDROSTATIC FIELD TESTING
A. Attach test heads to assembled pipe and hydrostatically test as specified in AWWA C200 before connecting closure pieces to existing pipe. Test assembled pipe including 12-inch connection with isolation valve. Provide dished heads for the hydrostatic test.
B. Before the pipe is filled with water, inspect the piping and remove all foreign material.
C. Notify Resident Engineer 5 working days before test. Provide all piping and valves needed to fill pipe from SPU fire hydrant or from dished head fitting on adjacent 42-inch pipe as directed by Resident Engineer. SPU will operate all valves on existing system.
D. Furnish the necessary pumps, shutoff valves, check valves, plumbing, meter, two pressure gages with petcocks, and other equipment required for the hydrostatic test. No direct connections to active water mains are allowed for supplying make-up water. Install temporary blocking and anchorage necessary to hold the pipe in position during the test. Allowable pipe horizontal movement at dished heads is not to exceed 1/2 inch during pressure test.

E. Open the ball valves at the dished heads to release air.

F. Test pipe at 225 psig. Maintain the pressure for 2 hours minimum by adding water if necessary. Visible leakage is cause for rejection.

G. Repair all visible leaks and defects, replace defective pipe, couplings, and valves and retest the pipe if it fails test.

3.05 POLYURETHANE COATINGS

A. General:
   1. Coat, inspect, and repair all exterior surfaces of steel pipe, specials, and fittings in accordance with the applicable AWWA standard, unless otherwise shown or specified.
   2. Shop-apply all coatings except field repairs and holdback areas. Notify Resident Engineer at least 7 days before coating work. Resident Engineer or Seattle Public Utilities may be present during application of any or all coatings. Damage to the coated materials during shipping and handling shall be repaired in accordance with the applicable AWWA standard at no additional cost to Sound Transit.

B. Provide surface preparation Near White Blast Cleaning SSPC-SP-10.

C. Provide coating thickness 40 mils (MDFT).

D. Do not coat the machined surfaces of flanges.

E. Repair coatings damaged during installation with materials supplied by the manufacturer in accordance with the manufacturer's written instructions.

F. Conform the application of polyurethane coating to AWWA C222

3.06 FIELD-APPLIED CEMENT MORTAR LINING

A. General:
   1. Use field-applied cement mortar lining only at field joints or to repair damaged shop-applied lining.
   2. Begin the cleaning and lining operation with the approval of Resident Engineer after joints are welded, air tested, and approved for application.
   3. Line steel pipe in accordance with AWWA C602.

B. Protection of Appurtenances: Prevent mortar from being thrown into openings in the pipeline in accordance with AWWA C602, Section 4.6. Trim, smooth, and bevel the outlet openings. Repair damaged or defective areas.

C. Internal Cleaning: Thoroughly clean the interior surface of the pipe of all foreign matter, including water, before placing lining. Cleaning may be by hand or mechanical method approved by Resident Engineer. Do not pass waste materials and water from cleaning
operations through sections of existing pipe or pipe that has already been lined. Do not line pipe until Resident Engineer has inspected and approved the cleaned interior.

D. Placing Lining:

1. General: Provide the mortar lining as a one-course application and be dense, smooth, without variation in quality, and of a consistency to assure efficient and uniform lining on the pipe wall. Provide a minimum thickness of the cement mortar lining of ½-inch with a tolerance of plus 1/8-inch and zero minus tolerance.

2. Hand Application: Perform cement mortar lining by hand work. Provide cement mortar for handwork of the same materials as the mortar for machine lining. Use wire mesh reinforcing on hand-placed mortar as directed by Resident Engineer. Provide the mesh as 13-gage, 2-inch by 4-inch welded steel wire. Weld mesh to the inside of the pipe before the application of the lining.

