

Section 02542**CONCRETE MANHOLES AND ACCESSORIES****1.0 GENERAL****1.01 SECTION INCLUDES**

- A. Pre-Cast Concrete Manholes for sanitary.
- B. Pre-Cast and Cast-in-Place Manholes for storm sewer.
- C. Iron castings for manhole frames and covers, inlet frames and grates, catch basin frames and grates, meter vault frames and covers, adjustment rings and extensions.
- D. Ring grates.
- E. References to Technical Specifications:
 - 1. Section 01200 – Measurement and Payment Procedures
 - 2. Section 01350 – Submittals
 - 3. Section 01500 – Temporary Facilities and Controls
 - 4. Section 03300 – Cast-in-Place Concrete
 - 5. Section 02255 – Bedding, Backfill, and Embankment Materials
 - 6. Section 02318 – Excavation and Backfill for Utilities
 - 7. Section 02530 – Gravity Sanitary Sewers
 - 8. Section 01140 – Contractor’s Use of Premises
- F. Referenced Standards:
 - 1. American Society for Testing and Materials (ASTM)
 - a. ASTM C 478, “Standard Specification for Precast Reinforced Concrete Manhole Sections”
 - b. ASTM C 443, “Standard Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets”
 - c. ASTM C 270, “Standard Specification for Mortar for Unit Masonry”
 - d. ASTM C 923, “Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes and Laterals”
 - e. ASTM C 1107, “Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)”
 - f. ASTM A 48, “Standard Specification for Gray Iron Castings”
 - g. ASTM A 615, “Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement”
 - h. ASTM D 698, “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort”

2. American Association of State Highway and Transportation Officials (AASHTO)
 3. American Water Works Association (AWWA)
 4. American Welding Society (AWS)
 - a. AWS D12.1, "Reinforcing Steel Welding Code"
 5. Texas Commission on Environmental Quality (TCEQ)
 - a. Chapter 217.55 "Minimum Clear Opening"
- G. Definitions:
1. Shallow Depth Manholes- manholes having a depth of 4 feet or less measured from the top of cover to sewer invert.
 2. Normal Depth Manholes- manholes having a depth of greater than 4 feet and up to 8 feet measured from top of cover to sewer invert.
 3. Extra Depth Manholes- manholes having a depth of greater than 8 feet measured from the top of cover to sewer invert.
 4. Corrosion Resistant Manholes- concrete manholes incorporating additional material, such as liners or coatings, which make them more resistant to corrosion than typical concrete manholes.
 5. Standard Manholes Drops- drops of up to 3 vertical feet measured from the invert of the T-fitting to the sewer invert.
 6. Extra Depth Manhole Drops- drops in excess of 3 vertical feet measured from the invert of the T-fitting to the sewer invert.

1.02 MEASUREMENT AND PAYMENT

- A. Measurement for Normal Depth Manholes and/or Normal Depth Corrosion Resistant Manholes shall be per each.
- B. Measurement for Shallow Depth Manholes and/or Shallow Depth Corrosion Resistant Manholes shall be per each.
- C. Measurement for Extra Depth Manholes and/or Extra Depth Corrosion Resistant Manholes is on a vertical foot basis for each foot of depth greater than 8 feet.
- D. Payment for Manholes under this Section shall be for complete installation including riser, frames, grates, adjustment rings, stainless steel inflow preventers, cut-in work, covers, penetrations, other appurtenances, and be in accordance with Section 01200 – Measurement and Payment Procedures.

- E. Measurement for Standard Manhole Drops shall be per each.
- F. Measurement for Extra Depth Manhole Drops is on a vertical foot basis for each foot of Drop greater than 3 feet.
- G. Payment for Drops under this Section shall be for assembly components, encasement, other appurtenances, and be in accordance with Section 01200 – Measurement and Payment Procedures.
- H. Payment for Air Release Manhole with Valves and Fittings installed is on a unit price basis for each manhole with air release valves, fittings and appurtenances installed and in accordance with Section 01200 Measurement and Payment Procedures.

