SECTION 8 STRUCTURAL DESIGN REQUIREMENTS

8.1 *General*

8.1.1 Responsibility

8.1.1.A The Engineer must bear the sole responsibility for meeting the engineering standard of care for all aspects of the design and providing a design that is appropriate for the site-specific conditions and intended use of the facilities.

8.1.1.B The structural design must be signed and sealed by a Professional Engineer competent in structural engineering and licensed in the State of Texas. The Engineer is responsible for all engineering of the structure and recognizes that specific site circumstances or conditions may require improvements that exceed minimum standards contained in the *Manual*. The Engineer is responsible for evaluating and applying appropriate standards and specifications.

8.1.1.C The Engineer must rely on the geotechnical investigation recommendations as minimum design criteria. If in the Engineer's judgment, the structural design needs to be based upon more conservative geotechnical design criteria, the Engineer must provide the more conservative design.

8.1.2 *Structures* – For this section of the *Manual*, structures will include the following items, but not be limited to: bridges, foundations, retaining walls, headwalls and wingwalls, bridge-class culverts, slopes and embankments, creek and channel structures, elevated (aerial) crossings, and other civil structures.

8.1.3 *Temporary Shoring* – Temporary shoring must be provided as applicable to protect adjacent infrastructure during construction. Infrastructure is defined as structures, pavement, utilities, hardscaping, or any other structure or facility. Design calculations and details sealed by a Professional Engineer licensed in the State of Texas must be submitted to the City of Midland and filed for record purposes before constructing the shoring.

8.1.4 *Right-of-Way (ROW)* – All elements of structures including foundations, walls, slabs, beams, etc. will not extend inside the City's public ROW.

8.1.5 *Inspections* – Inspections of structures must be performed in accordance with this section. Inspection for structures not performed directly by the City must be performed by a third-party and include a letter signed and sealed by a qualified Professional Engineer licensed in the State of Texas stating that the structure was constructed in general compliance with the City's *Standard Details* and *Standard Specifications*. Any structure outside the public ROW and any structure constructed with non-City funds whether inside or outside the public ROW or public easements, must require third-party inspection and be provided to the City.

8.1.5.A Non-Bridge Construction Inspection

8.1.5.A.i Inspections of non-bridge structures must be performed during construction and reports provided to the City. The inspections and reports must be performed at the following stages of construction (at a minimum):

- Subgrade/Foundation preparation – including but not limited to slabs, strips, and drilled shaft foundations prior to concrete placement;

- Formwork – including but not limited to formwork for footings, walls, slabs, and other elements requiring formwork prior to concrete placement;
- Reinforcing placement;
- Drainage system construction (if applicable);
- Concrete/Masonry/Mortar placement; and,
- Completion – post concrete placement.

8.1.5.A.ii Third-party inspector must verify and document that construction inspections were performed at the prescribed stages of construction. The inspection reports and final certificate of compliance must be submitted to the City and include the following:

- Specific reference to the City's *Standard Details* and *Standard Specifications*;
- Specific reference to the address and/or legal description for the construction location;
- Specific reference to the name and date of the project-specific geotechnical engineering report; and,
- A letter signed and sealed by a Licensed Professional Engineer in the State of Texas, that includes a statement that the structure was constructed in general compliance with the geotechnical design reviewed and approved by the Engineering Services Director or designee and in accordance with the City's *Standard Details* and *Standard Specifications*.

8.1.5.B Bridge Construction Inspection

8.1.5.B.i Third-party inspector must verify and document that bridge construction inspections were performed at the prescribed stages of construction in accordance with the Bridge Construction Inspection Checklist in Appendix B (City Checklists).

8.1.5.B.ii The inspection reports and final compliance documentation must be submitted to the City.