E. Lining Finish: Ensure that the finished surface is smooth and does not have a sand finish. Test the finished surface of hand-troweled linings for finish at locations selected by Resident Engineer. Provide the finished surface such that the troweled lining no point has a space between the lined surface and 12-inch straight edge laid parallel to the axis the straight edge greater than 1/16 inch.

F. Curing: As soon as practicable after placing the lining, maintain the cement mortar in a moist condition until Resident Engineer has approved the lining. Utilize methods, subject to the approval of Resident Engineer, to ensure a moist atmosphere to keep the lining damp. Bulkheading to prevent circulation of air will not be considered an adequate curing method.

G. Protection: Contractor is responsible for preventing damage to the lining. Remove and replace defective or damaged lining as approved by Resident Engineer. For a period of 10 days after the cement mortar lining is placed, keep all equipment 5 feet from outside edge of pipe.

H. Inspection: Before filling with water, the pipe lining will be inspected by Resident Engineer. The lining of the final connection pieces will be inspected before installation. Inspection shall be in accordance with the requirements of AWWA C602, Section 9.

I. Defective Lining: Repair defects in the cement mortar lining in accordance with AWWA C602, Section 9, except Resident Engineer will determine if full circle repair of the lining will be required.

3.07 SHOP-APPLIED CEMENT MORTAR LINING

A. Shop-apply cement mortar lining except at field welds and at field repairs.

B. Conform application of shop-applied cement mortar lining to AWWA C205 including Appendix A.

3.08 FIELD COATING REPAIRS FOR POLYURETHANE-COATED PIPE

A. Visually inspect polyurethane-coated pipe in the field for coating damage that occurs during transportation and handling. Holiday test all surfaces of coated pipe after the pipe is placed in the trench and before backfilling. Repair all coating defects in accordance with the manufacturer’s directions for surface preparation, coating materials, and application. Provide manufacturer’s written repair procedures to Resident Engineer for approval before field coating repairs are made.
3.09 FIELD JOINT COATINGS FOR POLYURETHANE-COATED PIPE

A. Coat all field-welded joints of pipe having polyurethane coating with heat shrink sleeves. Store, handle, and apply heat shrink sleeves in accordance with AWWA C216 and the sleeve manufacturer's written instructions. Install the sleeve to cover all pipe surfaces not coated by the shop-applied coating system. Extend sleeve width 3-inches minimum onto adjacent polyurethane coating and 3 inches minimum onto existing pipe surfaces beyond splice.

B. Clean and prepare pipe surface in accordance with AWWA C216, Section 3.1. Clean 10 to 12 inches onto shop-applied coating as recommended by the sleeve manufacturer. Preheat pipe and apply sleeve in accordance with the manufacturer's recommended heating equipment.

C. Holiday test the completed sleeve installation and repair defects in accordance with AWWA C216 and the manufacturer's directions.

D. Manufacturer's Services: The sleeve manufacturer to provide a factory-trained, qualified representative onsite at the start of sleeve installation for 1 day, minimum, to inspect surface preparation and sleeve application procedures. The coating manufacturer also to provide a factory-trained qualified representative onsite in the field as may be required during surface preparation and application of sleeve to resolve any problems that may arise in association with the sleeve products.

3.10 CONNECTIONS TO EXISTING PIPES

A. Jointly inspect the existing pipe with Seattle Public Utilities and Resident Engineer. All parties identify and agree on work required to clean or repair the existing lockbar pipe before connecting the new pipe. Work required to repair the existing pipes will be paid on a time and material basis.

B. Field adjust connection to existing pipes to position the connection at a distance from any existing circumferential joint in the existing pipe as shown in the connection details. The Resident Engineer directs the point of connection.

C. Cut existing pipe using cutting wheel and producing a clean surface with minimal disturbance to the existing pipe coatings. Grind exposed cut surface to produce a clean, straight edge before making final connections. Patch damaged surfaces to match existing as directed by Resident Engineer.

D. Remove existing rivets where required and as directed. Plug-weld rivet holes and attach splice plate to existing pipe as shown on Contact Drawings. Welds in area of existing rivets shall be made with caution to avoid heating of rivets, damage to pipe, and causing pipe leakage.