1.03 PERFORMANCE REQUIREMENTS

- A. Perform work needed to make manholes structurally sound, improve flow, prevent entrance of inflow or groundwater, prevent entrance of soil or debris, and provide protection against hydrogen sulfide gas attack.
- B. Manufacturer's Product Support.
 - 1. Through the Contractor, manufacturers of wall sealing or lining systems shall submit to Engineer for review and approval a detailed description of the proposed coating installation process. Describe surface preparation, independent laboratory test results, mix design procedures and method of controlling uniform thickness.
 - 2. A representative employed by the manufacturer and having technical training in epoxy or cementitious liner shall be named and available for consultation by telephone during business hours and on site upon 48 hours notice.
 - 3. Manufacturer's representative on concrete lining systems shall provide technical assistance to applicators to ensure proper usage of dispensing equipment and accurate proportions of admixtures.

1.04 SUBMITTALS

- A. Make Submittals required by this Section under the provisions of Section 01350 – Submittals.
- B. Submit proposed design mix and test data for each type and strength of concrete.
- C. Submit manufacturer's data and details of following items for approval:
 - 1. Frames, grates, rings, and covers.
 - 2. Materials to be used in fabricating drops.

3. Materials to be used for pipe connections at manhole walls.
 4. Materials to be used for stubs and stub plugs.
 5. Plugs to be used for sanitary sewer hydrostatic testing.
 6. Shop Drawings of manhole sections and base units and construction details, including reinforcement, jointing methods, materials and dimensions.
 7. Certification from manufacturer that precast manhole design is in full accordance with ASTM C 478 and design criteria as established in this Section, 2.03E, "Design Loading Criteria".
 8. Product data, materials and procedures for corrosion resistant liner and coatings, if required. For coating and resistant liner systems requiring 10-yr manufacturer warranty, submit specific coating system including product, thickness, and application for Engineer's approval.
 9. Manufacturer's data for pre-mix (bag) concrete, if used for channel inverts and benches.
- D. Installer Qualifications: Installers of liners and wall repair systems shall submit qualifications to Engineer at least 14 days prior to start of any material application. Submittal shall consist of:
1. Manufacturer's approved equipment list, by name and model number for application of product and contractor's equipment list showing approved equipment available for use in product application.
 2. List of contractor's personnel who have satisfactorily completed manufacturer's training in product application within previous two years. Include date of certification for each person.
- E. Provide Shop Drawings for fabrication and erection of casting assemblies. Include plans, elevations, sections and connection details. Show anchorage and accessory items. Include Setting Drawings for location and installation of castings and anchorage devices.

2.0 PRODUCTS

2.01 MATERIALS

- A. Concrete shall conform to requirements in Section 03300 - Cast-In Place Concrete.
- B. Minimum concrete compressive strength of 4000 psi.

- C. Reinforcing Steel shall conform to requirement in Section 03300 - Cast-In Place Concrete.
- D. Mortar shall conform to requirements of ASTM C 270, Type S using Portland cement.

2.02 PRECAST CONCRETE MANHOLES

- A. Use manhole sections and base sections conforming to ASTM C 478. Use base riser section with integral floors, unless shown otherwise. Provide adjustment rings which are standard components of the manufacturer of the manhole sections meeting material requirements of ASTM C 478. Mark date of manufacture and name or trademark of manufacturer on inside of barrel.
- B. Construct barrels for precast manholes from 48-inch diameter standard reinforced concrete manhole sections unless otherwise indicated on Plans. Use various lengths of manhole sections in combination to provide the correct height with the fewest joints. Wall sections shall be designed for depth as shown and loading conditions as described in this Section, 2.03E, "Design Load Criteria", but shall not be less than 5 inches thick. Base section shall have a minimum thickness of 12 inches under the invert.
- C. Provide cone tops to receive 30-inch cast iron frames and covers, unless indicated otherwise. Use tops designed to support an AASHTO H-20 loading.
- D. Where the Plans indicate that manholes larger than 48-inch diameter are required, precast base sections of the required diameter shall be provided with flat slab top precast sections used to transition to 48-inch diameter manhole access riser sections. Transition can be concentric or eccentric. The transition shall be located to provide a minimum of 7-foot head clearance from the top of bench to underside of transition.
- E. Design Loading Criteria: The manhole walls, transition slabs, cone tops, and manhole base slab shall be designed by the manufacturer to the requirements of ASTM C 478 for the depth as shown on Plans and the following design criteria:
 - 1. AASHTO H-20 loading applied to the manhole cover and transmitted down to the transition and base slabs.
 - 2. Unit soil weight of 120 pcf located above all portions of the manhole, including base slab projections.
 - 3. Lateral soil pressure based on saturated soil conditions producing an at-rest equivalent fluid pressure of 100 pcf, with soil pressure acting on empty manhole.
 - 4. Internal liquid pressure based on a unit weight of 63 pcf, with manhole filled with liquid from invert to cover, with no balancing external soil pressure.
 - 5. Dead load of manhole sections fully supported by the transition and base slabs.