8.1.6 *TxDOT Standard Sheets* – If TxDOT standard sheets pertaining to structures are utilized, the Engineer must ensure the loading, geometry, and allowable soil pressures are applicable to the standard design selected. The Engineer must ensure that interruptions to the structure (i.e., wall stem or footing reinforcement altered by openings, utilities, geometric changes, or curved sections of the wall) do not compromise the design and performance of the structure. Consideration must be given to the site-specific geotechnical requirements and whether a TxDOT standard design is applicable. No TxDOT standard sheets will be modified unless the Engineer designs, draws, signs, and seals the modified standard. If TxDOT standard sheets are not applicable, a custom structural design must be provided. The responsible Engineer must provide design calculations validating that TxDOT details used are applicable.

8.1.7 Structural Plan Requirements

8.1.7.A Construction plans and specifications must be prepared and submitted to the Engineering Services Director or designee in accordance with Section 2.3 (Submittal Requirements for Construction Plans and Drainage Analysis).

8.1.7.B Calculations pertinent to the design of all structures must be submitted to the City along with the construction plans and will be filed for record purposes by the City. The Engineer remains responsible for the design of the structure(s).

8.2 *Structural Code Requirements and Criteria*

8.2.1 At a minimum, all structures must be designed using the City's *Standard Details* and *Standard Specifications* and must meet all applicable Local, State, and Federal standards. For other standards not adopted by the City, the current version of that standard must be utilized.

8.2.2 The design and construction of roadway bridges and bridge-class culverts must be provided in accordance with the requirements of the AASHTO's current edition of the *Standard Specifications for Highway Bridges* and supplemented using TxDOT standards and guidelines as applicable.

8.2.3 Specifications for bridge construction must be in accordance with TxDOT's current edition of *Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges*.

8.2.4 All bridge railing must be in accordance with TxDOT's current edition of the *Bridge Railing Manual* and must meet the specifications outlined in AASHTO's current edition of the *Manual for Assessing Safety Hardware (MASH)* and the *National Cooperative Highway Research Program (NCHRP) Report 350.* All railing must be appropriately rated railing based on site and design conditions. Guardrail, end treatments, or other features associated with bridge construction must be in accordance with AASHTO's current edition of the *Policy on Geometric Design of Highways and Streets,* AASHTO's current edition of *Roadside Design Guide*, and current TxDOT standards. All bridge railing must meet applicable sight distance requirements.

8.2.5 For all bridges and bridge-class culverts adjacent to or in conjunction with roadways, sight visibility exhibits must be submitted to the City for review and approval in accordance with Section 3.4 (Sight Visibility).

8.2.6 More stringent requirements must be utilized as required for unusual designs such as rehabilitations, reconstructions, or for unusual site conditions. The codes cannot replace sound engineering knowledge, experience, and judgment.

8.2.7 For any structure, the City or the Engineer may require the quality of materials and construction to be higher than the minimum requirements as stated in the codes based on structure usage or site conditions.

8.3 *Excavation Support*

8.3.1 Trench excavation protection must be used for the installation of linear drainage or utility facilities that result in trenches deeper than 5'. Such trench protection includes vertical or sloped cuts, benches, shields, support systems, or other systems providing the necessary protection in accordance with Occupational Safety Heath Administration's (OSHA) current *Standards and Interpretations, 29 CFR 1926, Subpart P (Excavations)*. The Contractor must submit to the City, for informational purposes only, the design calculations and details sealed by a Professional Engineer licensed in the State of Texas before constructing the shoring. The design of the shoring must provide protection in accordance with OSHA's current Standards and Interpretations, 29 CFR 1926, Subpart P, Excavations.

8.3.2 Temporary shoring (including trench excavation discussed in Section 8.3.1 above) must be used for installations of walls, footings, and other structures that require excavations deeper than 5'. Temporary shoring must be designed and constructed to hold the surrounding earth, water, or both out of the work area. Options may include, but not be limited to, vertical or sloped cuts, benches, shields, support systems, or other systems to provide the necessary protection in accordance with the approved design. Unless a complete design for temporary shoring systems are included in the construction plans, the Contractor is responsible for the design of the temporary shoring system. The Contractor must submit to the City, for informational purposes only, the design calculations and details sealed by a Professional Engineer licensed in the State of Texas before constructing the shoring. The design of the shoring must provide protection in accordance with OSHA's current *Standards and Interpretations, 29 CFR 1926, Subpart P (Excavations)*.