E. Prepare existing interior pipe surface for mortar lining by wire brushing, sand blasting, or other approved means to remove existing linings and coatings to bare metal. Conform surface preparation to AWWA C205, Section 3.1.

F. Apply cement mortar lining to interior surface of field connection. Feather edges to produce smooth transition from existing lining to new.

G. Apply heat shrink sleeve to exterior connection at existing pipe. Clean pipe surface as recommended by shrink sleeve manufacturer. Use caution when applying heat to the sleeve to avoid damage to the existing rivets and coating.
3.11 INTERIOR BRACING

A. Prior to shipping and handling the pipe, install stulling and bracing with 60-degree spiders set 2 feet from each end and at intervals not exceeding 15 feet to ensure that the pipe does not exceed specified maximum out-of-roundness.

3.12 IDENTIFICATION MARKING

A. Mark each pipe section in accordance with the laying plan with non-toxic paint on each end both inside and outside the pipe. Provide 4-inch minimum lettering size. Mark field top on pieces with bends.

3.13 SHIPPING

A. Handle pipe, specials, and fittings at all times with equipment such as stout wide canvas slings and wide skids designed to prevent damage to pipe, specials and fittings and coatings. Cables, chains, hooks, metal bars or narrow skids are not permitted in contact with pipe, specials, and fittings. Carefully load pipes on padded saddles. Separate pipe sections so that they do not bear against each other and the whole load shall be securely fastened together and to the vehicles to prevent movement in transit.

B. Support the pipe in cradles of suitable timbers shaped on the supporting surface and padded to fit the curvature of pipe.

C. Provide a smoke tarp in place during transit of the pipe on each truck or train car. This requirement applies to both lined and unlined pipe.

D. Seal the ends of each length of pipe with a tight fitting cap to keep the pipe clean. Ensure that the seals remain in place at all times while the pipe is in storage or transit.

3.14 DELIVERY, STORAGE, AND HANDLING

A. Make all arrangements to deliver, store, handle and protect pipe, specials, and fittings.

B. Inspect coating on pipes for flaws and damage at trench side immediately before lowering into the trench. Repair flaws and damage.

C. Ensure that each length of pipe arrives at the storage area marked with painted numbers corresponding to the Laying Plans to indicate its location.

D. Support pipe stored at the water main site or in a storage area with sandbags, or by other means satisfactory to Resident Engineer.

3.15 INSTALLATION

A. General:

1. Install steel pipe in accordance with AWWA M11 and as specified herein.

2. Inspect pipe ends for burrs or indentations that could interfere with engagement of the joint. Wire brush to clean exposed ends of joint surfaces.

3. Limit excavation for pipe laying to 12 feet of full pipe exposure in accordance with the Construction Work Plan, unless otherwise approved in writing by the Resident Engineer. Protect the trench at the end of each construction period with steel plate or other means as provided in the Construction Work Plan.

4. Access Across New Water Main:
a. Allow no traffic or equipment to cross new water main until a minimum of 3 feet of compacted cover is in place over the pipe. Install protective barriers as required to restrict access.

5. Interior Bracing - Steel Pipe:
   a. Install pipe supports and place backfill in a manner that prevents the pipe from exceeding 3 percent out-of-roundness measured on the pipe diameter.
   b. Remove only that stulling and bracing necessary for access before backfilling.
   c. Remove all stulling and bracing after the backfill is complete. Avoid methods of stull removal that cause damage to the lining.

6. Provide adequate ventilation in the water main for safety and suitable working conditions

B. Coating of Field Weld Joints: After field butt-strap joints have been welded, tested, and approved by Resident Engineer, protect them with heat shrink sleeves as specified herein.

