Appendix G
Geotechnical Section

GENERAL

The selected plan consists of widening Williamson Creek in four discrete reaches in the south and southwestern section of the city of Austin, Texas, in order to reduce flood damages adjacent to the creek in those areas. The plan for widening consists of creating a flat bench (cut) on one side of the creek above the natural low flow channel. The excavation required to create the proposed benches is anticipated to have a maximum depth of 10 feet below existing grade in areas farthest from the channel (upslope). Slopes and widths of the benched areas will be variable. No recreation opportunities have been identified for Williamson Creek. No relocations of bridges or roads are anticipated for this project. Some existing utilities (e.g., storm drainage, sewer, and water) are anticipated to be relocated due to the proposed modification (refer to the Civil Design Appendix for additional details regarding existing utility relocations). New recreational developments are not included in the proposed project. The channel is well vegetated. All vegetation within the proposed benched areas will be removed and any existing building structures will be demolished.

The four reaches of Williamson Creek identified for channel widening are referred to, from east to west, as the Heartwood, Radam, Broken Bow, and Baytown Loop reaches. All four reaches are located within residential development areas of Austin. Heartwood reach has a length of approximately 1,200 feet, and extends from Heartwood Drive to Congress Avenue South. Benching within Heartwood reach will be on the right bank of the channel; the width of the benching within the Heartwood reach will vary from 0 to approximately 150 feet with respect to the centerline of the channel. The Radam reach has a length of approximately 1,300 feet, and extends from Radam Circle to Meadow Creek Drive. Benching within Radam reach will be on the right bank of the channel; the width of the benching within the Radam reach will vary from 0 to approximately 300 feet with respect to the centerline of the channel. An existing bridge along Emerald Forest Drive crosses the channel; however, this structure will not be modified. An existing residential structure at the end of Radam Circle closest to Williamson Creek is scheduled to be bought-out and demolished as part of the project. Broken Bow reach has a length of approximately 3,000 feet, and extends from Manchaca Road to Jones Road. Approximately 900 linear feet of the channel within Broken Bow reach will be benched on the left bank, while approximately 2,100 linear feet of channel will be benched on the right bank. The width of the benching within Broken Bow reach varies from 0 to approximately 130 feet with respect to the centerline of the channel. Bayton Loop reach has a length approximately 3,000 feet, and extends roughly from Valley Creek Park (on Reese Drive) to a point approximately 500 feet south of Jones Road. Approximately 1,200 feet of channel within Bayton Loop reach will be benched on the left bank (upstream of West Gate Boulevard), with the remaining 1,800 feet benched on the right bank. The width of the benching within Bayton Loop reach varies from 0 to 250 feet with respect to the centerline of the channel. An existing bridge at West Gate Boulevard will not be modified.

SUBSURFACE INVESTIGATION

GENERAL

Ten (10) borings (B-01 through B-10) were drilled adjacent to Williamson Creek in the areas of proposed channel modification during May 2006 by Holt Engineering, Inc., a geotechnical firm under contract to the project non-federal local sponsor, the city of Austin. Of

these ten borings, one (1) (B-08) was drilled within the Heartwood reach, four (4) (B-05, B-06, B-07, and B-09) were drilled within the Radam reach, two (2) (B-01 and B-02) were drilled within the Broken Bow reach, and three (3) (B-03, B-04, and B-10) were drilled within the Bayton Loop reach. The surface elevations at the respective test hole locations were not provided on the logs of borings. The borings were advanced to depths ranging from 14.6 feet to 29.5 feet below existing grade. Additional information regarding the type of drill rig (e.g., truck-mounted), and the

drill rig make and model, were not specified on the logs of borings or in the Subsurface Investigation and Geotechnical Data Report, dated 12 June 2006, prepared by the geotechnical contractor. However, based on information provided on the logs of borings and in the contractor's report, the borings were advanced and soil and rock specimens were collected using a 4-inch diameter auger (type not specified (e.g., hollow stem, solid stem, short flight, continuous flight, etc.)), a shelby tube sampler (diameter not specified), a 2-inch nominal split spoon sampler, and a 1 $^{7}/_{8}$-inch diameter NXB wire line core barrel sampler. Although not explicitly stated in the geotechnical contractor's report, the soil and rock specimens appear to have been tested at a laboratory under the administration of the geotechnical contractor. Results of the field investigation (boring location maps and logs of borings, prepared by Holt Engineering, Inc.) are presented immediately following this narrative.