8.4 *Geotechnical Performance Specifications*

8.4.1 Field investigation, geotechnical testing, and geotechnical engineering shall be performed in accordance with this *Manual* considering local experience and conditions. The geotechnical recommendations shall establish the minimum design criteria upon which the Engineer can rely.

8.4.2 A ROW Permit must be obtained prior to performing any coring, trenching, or excavation within the City's ROW or public easements.

8.4.3 The complexity of geological conditions and the type, length, and width of the structure shall determine the number and locations of test holes required. The following should be considered by the Engineer in coordination with the Geotechnical Engineer:

8.4.3.A Depth of test hole;

8.4.3.B Location of proposed grade relative to existing grade;

8.4.3.C Location of groundwater;

8.4.3.D Channel relocations and/or channel widening;

8.4.3.E Scour;

8.4.3.F Foundation loads; and,

8.4.3.G Foundation types.

8.4.4 Test holes shall be located in an accessible area. Identify test hole locations on the construction plans.

8.4.5 Provide a complete soil and bedrock classification and log record for each test hole, including all pertinent information to complete the standard log. Location and surface elevation shall be shown on the coring logs.

8.4.6 Perform the appropriate field and laboratory tests necessary to determine the soil properties for geotechnical design criteria. The Geotechnical Engineer shall consider both the short-term and long-term conditions.

8.4.7 Ground water elevations shall be included as part of the data acquisition. Site conditions may require the installation of piezometers to establish a true groundwater surface elevation and a method of monitoring water surface fluctuations.

8.4.8 *Coring Requirements* – Minimum coring requirements are specified below. Based on the Geotechnical Engineer's experience and engineering judgment, if competent rock is encountered, the minimum coring depths specified below may be reduced with approval from the Engineering Services Director or designee.

8.4.8.A *Slopes and Embankments including Bridge Approaches* – Obtain soil coring for cuts greater than 10' or embankments taller than 10'. The exploration shall include the following:

8.4.8.A.i *The Soil Under Future Embankments* – Advance coring to a depth at least equal to the embankment height or 20', whichever is greater, unless a greater depth is recommended by the Geotechnical Engineer.

8.4.8.A.ii *Soil in Proposed Cuts* – Advance coring to a depth of at least 15' below the bottom of the proposed cut, unless a greater depth is recommended by the Geotechnical Engineer.

8.4.8.B Bridges

8.4.8.B.i In general, drill test holes shall penetrate a minimum of 15' into proposed bearing strata. Where depth of bearing strata becomes impractical, the Engineering Services Director or designee may determine minimum core depth.

8.4.8.B.ii Test holes shall be drilled near each abutment and bent location of the proposed structure plus a sufficient number of intermediate holes to determine depth and location of all significant soil and rock strata.

8.4.8.B.iii A site inspection by the driller or logger shall be performed to evaluate site accessibility and special equipment needs.

8.4.8.B.iv *Grade Separations* – If the coring indicates soft surface soils (fewer than 10 blows per foot), additional coring and testing shall be required for the design of the bridge approach embankments.

8.4.8.C *Retaining Walls* – Obtain soil coring for walls taller than 4'. Soil coring shall also be obtained for any retaining wall (regardless of height) under unusual circumstances, such as live loading or other surcharges.

8.4.8.C.i *Minimum Number/Spacing* – Obtain a minimum of two soil coring within limits of wall footprint. For walls longer than 200', coring shall be obtained at a maximum spacing of 200' unless site conditions or the Engineer requires alternate spacing. A greater spacing may be allowed by the Engineering Services Director or designee only if recommended in writing by the Geotechnical Engineer.