C. Field Quality Control:
   1. Provide visual inspection by the Contractor Field Welding Inspector of all welds and mark to indicate acceptance or rejection.
   2. Test butt strap joint field welds by shop drilling and tapping for 1/4-inch NPT in the lap ends of the joint. Apply air or other satisfactory gas into the connection between the two fillet welds in accordance with AWWA C206. Paint the welds with a soap solution. Mark all leaks indicated by the escaping gas bubbles. Repair and retest leaking joints. Seal the threaded openings with flush pipe plugs or by welding.
   3. Test welds of new filler plate in the existing lockbar pipe by Magnetic Particle (MT): Perform 100 percent MT on all fillet and partial penetration groove welds in accordance with AWS D1.1, paragraph 6.10; verify weld acceptance: in accordance with VT standards.
   4. Seattle Public Utilities reserves the right to conduct random nondestructive inspections of the field-welded joints. Provide access for Seattle Public Utilities testing. The inspections will be by a certified welding inspector and will be of an appropriate type for the weld being evaluated. Possible types of inspection include but are not limited to radiographs, magnetic particle, and ultrasonic. Testing will be performed and evaluated in accordance with American Welding Society Standard D1.1, Sections 6 and 8. Repair defects in welds by welding or by completely removing. Caulking or penning of defective welds is not permitted.
   5. Retest all repaired welds.
   6. Cost of Seattle Public Utilities-performed inspection will be by Seattle Public Utilities. All other required test cost shall be by Contractor.
   7. Provide Contractor welding inspector presence onsite whenever welding is occurring.
3.16 MAINTAINING CLEAN MAIN

A. Utilize all reasonable means to prevent possible contamination of both the existing and the new water main.

B. Seal the existing pipe ends tight to prevent entry of water, dirt, or other foreign material during periods when no construction activity is in progress.

C. Maintain the new pipe as clean as possible during all phases of installation. Keep protective covers over exposed pipe ends during transport and storage.

D. Unseal no pipe ends at night or unguarded during working hours. Keep animals out and prevent materials from falling, washing, or blowing into exposed pipe.

E. Completely clean and sweep, or power wash and remove foreign materials including all bracing before sections of the new water main are filled with water. Submit proposed method of cleaning the pipe for approval before beginning work.

F. Seattle Public Utilities and Resident Engineer will conduct internal inspection of water main for cleanliness before main is placed in service. Provide access and ventilation for proper main internal inspection.

G. Seattle Public Utilities will open the valves required to re-fill the system and begin activation of replaced pipe.

3.17 DRAINING OF WATER USED FOR FLUSHING AND DISINFECTING

A. SPU will discharge the flushing and disinfection water with Contractor assistance under the Contractor permits. SPU will discharge the water into the combined sewer in NE 65th Street. Provide pumps as needed. The rate of flow shall not exceed 500 gallons per minute without permission from Resident Engineer. The rate of discharge will depend on available sewer capacity and can be impacted by storm water drainage.

B. Record the rate and discharge volume of drainage water. Submit discharge records to Resident Engineer weekly.

3.18 DISINFECTION, SAMPLING AND FLUSHING

A. After the new pipe is assembled and pressure tested, disinfect pipe and flush clean for approval by SPU Water Quality. Comply with COS Standard Specification 7-11.3(12).

B. Thoroughly clean all new work using potable pressure water, brushes, and approved sanitary measures. Adequately ventilate water main during cleaning. Flush all cleaning water from the system.

C. Fill water main with highly chlorinated water. The chlorinated water must remain in the pipe for a minimum of 24 to 48 hours. Flush and dispose the chlorinated water to sanitary sewer after disinfection.

D. After the chlorinated water is flushed from the pipe, SPU Water Quality will sample and test for bacteriological level. Test results will take approximately 48 hours. If sample passes Water Quality test, pipe is ready for Contractor connection to existing pipe. If Water Quality does not provide notification of approved biological test, disinfect and retest pipe for bacteriological level.