GROUNDWATER CONDITIONS

Groundwater conditions were monitored during drilling. Due to the rotary wash method of drilling, verifiable groundwater levels were determined at only two boring locations. Groundwater was encountered within boring B-02 at a depth of 4.8 feet below existing grade. The geotechnical contractor's report indicates that groundwater was encountered at 16.2 feet at another boring location, although this information is not shown on the logs of borings or clarified elsewhere in the contractor's report. However, based on local engineering experience, groundwater is at or slightly above the interface of the alluvial overburden soils and the rock primary. It should also be noted that groundwater conditions are relative to the time of drilling, annual precipitation, and drainage conditions at the site.

SUBSURFACE CONDITIONS

GENERAL GEOLOGY

The Williamson Creek study area lies within the Blackland Prairies subprovince of the Gulf Coastal Plains physiographic province, which is characterized by gently rolling prairies that slope regionally southeastward toward the Gulf of Mexico. Geologic formations within the Austin area strike in a northeast-southwest orientation, while Williamson Creek flows across, incising these formations in a northwest-southeast direction. The predominant structural feature in the study area is the Balcones fault zone which forms the transition from the moderately rugged Edwards Plateau immediately west of the study area and the gently rolling Gulf Coastal Plains on the east. The Balcones fault zone consists of a series of nearly parallel faults trending in a northeast-southwest direction through the region. Most of the faults are normal or gravity faults with the downthrown side to the southeast. Maximum vertical displacement along any single fault is about 600 feet. The zone is underlain by fault blocks composed of Cretaceous age limestone, dolomite, and shale strata. Faults within the zone are classified as inactive. Prominent escarpments at the surface are common in the more erosive resistant beds. The Williamson Creek study area lies within an area of low seismic risk.

Geologic formations (primary) occurring within the limits of the study area, from oldest to youngest, include the Lower Cretaceous age Del Rio (clay shale) and Buda formations, which

were encountered in the two upstream reaches (Bayton Loop and Broken Bow), and the Upper Cretaceous age Austin group (limestone), encountered in the two downstream reaches (Radam and Heartwood). These primary formations are overlain by Quaternary age alluvial and terrace deposits (overburden). The Del Rio formation consists of blocky, calcareous, gypsiferous, medium gray clay shale, weathered light gray to yellowish gray. The Buda formation consists typically of limestone that is gray to yellow brown, hard, slightly nodular, with abundant mollusk fossils. The Austin group consists of beds of light gray to white, moderately hard, ledge-forming, impure, chalky limestone interstratified with beds of softer marl. Quaternary terrace and alluvial deposits consist typically of varying mixtures and thicknesses of clay, silt, sand, and gravel. The silt and clay are generally calcareous, dark gray to dark brown; sand is mostly quartz; gravels are siliceous, mostly chert, quartzite, limestone, and petrified wood. Some areas of Williamson Creek contain a cover of cobble to boulder size rubble derived from erosion along the stream.

SITE CONDITIONS

The descriptions of the subsurface materials at the project site are based on the field investigation and the results of laboratory testing. Based on experience, some of the strata described as clay on the logs of borings are interpreted as being clay shale (marl) based on the material descriptions on the logs of borings.

Subsurface materials encountered during the field investigation typically consist of low to high plasticity clays (CL to CH, respectively) and clayey sand (SC) that overly formations of weathered clay shale (marl) and limestone (typically interbedded). Clays area generally stiff, yellow brown to brown to dark brown, silty to very silty, sandy to very sandy, and gravelly. Clayey sands, encountered overlying the clay shale primary within boring B-02, are light brown and gravelly. It should be noted that gravelly, sandy, silty, clayey fill material was encountered at the surface during drilling for four of the test holes; fill was encountered in the Radam reach within borings B-06 (15.0-foot fill thickness) and B-07 (3.0-foot fill thickness), in the Broken Bow reach within boring B-02 (1.0-foot fill thickness), and in the Bayton Loop reach within boring B-04 (11.0-foot fill thickness). The fill materials are described as soft to firm, brown to yellow brown, silty, sandy (loose), with gravel and possible cobble; concrete debris was noted within fill encountered in the upper 1 foot of subsurface materials at the location of boring B-02. Clay shale (marl) primary was frequently encountered in the borings, particularly in the two upstream reaches (Bayton Loop and Broken Bow). The clay shale (marl) primary is described as soft (in terms of Rock Classification), gray to olive to yellow brown, jointed, with calcite crystals and ferrous deposits noted. Seams of limestone were also observed interbedded within the clay shale (marl). The limestone primary is described as moderately hard to hard (Rock Classification), yellow brown to gray, thin to thick bedded to massive, solid to fractured (slickensides noted), fossiliferous, with pyrite nodules and glauconite, and interbedded with clay shale (marl). Although not specified, based on material descriptions provided on the logs of borings, the clay shale (marl) and limestone primary encountered in the ten test holes are interpreted as being weathered (i.e., unweathered primary was not encountered). The thickness of the overburden soils and depth to primary contacts were quire variable across and within each of the four reaches; these variations are described below. Where performed, classification testing results are also discussed in relation to the subsurface materials described.