6. Design additional reinforcing steel to transfer stresses at openings.
 7. The minimum clear distance between any two wall penetrations shall be 12 inches or half the diameter of the smaller penetration, whichever is greater.
- F. Form joints between sections with O-ring gaskets conforming to ASTM C 443.
- G. Do not incorporate manhole steps in manhole sections.
- H. Do not use brick masonry in construction of sanitary sewer manholes.

2.03 MISCELLANEOUS METALS

- A. Provide cast-iron frames, grates, rings, covers, and stainless steel inflow preventers conforming to requirements of this Section and the City of Pearland Standard Construction Details.

2.04 DROPS

- A. Drops shall conform to the same pipe material requirements used in the main pipe, unless otherwise indicated on the Plans.

2.05 PIPE CONNECTIONS

- A. Use resilient connectors conforming to requirements of ASTM C 923. Metallic mechanical devices as defined in ASTM C 923 shall be made of the following materials:
1. External clamps:
 - a. Type 304 stainless steel.
 2. Internal, expandable clamps on standard manholes:
 - a. Type 304 stainless steel, 11 gage minimum.
 3. Internal, expandable clamps on corrosion-resistant manholes:
 - a. Type 316 stainless steel, 11 gage minimum.
 - b. Type 304 stainless steel, 11 gage minimum, coated with minimum 16 mm fusion-bonded epoxy conforming to AWWA C-213.
 4. All precast openings shall be fully circular, 360° openings.
- B. Where rigid joints between pipe and a cast-in-place manhole base are specified or shown on the Plans, use polyethylene-isoprene water-stop meeting the physical property requirements of ASTM C 923, Press-Seal WS Series, or equal.

- C. Storm sewer pipe connections:
 - 1. Connections acceptable for sanitary sewers.
 - 2. Line pipe grouted in place with mortar. Rehabilitate.

2.06 WALL CLEANING MATERIAL

- A. Cleaners: Detergent or muriatic acid capable of removing dirt, grease, oil and other matter which would prevent a good bond of sealing material to wall. Refer to sealing material manufacturer's recommendations.

2.07 SEALANT MATERIALS

- A. Sealing materials between precast concrete adjustment ring and manhole cover frame shall be Adeka Ultraseal P201, or approved equal.

2.08 WALL REPAIR MATERIALS

- A. Hydraulic Cements: Use a blend of cement powders or hydraulic cement to stop active leaks in the manhole structure.
- B. Quickset Mortar: Use a quickset mortar to repair wide cracks, holes or disintegrated mortar.

2.09 CORROSION RESISTANT MANHOLE MATERIALS

- A. Provide one of the following as indicated on the Plans:
 - 1. Precast cylindrical Portland cement concrete sanitary sewer manhole sections, base sections, and cone sections with one of the following factory applied internal coatings or approved equal:
 - a. NeoPoxy™ NPR-5300 Series "PureEpoxy" spray on epoxy liner and other required fillers/sealants per manufacturer's recommendations:
 - b. NeoPoxy NPR-3501 high tensile elongation epoxy elastomeric gout and sealant.
 - c. NeoPoxy NPR-5305 trowelable epoxy filler, grout and sealant,
 - d. Chemical and cementitious rapid set hydraulic grouts such as Strong-Plug, Strong-Seal QSR, Quadex Hyperform and Quadex Hydro-Plug, or other equivalents pre-approved by the engineer.