E. SPU with Contractor will drain existing 42-inch water main for connection to the disinfected and approved new water main.
F. Disinfect closure pieces using chlorinated solution, brushes, and swabs before installing between new and existing water mains in accordance with AWWA Standard C651, Part 5. Wash chlorine residual from pipe surfaces. SPU will observe disinfecting and flushing of pipe.

G. Connect new pipe to existing pipe ends and return to service within a 14-calendar day period following flushing chlorinated water from new 42-inch water main. If pipe is not ready for SPU to return to service within the 14-calendar day period, it must be re-disinfected by Contractor and retested as described above. Also, if existing 42-inch water main is not returned to service within a 14-calendar day period after water main shutdown begins, the temporary bypass must be restored and SPU will reactive the existing 42-inch water main.

H. SPU will fill entire water main after Contractor installation is approved for service. Closure pieces shall be visually inspected for leakage and approved for backfill by Resident Engineer.

I. SPU reserves the right to conduct field testing and Water Quality testing of new installation over a 5-day calendar period. Assist SPU during this testing period.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing the sanitary sewerage and combined sewerage systems and connection to the existing sanitary and combined sewer systems as indicated, temporary bypasses, utility support system, including but not limited to pipes, manholes, and the related cast iron and steel products required for covers and manhole steps and ladders.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 78 39, As-Built Drawings
2. Section 02 41 00, Demolition
3. Section 31 23 19, Dewatering
4. Section 31 23 33, Trenching and Backfilling
5. Section 31 50 00, Excavation Support and Protection
6. Section 33 01 30.73 Cured-in-Place Pipe Liner

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Water Works Association (AWWA):
   a. AWWA C104, Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
   b. AWWA C111, Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
   c. AWWA C150, Standard for Thickness Design of Ductile-Iron Pipe
   d. AWWA C151, Ductile-Iron Pipe, Centrifugally Cast, for Water
   e. AWWA C900, Standard for Polyvinyl Chloride Pressure Pipe and Fabricated Fittings

2. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge, and Municipal Construction
   b. Standard Plans for Municipal Construction
1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Certification: Submit a Manufacturer’s Certificate of Compliance, based on the manufacturer’s routine quality control tests showing that the pipe meets or exceeds the requirements of the pertinent ASTM, ANSI, or AWWA specification.

C. Construction Work Plan:

D. 1. Attend a readiness review meeting with representatives of Sound Transit and SPU to determine roles and responsibilities for the tasks and timing of the work to be incorporated into the Construction Work Plan.

E. 2. Submit a Construction Work Plan covering the work in accordance with the requirements of Section 01 45 00.20, Quality Assurance/Quality Control. Include construction sequence of work, and schedule.

F. Submit to the Resident Engineer, for review, a written proposal for temporary sewer bypasses including a list of all equipment being used. Include the temporary construction bypass in NE 66th between Brooklyn Avenue NE and Roosevelt Way NE, across 12th Avenue NE to allow construction of station box shoring in the submittal. Submit at least 10 Working Days in advance of scheduled work. The Resident Engineer’s review does not relieve the Contractor of its responsibilities for any public liability for sewage spills.

G. Structural Engineer’s Qualifications: For Contractor-designed utility support systems, submit qualifications of design engineer demonstrating similar recent design experience.

H. Working Drawings: For the utility support system designed by the contractor, submit Working Drawings signed and sealed by a structural engineer currently registered in the State of Washington. Design the support system to conform to the City of Seattle Building code and the seismic design criteria indicated in the Contract Drawings. Include the following in the Working Drawings:

1. Element sizes and locations
2. Element assembly and connection details
3. Interfacing details for adjacent construction elements

I. Calculations: For the utility support system designed by the Contractor, submit calculations to support the design shown on the Working Drawings. Ensure calculations are signed and sealed by a structural engineer currently registered in the State of Washington.

J. Record Documents: Show actual locations of piping mains, connections, and pipe inverts at manholes on as-built drawings in accordance with Section 01 78 39, Project Record Documents, for review.