8.4.8.C.ii *Fill Walls* – For spread footing walls and Mechanically Stabilized Earth (MSE) walls, the depth of the coring shall be at least equal to the wall height depending on the wall type. The minimum coring depth is 10' below the bottom of the proposed wall unless rock is encountered (see Section 8.4.8). Extend coring at least 5' into rock for fill walls unless additional depth is recommended by the Geotechnical Engineer.

8.4.8.C.iii *Cut Walls* – For drilled shaft walls, tied-back walls, and soil and rock nail walls, the depth of the coring shall be based on the proposed ground line. Cantilever drilled shaft walls require the depth of coring to extend to the anticipated depth of the shaft below the cut, which is typically between one and two times the wall height unless additional depth is recommended by the Geotechnical Engineer. Coring for soil nails, tiebacks, and rock nailed walls shall be advanced through the material that is to be nailed. The minimum coring depth is 15' below the bottom of the proposed wall. Coring for proposed cut walls may need to penetrate bearing strata significant distances depending on the depth of the cut and wall height.

8.4.8.C.iv *Additional Testing/Modeling* – Additional testing and modeling shall be provided for taller walls, walls on slopes, or walls on soft founding strata as necessary or as recommended by the Geotechnical Engineer to completely evaluate wall stability.

8.5 *Bridges*

8.5.1 The Engineer must be responsible for selecting the appropriate bridge foundation. The Engineer must consider the following factors in that selection:

8.5.1.A *Design Load* – The magnitude of the design load and existing geotechnical conditions dictate the required size of the foundation.

8.5.1.B *Geotechnical Engineering Recommendations* – The strength and depth of subsurface formations determine the type of foundation chosen. In general, drilled shafts are well suited to areas with competent soil and rock, and are the preferred foundation type subject to concurrence from the Geotechnical Engineer. Alternative foundation types require approval in writing from the Engineering Services Director or designee.

8.5.2 Disregard surface soil in the design of drilled shaft foundations. The discounted depth is the amount of surface soil that is not included in the design of the foundation due to potential erosion from scour, future excavation, seasonal moisture variation (shrinkage and swelling), lateral migration of waterways, disturbed material or fill, and recommendations of the geotechnical investigation.

8.5.3 Drilled shaft capacity relies upon penetrating a specific stratum a specified depth. The construction plans must provide a note instructing the contractor and field personnel of the penetration requirement. The construction plans must identify the specific type of material to be penetrated and the minimum penetration depth. The plan may allow for the drilled shaft to be shortened if the founding stratum is encountered at a shallower depth, and it requires the shaft to be lengthened if the founding stratum is not encountered at the expected elevation.

8.5.4 *Railing* – In addition to the requirements in Section 8.2.4, the following bridge railing criteria must be met:

8.5.4.A The face of railing must be a minimum of 2' beyond edge of outside travel lane.

8.5.4.B Separation rails must be provided on all Major and Minor Arterial bridges. Separation rails will not be required on Collectors or Local streets, or on culverts where the sidewalk is not located adjacent to the back of curb.

8.5.4.C *Concrete Rail Finish* – Formline all vertical surfaces where aesthetic conditions apply with an Ashlar Stone or approved equal pattern. Stain and color(s) must be approved by the Engineering Services Director or designee. Formliners must meet the requirements as described in Section 8.2.4.

8.5.4.D *Steel Rail Finish* – All rail surfaces must be hot-dipped galvanized. Color must be approved by the Engineering Services Director or designee.

8.5.5 *Pedestrian Bridges* – Pedestrian bridges must be designed in accordance with AASHTO's current edition of the *LRFD Guide Specifications for the Design of Pedestrian Bridges* and AASHTO's current edition of *Guide for the Development of Bicycle and Pedestrian Facilities*, and must meet the following additional criteria:

8.5.5.A *Design Requirements* – Refer to Section 4 (Pedestrian Facilities) for applicable design requirements.