Overburden soils (medium plasticity, sandy, silty clays (CL)) with a thickness of approximately 2.5 feet were encountered at the location of boring B-08, drilled within the Heartwood reach; a limestone primary formation is present immediately below the overburden soils at the location of boring B-08. A liquid limit of 48 percent, a plastic limit of 18 percent, a plasticity index of 30 percent, and an in situ moisture content of approximately 13 percent was measured from a specimen of the medium plasticity overburden clay encountered within boring B-08.

The depth to primary within Radam reach was quite variable, and appears to be related to the proximity of the boring location to the channel centerline. Limestone primary was encountered at the surface at the location of boring B-05, which was drilled through a low-water crossing of Williamson Creek. Conversely, at the locations of borings B-06 and B-07, drilled outside the channel adjacent to the Emerald Forest Drive bridge, the depth to primary was determined to range from 11.0 feet (B-07) to 15.0 feet (B-06). At the location of boring B-09, drilled at the top of the channel at the southern (downstream) portion of Radam reach, limestone primary was encountered at a depth of 1.0 feet below existing grade. Clay shale (marl) primary was encountered only at the location of boring B-06 (at a depth of 15.0 feet below existing grade); limestone primary was encountered at a depth of 17.0 feet below existing grade at this boring location. A liquid limit of 30 percent, a plastic limit of 16 percent, a plasticity index of 14 percent, and an in situ moisture content of approximately 7 percent was measured from a specimen of the low plasticity overburden clay encountered within boring B-07. Also, a liquid limit of 41 percent, a plastic limit of 17 percent, a plasticity index of 24 percent, and an in situ moisture content of about 8 percent was measured from a specimen of the medium plasticity clay fill encountered within boring B-06.

Overburden soils at the locations of borings B-01 and B-02, drilled outside the channel within Broken Bow reach, had thicknesses of 5.0 and 12.5 feet, respectively, above the clay shale (marl) primary; limestone primary was not encountered at these test hole locations. Liquid limits measured from representative samples of the high plasticity clay and clayey sand overburden soils encountered within boring B-02 range from 27 to 59 percent, plastic limits vary from 15 to 20 percent (with plasticity indices ranging from 12 to 39 percent), and in situ moisture contents range from approximately 11 to 24 percent. A liquid limit of 66 percent, a plastic limit of 21 percent, a plasticity index of 45 percent, and an in situ moisture content of approximately 19 percent was measured from a specimen of the low plasticity overburden clay encountered within boring B-01.

The thicknesses of overburden soils at the test hole locations within the Bayton Loop reach vary from 2.5 feet (B-03) to 8.5 feet (B-10) to 17.0 feet (B-04). Borings B-03 and B-04 were drilled outside of the channel adjacent to the West Gate Boulevard bridge. Clay shale (marl) primary is encountered at a depth of 2.5 feet below existing grade at the location of boring B-03; the clay shale (marl) has a thickness of approximately 6.5 feet to the top of the limestone primary (encountered at a depth of 9.0 feet below existing grade). At the location of boring B-04, subsurface materials encountered consist of approximately 11.0 feet of silty, sandy, gravelly clay fill material that is underlain by about 3.0 feet of alluvial low to high plasticity clays, and ultimately by a formation of clay shale (marl), encountered at a depth of 17.0 feet below existing grade; limestone primary was not encountered at the location of boring B-04. Boring B-10 was drilled outside of the channel at the upstream limit of Bayton Loop reach, near Reese Drive and Valley Creek Park. Subsurface materials encountered at the location of boring B-10 consist of approximately 8.5 feet of alluvial silty, sandy, gravelly clays that are immediately underlain by limestone primary. A liquid limit of 20 percent, a plastic limit of 14 percent, a plasticity index of 6 percent, and an in situ moisture content of about 4 percent was measured from a specimen of the clayey, silty, gravelly sand fill encountered within boring B-06. Liquid limits measured from representative samples of the clay shale (marl) primary encountered within borings B-03 and B-04 range from 48 to 59 percent, plastic limits vary from 18 to 20 percent (with plasticity indices ranging from 30 to 39 percent), and in situ moisture contents range from approximately 11 to 20 percent.