- e. NeoPoxy P-88 ultraviolet light resistant topcoat.
 - f. EMACO liner (contact City of Pearland Public Works Department for specific type).
 - g. Raven liner (contact City of Pearland Public Works Department for specific type).
 - h. SewperCoat 100% Calcium aluminate by Kerneos™ Aluminate Technologies.
2. Type I Coating: The manufacturer of these applied products shall provide a minimum 10-year material and labor warranty. A 10-year manufacturer warranty shall be applicable for the following sanitary sewer manholes:
 - a. Manholes that receive force main discharge.
 - b. Manholes within the lift/pump station site including last manhole before wet well.
 - c. Manholes with 5 feet diameter and larger or manholes that receive discharge from 15" or larger diameter gravity sewer.
 - d. Manholes as determined by City Engineer.
 3. Type II Coating: All other sanitary sewer manholes shall be coated with minimum 125 mil thick coating of products specified in Section 2.09.1.a-d, or approved equal.

2.10 BACKFILL MATERIALS

- A. Backfill materials shall conform to the requirements of Section 02255 – Bedding, Backfill, and Embankment Materials.

2.11 NON-SHRINK GROUT

- A. For non-shrink grout, use prepackaged, inorganic, flowable, non-gas-liberating, non-metallic, cement-based grout requiring only the addition of water. It shall meet the requirements of ASTM C 1107 and shall have a minimum 28-day compressive strength of 7000 psi.

2.12 CASTINGS

- A. Castings for frames, grates, rings and covers shall conform to City of Pearland Standard Construction Details and shall be ASTM A 48, Class 30. Provide locking covers if indicated on Plans.
- B. Castings shall be capable of withstanding the application of an AASHTO H-20 loading without permanent deformation.
- C. Fabricate castings to conform to the shapes, dimensions, and with wording or logos shown on the Plans.
- D. Castings shall be clean, free from blowholes and other surface imperfections. Cast holes in covers shall be clean and symmetrical, free of plugs.

2.13 BEARING SURFACES

- A. Machine bearing surfaces between covers or grates and their respective frames so that even bearing is provided for any position in which the casting may be seated in the frame.

2.14 SPECIAL FRAMES AND COVERS

- A. Where indicated on the Plans, provide watertight manhole frames and covers with a minimum of four bolts and a gasket designed to seal cover to frame. Supply watertight manhole covers and frames, Model R-1916 manufactured by Neenah Foundry Company, Model V-2420 by East Jordan Iron Works, or approval equal.
- B. Where personnel entry is anticipated, minimum clear openings of 30-inches is required.

2.15 FABRICATED RING GRATES

- A. Ring grates shall be fabricated from reinforcing steel conforming to ASTM A 615.
- B. Welds connecting the bars shall conform to AWS D12.1.

2.16 INFLOW PREVENTERS

- A. Provide stainless steel inflow preventers with air release vents on all sanitary sewer manholes.

3.0 EXECUTION

3.01 EXAMINATION

- A. Verify lines and grades are correct.
- B. Determine if the subgrade, when scarified and re-compacted, can be compacted to 95 percent of maximum Standard Proctor Density according to ASTM D 698 prior to placement of foundation material and base section. If it cannot be compacted to that density, the subgrade shall be moisture conditioned until that density can be reached or shall be treated as an unstable subgrade.
- C. Do not build sanitary or storm sewer manholes in ditches, swales, or drainage paths unless approved by the Engineer.

3.02 PLACEMENT OF PRECAST MANHOLES

- A. Install precast manholes to conform to locations and dimensions shown on Plans.
- B. Place manholes at points of change of alignment, grade, size, pipe intersections, and end of sewer.

3.03 MANHOLE BASE SECTIONS AND FOUNDATIONS

- A. Place precast base on 12-inch-thick (minimum) foundation of cement stabilized sand or a concrete foundation slab. Compact cement-sand in accordance with requirements of Section 02318 – Excavation and Backfill for Utilities.
- B. Unstable Subgrade Treatment: When unstable subgrade is encountered, the subgrade will be examined by the Engineer to determine if the subgrade has heaved upwards after being excavated. If heaving has not occurred, the subgrade shall be over-excavated to allow for a 24-inch thick layer of crushed stone wrapped in filter fabric as the foundation material under the manhole base. If there is evidence of heaving, a pile-supported concrete foundation, as detailed on the Plans, shall be provided under the manhole base, when indicated by the Engineer.