8.5.5.B *Loading* – Design loads must be in accordance with the applicable codes outlined in this section and must include, but not be limited to, construction loads, surcharge loads, slopes, wind, stream loads, and other structures. Loading must conform to the specified use (i.e., bicycle, pedestrian, emergency vehicle traffic, and/or maintenance vehicle traffic).

8.5.5.C *Construction Plans* – Cast-in-place bridge foundations must be designed for a specified pre-cast bridge structure. The foundation plans and shop drawings for the pre-cast bridge structure must be submitted for review and approval.

8.5.5.D *Hydraulics* – Refer to Section 3.6 (Floodplain Alterations) for design flood, freeboard, and flood study requirements associated with pedestrian bridge design.

8.6 *Retaining Walls*

8.6.1 The Engineer is responsible for ensuring that the type of retaining wall selected for a given location is appropriate. The retaining wall selection process must consider the following:

8.6.1.A Height

8.6.1.A.i Walls must be measured from the top of wall footing to the top of the wall (not the top of the retained fill). An engineered design by a licensed Texas Professional Engineer is required for all walls 2' in height or greater (designed to ensure stability against overturning, sliding, bearing failure, excessive differential movement, and water uplift). For commercial and multi-family applications, all walls require an engineering design regardless of height.

8.6.1.A.ii For a wall that has a variable height where part of the wall is under 2' and part of the wall is over 2', an engineering design will be necessary for the entire wall.

8.6.1.A.iii Factors of safety for design must be as described in the current edition of the *International Building Code (IBC)* and *International Residential Code (IRC)* adopted by the City but at a minimum must meet the following:

- Overturning: 2.0;
- Sliding: 1.5; and,
- Bearing: 2.0.

8.6.1.A.iv If any wall has embedded posts, poles, or other structures anchored directly into the wall structure, wall design must also take into consideration the additional loadings due to these structures (axial, lateral, and wind). The structural design must be provided in accordance with the geotechnical recommendations and minimum design criteria provided herein.

8.6.1.B *Geometry* – Determine applicability of wall type – cut, cut/fill, or fill – based on geometry, site constraints, existing and proposed topography, and wall alignment and location. Identify available ROW and any necessary ROW or easements to accommodate the proposed improvements and the access necessary to accommodate access for maintenance. Identify location and type of existing and proposed utilities and drainage structures.

8.6.1.C *Global Stability* – The Engineer is responsible for the global stability design of the wall. Evaluate all walls to ensure that the minimum applicable factors of safety are met, if not exceeded. Walls will not be placed on slopes if avoidable.

8.6.1.D *Passive Resistance to Sliding* – The Engineer must follow the Geotechnical Engineer's guidance for use of passive resistance. If there is a slope in front of the wall, passive resistance must be neglected.

8.6.1.E *Maintenance* – Consider long-term maintenance requirements. Identify necessary excavation requirements (including shoring), required utility adjustments, construction phasing requirements, and these effects on the wall design and construction.

8.6.1.F *Drainage* – Design the wall to prevent the build-up of hydrostatic pressure behind the wall. If conditions warrant, such as but not limited to, the inability to include a drainage system or situations of rapid drawdown, the City may require the wall design to withstand full hydrostatic pressure load. The wall design must consider potential deleterious short- and long-term effects of water inundation including scour and rapid draw down.

8.6.1.G *Loading* – Design loads must be in accordance with the *Manual*, including construction loads and surcharge loads from slopes, structures, and vehicles.

8.6.1.H *Constructability* – Determine whether walls are near water or subject to inundation or groundwater. Identify access limitations for equipment both during and after construction. Ensure adequate horizontal and vertical clearances are provided.

8.6.2 Analyze and design walls following accepted geotechnical engineering industry standards for the area and in accordance with the *Manual*. In analysis, use earth pressures that follow the requirements of the project's geotechnical investigation specifically addressing the retaining wall design requirements for the project's specific location.