Subsurface conditions representative of the project site are shown on the boring logs (immediately following this narrative). It should be noted that the actual interface between material types may be far more gradual or abrupt than represented; therefore, actual subsurface conditions in areas not sampled may differ from those predicted. The nature and variations across the site, to include perched water locations, may not become evident until construction commences, and the actual construction process may alter subsurface conditions as well. If

variations become evident at the time of construction, CESWF-EC-DG should be contacted to determine if the recommendations presented in this or subsequent design reports need to be reevaluated.

TESTING

LABORATORY TESTING

Representative soil and rock samples recovered from the borings were subjected to laboratory testing for identification, moisture content, percent passing the No. 200 sieve, Atterberg limits, density, and strength. Results of the laboratory testing program, by testing parameter, are shown on the individual logs of borings. The laboratory test results by project reach are also presented graphically following the logs of borings at the end of this narrative. Plasticity characteristics are shown on Plate 1, Plasticity Chart. Moisture content values are shown with respect to depth on Plate 2. Liquid limit and plastic limit test results are shown with respect to depth on Plates 3a and 3b, respectively. Dry density values of representative undisturbed samples are shown with respect to depth on Plate 4. Ultimate compressive strengths of the clay shale and limestone primary are shown with respect to depth on Plate 5.

Shear Strength Testing

Shear strength characteristics of the weathered clay shale (marl) and limestone primary were analyzed in the laboratory using unconfined compression strength testing. One specimen of clayey sand collected within boring B-02 at a depth of 5.5 feet below existing grade was also subjected to unconfined compression strength testing. The ultimate compressive strengths recorded are presented on the individual logs of borings and summarized below. Specimens (typically limestone) for which density testing was not conducted (in addition to strength testing) are noted as 'NT' (not tested). All primary (rock) specimens are considered weathered.

Boring	Depth, ft	γ_d, pcf	Q_u, tsf	Material Type
		- HEARTWOOD REACH -		
B-08	7.50	NT	183.8	Limestone
B-08	13.00	NT	50.6	Limestone
		- RADAM REACH -		
B-05	0.75	NT	131.8	Limestone
B-05	4.50	NT	188.7	Limestone
B-05	10.25	NT	147.9	Limestone
B-07	14.75	NT	78.0	Limestone
B-07	21.00	NT	95.9	Limestone
B-09	6.00	NT	220.8	Limestone
B-09	14.00	NT	126.1	Limestone
		- BROKEN BOW REACH -		
B-01	9.00	111.2	8.9	Clay Shale (Marl)
B-02	5.50	124.7	1.0	Clayey Sand

- BAYTON LOOP REACH -

B-03	5.50	103.4	6.2	Clay Shale (Marl)
B-03	13.00	NT	70.0	Limestone
B-03	22.50	NT	155.7	Limestone
B-04	18.00	101.8	7.1	Clay Shale (Marl)
B-10	16.50	NT	172.0	Limestone

GEOTECHNICAL DESIGN DISCUSSIONS AND RECOMMENDATIONS

The following geotechnical design discussions and recommendations in support of the project are based on the results of the field investigation, laboratory testing, and engineering studies.