1.04 QUALITY ASSURANCE

A. Structural Engineer: For contractor-designed utility support systems, select a licensed structural engineer currently registered in the State of Washington, with a minimum of 5 years of experience in the design and construction of utility support systems or similar systems.
1.05 DESIGN CRITERIA FOR UTILITY SUPPORT

A. Design and maintain utility support system so that the vertical deflection of the utility does not exceed 3/4 inch over 48 feet more or less than the design grade specified in the Contract Drawings.

B. Design utility support system with allowances for eccentricities resulting from the misalignment of framing elements.

C. Design utility support system to allow in the field and periodic adjustment to remediate unacceptable vertical deflections.

D. Ensure that connections of the utility support system to any adjacent structural element, such as shoring walls or station excavation structural elements, does not compromise the strength of those structures.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General:

1. Install only new materials. Materials used for temporary purposes may be either new or previously used materials and are subject to the Resident Engineer's inspection and approval prior to installation.

B. Pipe, fittings, and joints: In accordance with COS Standard Specifications Section 9-05. Pipe type used for sanitary, combined and side sewers is as specified on the Contract Drawings.

1. Restrained Joint Ductile Iron Pipe and Fittings:
   a. Ductile Iron Pipe conforming to AWWA C151.
   b. Push-on joints conforming to AWWA C111.
   c. Double thickness (one-eighth inch) cement mortar lined in accordance with AWWA C104.
   d. Thickness Class 50 in accordance with AWWA C150.
   e. Restrained Joint pipe and fittings: Boltless design which is flexible after assembly and can be disassembled without special tools, such as TR Flex Restrained Joint Pipe as manufactured by U.S. Pipe Co., or approved equal. Joint to have a positive metal to metal contact locking system without the use of gripping teeth and the joint restraint system for the pipe must be the same as the joint restraint system for the pipe fittings.

2. Polyvinyl Chloride (PVC) Pipe for gravity sewer: Pipe, fittings and joints in accordance with AWWA C900, Pressure Class 100.

3. Steel Casing Pipe
   a. Pipe: In accordance with COS Standard Specifications Section 9-30.2(14).
   b. Seals and Spacers: In accordance with COS Standard Specifications Section 9-30.2(15).
PART 3 - EXECUTION

3.01 PREPARATION

A. Notify Resident Engineer at least 20 days prior to beginning Work associated with the new or existing sanitary/combined sewer system. In addition to the Resident Engineer’s inspection, SPU will provide its own inspection services for the Work associated with the sanitary/combined sewer systems within City Right-of-Way. COS Department of Planning and Development will inspect side sewer replacements and connections before reactivation. Provide side sewer as-built drawings to COS Department of Planning and Development in accordance with their standards.

B. Inspection: Inspect pipe before it is installed. Remove defective products from the Project Site.

3.02 CONSTRUCTION

A. Pipe Trenching, Bedding, and backfilling are specified in Section 31 23 33, Trenching and Backfilling.

B. Pipe abandonment and removals are specified in Section 02 41 00, Demolition.

C. Dewatering: Keep excavations free of water during excavation, installation of pipeline, and placement of bedding and trench backfill. Control surface run-off so as to prevent entry or collection of water in excavations. Dewater excavations containing water per the requirements of Section 31 23 19, Dewatering.

D. Trench Safety and Support Systems: Where trench excavation is deeper than 4 feet, construct and maintain safety systems that meet the requirements of the Washington Administrative Code (WAC) Chapter 296-155 Part N. Comply with the requirements of Section 31 50 00, Excavation Support and Protection.

E. Design and install a utility support system to support and protect the 8-inch sanitary sewer which crosses over the Roosevelt Station excavation. This support system will be left in place to continue supporting the pipe at the end of the Contract.

F. Monitor structurally supported sewer for movement throughout the project duration. Notify Resident Engineer and implement remedial measures if movement exceeds the maximum allowable amount specified in Article 1.05A.