8.6.3 The Engineer must ensure that the retaining wall system is appropriate for its location and application. The Engineer must design for all potential modes of wall system failure; including sliding, overturning, bearing pressure, global stability, and structural capacity of the wall itself. Placement of walls adjacent to roadways must comply with AASHTO's current edition *Roadside Design Guide* unless otherwise approved by the Engineering Services Director or designee.

8.6.4 Perched walls will not be placed on slopes steeper than 8H:1V. When walls must be placed on slopes, or the retaining wall height or the combined wall and slope heights exceed 8', the Geotechnical Engineer must conduct a short-term and long-term global stability analysis using applicable soil strength characteristics, geometry, and loading conditions (including load surcharge and hydrostatic). The Engineer is responsible for the design of the wall system, including its global stability.

8.6.5 Perched walls must be analyzed as both independent structures and as a single unit for all design parameters.

8.6.6 If barriers, fences, or other structures will be installed on top of walls, connection details must be included in the construction plans and taken into account during design as a part of the calculation package.

8.6.7 Tree placement within the zone of influence of a retaining wall must be avoided. Any trees placed within zone of influence must be addressed in the structural design of the wall and submitted as a part of the calculation package.

8.6.8 Swimming pools, pergolas, and other structures placed within the zone of influence of a retaining wall must be avoided. Any of these placed within the zone of influence must be addressed in the structural design of the wall and submitted as a part of the calculation package.

8.7 *Slope Stability*

8.7.1 All slopes exceeding 8' in height with a steepness greater than 4H:1V, regardless of soil type, cut, or fill, must be evaluated for global stability for both the short-term and the long-term conditions. Additionally, any known areas of existing fill, deleterious material, or soft soils which have a height over 4' or slope angle greater than 6H:1V must be evaluated for global stability for both the short-term and the long-term conditions. Specific site conditions may require evaluation for additional types of slope failure, such as bearing capacity, settlement, shear, and undercutting. Calculations pertinent to the analysis must be submitted with the construction plans when required by the City.

8.7.2 Use the following data to analyze global stability of a slope:

- Geometry (cross section and loading conditions);
- Location of the water table;
- Soil/rock stratigraphy; and,
- Soil/rock properties (unit weight, Atterberg Limits, undrained and drained shear strength)

8.7.3 For global stability of a slope, minimum factors of safety must be met for long-term and short-term stability.

8.8 *Culverts, Headwalls, and Wingwalls*

8.8.1 All headwalls and wingwalls must be reinforced concrete. Wingwalls must be either straight (parallel), flared, or tapered. Approach and discharge aprons must be provided for all culvert headwall designs.

8.9 *Drop Structures*

8.9.1 The design of vertical runoff adjustment structures must be based on the height of the drop, the flow depths upstream and downstream of the vertical runoff adjustment structure, and the flow rate. All vertical runoff adjustment structures must be constructed of reinforced concrete, gabions, or other material approved by the Engineering Services Director or designee. To facilitate maintenance, vertical runoff adjustment structures should be accessible to equipment normally used for maintenance, as approved by the Engineering Services Director or designee.

8.9.2 An apron must be provided immediately upstream and downstream of a vertical runoff adjustment structures to protect against scour caused by the increasing velocities and turbulence at each vertical runoff adjustment structure. Apron dimensions must be site specific and based on velocities. At a minimum, the upstream apron must extend at least 10’ upstream from the point where flow becomes supercritical and must include a cutoff wall into the ground sufficient to protect the structure from scour and hydraulic uplift. The downstream apron must extend a minimum of 20’ beyond the anticipated location of the jump and must include a cutoff wall into the ground. The cutoff wall at each end must extend below the calculated scour depth or sound bedrock (in accordance with FHWA’s current edition *Hydraulic Engineering Center No. 18 (HEC-18))* but must be a minimum of 3’ below channel flowline.