3.04 PRECAST MANHOLE SECTIONS

- A. Install sections, joints, and gaskets in accordance with manufacturer's printed recommendations.
- B. Install precast or steel adjustment rings above tops of cones or flat-top sections as required to adjust the finished elevation and to support manhole frame.
- C. Seal any lifting holes with non-shrink grout.

- D. Where PVC liners are required, seal joints between sections in accordance with manufacturers recommendations.

3.05 PIPE CONNECTIONS AT MANHOLE

- A. Install approved resilient connectors at each pipe entering and exiting sanitary sewer manholes in accordance with manufacturer's instructions.
- B. Ensure that no concrete, cement stabilized sand, fill, or other rigid material is allowed to enter the space between the pipe and the edge of the wall opening at and around the resilient connector on either the interior or exterior of the manhole. If necessary, fill the space with a compressible material to guarantee the full flexibility provided by the resilient connector. All pipe openings shall be fully circular, 360° openings.
- C. Where a new manhole is to be constructed on an existing sewer, install precast manhole base with factory installed Fernco type connections and pipe stubouts at least two (2) feet outside manhole wall. Manhole shall be cut-in to existing pipe. No "horseshoe" or "dog house" type connections will be permitted.
- D. Do not construct joints on sanitary sewer pipe within wall sections of manholes. Use approved connection material.
- E. Construct pipe stubs with resilient connectors for future connections at locations and with material indicated on Plans. Install approved stub plugs at interior of manhole.
- F. Test connection for watertight seal before backfilling.

3.06 INVERTS FOR SANITARY SEWERS

- A. Construct invert channels to provide a smooth flow transition waterway with no disruption of flow at pipe-manhole connections. Conform to following criteria:
 - 1. Slope of invert bench: 1 inch per foot minimum; 1-1/2 inch per foot maximum.
 - 2. Depth of bench to invert:
 - Pipes smaller than 15-inches: one-half largest pipe diameter
 - Pipes 15 to 24-inches: three-fourths the largest pipe diameter
 - Pipes larger than 24-inches: equal to the largest pipe diameter
 - 3. Invert slope through manhole: 0.10-foot drop across manhole with smooth transition of invert through manhole, unless otherwise indicated on Plans.
- B. Form invert channels with class A concrete if not integral with manhole base. For direction changes of mains, construct channels tangent to mains with maximum possible radius of curvature. Provide curves for side inlets and smooth invert fillets for flow transition between pipe inverts.

3.07 DROPS FOR SANITARY SEWERS

- A. Construct Drops with same materials used in main pipe unless otherwise indicated on Plans or approved by the Engineer. Install a Drop when a sewer line enters a manhole higher than 30-inches above the invert of the manhole. All drops must be interior drops.
- B. Terminate encasement of blind drops a minimum of 5 inches below top of bell and not less than 12 inches above top of next lower bell. Install approved plug at bell.

3.08 MANHOLE FRAME AND ADJUSTMENT RINGS

- A. Combine precast concrete adjustment rings so that the elevation of the installed casting cover is 3/8 inch below the pavement surface. Seal between adjustment ring and the manhole top with non-shrink grout; do not use mortar between adjustment rings. Apply a latex-based bonding agent to concrete surfaces to be joined with non-shrink grout. Set the cast iron frame on the adjustment ring in a bed of approved sealant. The sealant bed shall consist of two beads of sealant, each bead having minimum dimensions of 1/2-inch and 3/4-inch wide.
- B. For manholes in unpaved areas, top of frame shall be set a minimum of 6 inches above existing ground line unless otherwise indicated on Plans. In unpaved areas, encase the manhole frame in mortar or non-shrink grout placed flush with the face of the manhole ring and the top edge of the frame. Provide a rounded corner around the perimeter.

3.09 BACKFILL

- A. Place and compact backfill materials in the area of excavation surrounding manholes in accordance with requirements of Section 02318 – Excavation and Backfill for Utilities. Use embedment zone backfill material, as specified for the adjacent utilities, from manhole foundation up to an elevation 12 inches over each pipe connected to the manhole. Provide trench zone backfill, as specified for the adjacent utilities, above the embedment zone backfill.
- B. Where rigid joints are used for connecting existing sewers to the manhole, backfill under the existing sewer up to the spring-line of the pipe with Class B concrete or flowable fill.