G. Pipe installation: COS Standard Specification Section 7-17.3(2).

H. Install manholes, re-channel existing manholes, make manhole pipe connections, and connections to existing manholes in accordance with the City of Seattle Standard Specifications Section 7-05.3.
1. Temporary Sewer Bypass: The temporary sewer bypass in NE 65th St. shall be capable of bypassing full pipe flow of 1,600 gpm with full standby capacity for the duration of the bypassing. If the 5-day weather forecast is for no precipitation, the bypass flow capacity may be reduced to one-half of the full flow or 800 gpm. Convey pumped sewage in an enclosed hose or pipe that is adequately protected from traffic, and redirect flows into the combined sewer system. Dumping or free flow of sewage on private property, gutters, streets, or sidewalks, is prohibited.

I. When connecting new pipe to existing pipe where materials differ, use only new pipe having the same inside diameter as the existing. Match inverts, grade, and alignment. Connect joints between pipes with a mismatched wall thickness with a flexible gasketed coupling, adapter or coupling-adapter to make a watertight joint.

J. Leave side sewer connections and sewer mains uncovered until the Resident Engineer has inspected and approved the work.

3.03 FIELD QUALITY CONTROL

A. Notice of Testing

1. Notify the Resident Engineer at least 2 Working Days before testing. Perform all testing in the presence of the Resident Engineer.

B. Cleaning and Testing:

1. Clean pipes and manholes and perform testing as specified in the COS Standard Specification Section 7-17.3(4).

2. Furnish, install, and operate pumps, gages, meters, and individual pipe connections for testing.

C. Television Inspection

1. Videotape the interior of all newly installed sewer pipes 6 inches through 48 inches to determine the acceptance of the Work. Perform television inspection work in accordance with the City of Seattle Standard Specifications Section 7-17.3(4).

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing the storm water drainage system and connection to storm drainage mains as indicated, including but not limited to drainage pipes, culverts, related drainage structures, trench drains, catch basins, drainage inlets, storm manholes, and the related cast iron and steel products required for gratings, covers, and manhole steps and ladders.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 02 41 00, Demolition
2. Section 31 23 33, Trenching and Backfilling
3. Section 31 50 00, Excavation Support and Protection
4. Section 33 01 00, Operation and Maintenance of Utilities.
5. Section 33 30 00, Sanitary Sewerage Utilities

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge and Municipal Construction
   b. City of Seattle Standard Plans for Municipal Construction

1.03 DEFINITIONS

A. COS Standard Specifications: City of Seattle Standard Specifications for Road, Bridge and Municipal Construction

B. COS Standard Plans: City of Seattle Standard Plans for Municipal Construction

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Certification: Submit certification or other acceptable evidence that the following meet the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction.

1. Pipe
2. Jointing
3. Catch Basins and Manholes
4. Frame, Grates and Solid Covers
5. Flexible Couplings
6. Manhole Steps, Handholds, and Ladders
7. Manufacturer’s affidavit certifying compliance of materials with specifications.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe

1. Pipe used for storm drains is as specified or herein:
   a. Flexible Pipe Material:
      1) Polyvinyl Chloride (PVC)
      2) Corrugated Metal
      3) Polyethylene (PE)
   b. Rigid Pipe Material:
      1) Concrete
      2) Ductile Iron

2. Steel Casing Pipe
   a. Pipe: In accordance with COS Standard Specifications Section 9-30.2(14).
   b. Seals and Spacers: In accordance with COS Standard Specifications Section 9-30.2(15).

3. Meet the requirements of the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-05, Pipe.
   a. Clearly mark all pipe with type, class, date of manufacturer, location of manufacturing plant and thickness. Lettering: Legible and permanent under normal conditions of handling and storage.
   b. Design pipe exterior loading strength and bedding to accommodate construction and permanent loading.

B. Jointing: Provide jointing material from same material as pipes and in accordance with the manufacturer’s recommendations. Meet the requirements of the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-05.