CHANNEL EXCAVATION

Construction of the proposed channel modifications to the four study area reaches of Williamson Creek will necessitate extensive excavation along the existing channel. Based on the results of the field investigation, the types of subsurface materials that should be anticipated during construction are gravelly, sandy, and silty low to high plasticity clay alluvial overburden soils and gravelly, sandy, silty, and clayey fill materials with occasional cobbles. These soils are typically underlain by soft (Rock Classification) clay shale (marl) and moderately hard to hard (Rock Classification) limestone primary. The two types of rock primary encountered in the test holes were typically interbedded (alternating strata of clay shale and limestone), but massive (homogeneous) depositional units were also encountered. Jointing was also observed in the clay shale (marl) and limestone primary. As evidenced by unconfined compression shear strength testing, the overburden soils and fill materials are relatively low shear strength materials (with an unfactored cohesion on the order of 1.0 ksf or less), the clay shale (marl) primary is a low to medium shear strength material (with an unfactored cohesion on the order of 5.0 to 9.0 ksf), and the limestone primary is a high shear strength material (with an unfactored cohesion on the order of 50 to 200 ksf). Conventional excavating equipment should be capable of excavating the alluvial and fill soils and the clay shale (marl). However, it is anticipated that heavy-duty excavation equipment will be required to excavate the limestone primary. As previously noted, the depth to limestone was quite variable across the four reaches. Based on the field investigation, it can be tentatively estimated that rock excavation will account for approximately 60 percent of the total excavation, while common excavation will account for approximately 40 percent of the total excavation. Additional borings should be drilled within the four project reaches during subsequent project phases to refine these preliminary estimates.

The in situ alluvial soils and fill materials will be subject to sloughing, particularly due to the anticipated presence of groundwater immediately above (and below) the contact between the alluvial soils and fill materials and the clay shale (marl) and limestone primary. At this time, to minimize the potential for slope failures associated with channel excavation, it is recommended that excavation slopes be graded no steeper than 3V:1H. Additional subsurface material samples should be collected during the next project phase, and subjected to triaxial shear strength testing. This information should be used to analyze slope stability within areas of channel excavation, to determine the stability of steeper cut slopes.

Groundwater should be anticipated during excavation operations. The presence of groundwater should be controlled to prevent sloughing of the excavation slopes, and to eliminate adverse impacts to the orderly progress of construction. To this end, control measures should be

taken to ensure groundwater is pumped away from the construction area to maintain the integrity of the in situ materials.

FILL MATERIALS

Fill materials, if necessary, to prepare the modified channel slopes to the specified lines and grades, can be obtained from on-site excavations or from approved borrow areas. Satisfactory materials for use as engineered fill include materials classified in ASTM D 2487 as GW, GM, GC, GP, SW, SP, SM, SC, CL, and CH and shall be free of trash, debris, roots or other organic matter, or stones larger than 3 inches in any dimension. Unsatisfactory materials include materials classified in ASTM D 2487 as Pt, OH, OL, ML, MH and any other materials not defined as satisfactory; unsatisfactory materials also include material classified as satisfactory which contains root and other organic matter or frozen material. Satisfactory materials used for engineered fill shall be placed in controlled lifts not exceeding 8 inches in loose thickness and compacted to at least 92 percent of laboratory maximum density in accordance with ASTM D 1557. Where present, and to the extent practicable, existing topsoil and turf should be stripped and stockpiled for reuse.

PAVEMENT DESIGN

Although no new pavement structures are required for the Williamson Creek study, other subareas of the Lower Colorado River (Onion Creek) Local Flood Damage Reduction project, such as Timber Creek and Yarrabee Bend (also located within the

city of Austin), will require new pavement features for proposed recreational facilities to be constructed subsequent to the buyout and demolition of existing structures within the floodplain. To this end, preliminary pavement designs are provided for asphalt and optional aggregate-surfaced access roads and concrete aprons in front of trash dumpster pads. These preliminary pavement designs can be used for the development of preliminary cost estimates. It should be noted that the preliminary pavement designs presented herein are based on criteria contained in *TM 5-822-5/AFM 88-7, Chapter 1, TM 5-822-2/AFM 88-7, Chapter 5, TM 5-809-12/AFM 88-3, Chapter 15, TM 5-822-12,* and engineering judgment.

Types of vehicles anticipated to occupy the access roads include light- to medium-duty passenger cars and trucks and, infrequently, trash collection trucks. It is anticipated that the access roads may experience between 25 and 249 passes of passenger cars and trucks per hour (Class E street). Based on Category II traffic and a Class E street, a pavement Design Index (DI) of 2 is assigned to the access drives. A pavement Design Index of 3 is assigned to the concrete aprons in front of trash dumpster pads (assuming Category IV traffic making less than 25 passes per hour (Class F street)).