3.10 MANHOLE WALL CLEANING

- A. The floor and interior walls of the manhole shall be thoroughly cleaned and made free of all foreign materials including dirt, grit, roots, oils, grease, sludge, incompatible existing coatings, waxes, form release, curing compounds, efflorescence, sealers, salts, or other contaminants which may affect the performance and adhesion of the coating to the substrate.

1. High pressure water blasting with a minimum of 3,500 psi shall be used to clean free all foreign material within the manhole
 2. When grease and oil are present within the manhole, an approved detergent or muriatic acid shall be used integrally with the high pressure cleaning water.
 3. All materials resulting from the cleaning of the manhole shall be removed prior to application of the coating.
 4. All loose grout, ledges, steps and protruding ledges shall be removed to provide an even surface prior to application of coating.
- B. Prevent any foreign material from entering the adjoining pipes. Remove droppings of foreign and wall sealant materials before they harden on the bottom of the manhole.
- C. No separate pay shall be made for this item. Include cost for sealing in the unit price for manholes.
- D. Manufacturer's representative shall be available at all times on site to answer questions and approve manhole preparation work prior to lining.

3.11 MANHOLE WALL SEALING

- A. Seal active leaks in the manhole structure by using non-shrink grout.
- B. Remove loose or defective wall material. Wipe or brush surface clean prior to the application of hydraulic cement
- C. Drill weep holes at bottom of manhole walls to relieve hydrostatic pressure to stop leaks. Plug pressure relief holes after leaks are stopped using hydraulic cement materials. Lead wool may also be used to plug large leaks.
- D. Repair wide cracks, or holes with quickset mortars. Follow manufacturer's application procedures.
- E. Shape manhole inverts before wall sealing work. Apply concrete to cleaned manhole benches as specified in Section 03300.
- F. After all active leaks have been stopped, clean and prepare walls for application of selected liner material.
- G. Properly apply the sealing compound to provide the minimum required uniform coating to the wall surface.
- H. Prevent any foreign material from entering the adjoining pipes. Remove droppings of foreign and wall sealant materials before they harden on the bottom of the manhole.

- I. Strictly follow product manufacturer's published technical specifications and recommendations for surface preparation, application and proportioning.

3.12 FIELD QUALITY CONTROL

- A. Conduct leakage testing of manholes in accordance with requirements of Section 02530 – Gravity Sanitary Sewers. Vacuum test shall be completed prior to coating of the manhole.

3.13 INSPECTION

- A. After manhole wall sealing has been completed, visually inspect the manhole in the presence of Engineer. Check for cleanliness and for elimination of active leaks.
- B. At completion of manhole construction, assist Engineer in verifying installation of minimum coating thickness of concrete liner. Test several points on the manhole wall. Repair verification points prior to final acceptance for payment.
- C. During application of corrosion resistant liner, a wet film thickness gauge, meeting ASTM D4414, shall be used. Measurements shall be taken, documented and attested by the Contractor for submission to the Owner.
- D. At completion of manhole construction, assist Engineer in inspection of installation.

3.14 TESTING

- A. After the coating product(s) have set in accordance with manufacturer's instructions, all surfaces shall be inspected for holidays with high-voltage holiday detection equipment. Reference NACE RPO 188-99 for performing holiday detection. All detected holidays shall be marked and repaired by abrading the coating surface with grit disk paper or other hand tooling method. After abrading and cleaning, additional coating can be hand applied to the repair area. All touch-up/repair procedures shall follow the coating manufacturer's recommendations. Documentation on areas tested, results and repairs made shall be provided to Owner by Contractor.
- B. Visual inspection shall be made by the Project Engineer and/or Inspector. Any deficiencies in the finished coating shall be marked and repaired according to the procedures set forth herein by Contractor.

3.15 CLEAN-UP AND RESTORATION

- A. Perform clean-up and restoration in and around construction zone in accordance with Section 01140 – Contractor's Use of Premises.

3.16 PROTECTION OF THE WORK

- A. Protect Manholes from damage until subsequent work has been accepted.
- B. Repair or replace damaged elements of Manholes at no additional cost to the Owner.
- C. In unpaved areas, provide positive drainage away from manhole frame to natural grade.

END OF SECTION