C. Catch Basins and Manholes: Use type as indicated on the Contract Drawings and in accordance with the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-12.

D. Frame and Grate: Use cast iron in accordance with the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-12.
E. Flexible Couplings: Use type as indicated on the Contract Drawings and/or in accordance with the City of Seattle Standard Specifications.

F. Manhole Steps, Handholds, and Ladders: Use type as indicated on the Contract Drawings and/or in accordance with the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-12.

PART 3 - EXECUTION

3.01 PREPARATION

A. Existing storm sewer systems shown on the plans to be abandoned and/or removed shall be abandoned and/or removed in accordance with Section 02 41 00, Demolition.

3.02 CONSTRUCTION

A. Excavate trenches, and place pipe bedding backfill for utility burial in accordance with Section 31 23 33, Trenching and Backfilling and Section 31 50 00, Excavation Support and Protection.

B. Follow the specifications of the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 7-17.3 and Section 7-08.3(2) for the construction and installation requirements for the pipe, related structures, and other incidental work.

C. Maintain uninterrupted service with temporary storm sewer bypass as depicted on the Contract Drawings, when construction work will interfere with storm water flow in the existing sewer. Install Temporary Sewer Bypass in accordance with the City of Seattle Standard Specifications, Section 7-17.3(2) K.

D. Remove and/or abandon existing Storm Drain System as depicted in the Contract Drawings, in accordance with Section 02 41 00, Demolition.

E. Keep excavations free of water during excavation, installation of pipeline, and placement of bedding and trench backfill. Control surface run-off so as to prevent entry or collection of water in excavations. Dewater excavations containing water per the requirements of Section 31 23 19, Dewatering.

F. Where trench excavation is deeper than 4 feet, construct and maintain safety systems that meet the requirements of the Washington Administrative Code (WAC) Chapter 296-155 Part N. Comply with the requirements of Section 31 50 00, Excavation Support and Protection.

G. Where storm drains are temporarily cut or plugged, temporary mitigation is to be provided, including pumping storm water if required to maintain uninterrupted storm drainage service.

3.03 FIELD QUALITY CONTROL

A. Clean and test pipelines and appurtenances within 15 working days after backfilling of pipelines and structures. Test pipe for leakage after installation in accordance with the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 7-17.3(4).

B. TV Inspection: Videotape the interior of all storm pipes 6 inches through 48 inches to determine the acceptance of this portion of the Work. Follow the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 7-17.3(4) I for the TV inspection work.
C. Provide as-built surveys of all new storm drainage system.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for modifications to any traffic signal system, as indicated in the Contract or as directed by Resident Engineer.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. City of Seattle
      a. City of Seattle Standard Specifications for Road, Bridge, and Municipal Construction, including applicable provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.
   2. Washington State Department of Transportation (WSDOT)
      a. WSDOT Standard Specifications for Road, Bridge, and Municipal Construction, including applicable provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Submit plan for modifying traffic signal system with schedule for work to the Resident Engineer and City of Seattle for review and approval.
C. Submit as-built for modifications to existing traffic signals to the Resident Engineer and City of Seattle for record keeping.

PART 2 - PRODUCTS

A. Equipment
   1. For traffic signals on streets, roadways, and parking areas that are to be owned or maintained by jurisdictions other than Sound Transit, the materials used shall conform to the applicable requirements of the jurisdictional agency’s standard drawings and specifications.
PART 3 - EXECUTION

3.01 CONSTRUCTION

A. For traffic signals on streets, roadways and parking areas that are to be owned or maintained by jurisdictions other than Sound Transit, the work described in this Section shall be performed in accordance with the applicable requirements of the jurisdictional agency’s standard drawings and specifications.

B. Coordinate with the Resident Engineer for modification to City of Seattle traffic signals. Notify the Resident Engineer a minimum of 3 weeks in advance of any scheduled traffic signal work.

END OF SECTION