Laboratory and in situ testing (such as Dynamic Cone Penetrometer (DCP) testing) have not been performed on soils within the areas of proposed new pavement construction. However, based on previous engineering experience with subsurface conditions similar to those anticipated in the areas of new pavement construction, the preliminary pavement designs consider a CBR of 5 percent and subgrade modulus of 100 pci for the raw subgrade when compacted to 90 percent of laboratory maximum density (ASTM D 1557). Geotechnical borings and DCP testing should be conducted in the areas of proposed new pavement construction during the next project phase to establish parameters for use in the final pavement design.

Rigid Pavement – Apron(s) in front of Trash Dumpster Pads

The following pavement section is recommended for a minimum distance of 15 feet in front of trash dumpster pads. The design is based on Category IV traffic and a Class F street (DI=4). The design considers a concrete flexural strength of 650 psi at 28 days.

6” Portland Cement Concrete reinforced with No. 4 bars spaced 16 inches o.c.e.w.

6” Aggregate Base Course compacted to at least 95 percent of laboratory maximum density (ASTM D 1557)

6” Raw Subgrade compacted to at least 90 percent of laboratory maximum density (ASTM D 1557)

Recreational Facility Access Roads – Flexible Pavement Option

The design is based on Category II traffic and a Class E street (DI=2).

1.5” Hot-Mix Surface Course

6” Aggregate Base Course compacted to at least 100 percent of laboratory maximum density (ASTM D 1557)

6” Subbase Course compacted to at least 95 percent of maximum laboratory density (ASTM D 1557)

6” Raw Subgrade compacted to at least 90 percent of laboratory maximum density (ASTM D 1557)

Recreational Facility Access Roads – Aggregate-Surfaced Pavement Option

The design is based on Category II traffic and a Class E street (DI=2; based on criteria in TM 5-822-12).

6” Aggregate-Surface Course compacted to at least 100 percent of maximum laboratory density (ASTM D 1557)

4” Aggregate Base Course compacted to at least 95 percent of maximum laboratory density (ASTM D 1557)

6” Raw Subgrade compacted to at least 90 percent of maximum laboratory density (ASTM D 1557)

ADDITIONAL GEOTECHNICAL STUDIES

As previously noted, additional geotechnical studies will be required in subsequent project design phases. Additional geotechnical field investigations will be required to clarify top-of-rock elevations within the areas of proposed channel modification for Williamson Creek. Test holes and in situ (DCP) tests should be accomplished for the areas of proposed new pavement construction for the Timber Creek and Yarrabee Bend Onion Creek project subareas, and this information should be used to develop final pavement designs. More detailed information regarding the presence of groundwater should also be collected in conjunction with the

subsequent field investigations. Additional soil and rock specimens should be collected from these areas and subjected to tests for classification and strength. Slope stability analyses should be performed to verify the preliminary recommendation for cut slopes no steeper than 3V:1H.

SUMMARY

A preliminary geotechnical field investigation and laboratory testing program has been completed for the Williamson Creek study subarea of the Lower Colorado River (Onion Creek) Local Flood Damage Reduction project. These subsurface data, the referenced design criteria, and engineering judgment have been used to develop preliminary geotechnical and pavement design recommendations. Based on these data and analyses, the proposed Williamson Creek channel modification is considered feasible from a geotechnical design perspective. Additional geotechnical field investigations, laboratory tests, and analyses are recommended to develop final design recommendations.

REFERENCES

- Subsurface Investigation and Geotechnical Data Report for Williamson Creek Terracing and Benching Project, Austin, Texas, dated 12 June 2006 – Holt Engineering, Incorporated
- TM 5-818-7 – Foundations In Expansive Soils
- TM 5-818-1/AFM 88-3, Chapter 7 – Soils and Geology Procedures for Foundation Design of Buildings and Other Structures
- TM 5-822-5/AFM 88-7, Chapter 1 – Pavement Design for Roads, Streets, Walks, and Open Storage Areas
- TM 5-822-2/AFM 88-7, Chapter 5 – General Provisions and Geometric Design For Roads, Streets, Walks, and Open Storage Areas
- TM 5-822-12 – Design of Aggregate Surfaced Roads and Airfields
- Architectural and Engineering Instructional Manual - SWD-AEIM, current edition