US Army Corps
of Engineers®
Fort Worth District

September 2019

Final Environmental Impact Statement

Lake Ralph Hall Regional Water Supply Reservoir Project

Volume II

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Volume II

Appendix A

Alternative Analysis Supporting Documents

A-1: Applicant Provided Summary of Water Supply Strategies[1]

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[1] Information and conclusions contained in Chapter 2 of the DEIS are controlling.

DRAFT

Summary of Additional Water Supply Strategies

Prepared for

Upper Trinity Regional Water District

Prepared by

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September, 2009

Summary of Additional Water Supply Strategies

Submitted to

Upper Trinity Regional Water District

This Document Was Completed
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This Document is Released for the Purposes
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Introduction

The Upper Trinity Regional Water District (UTRWD) filed an application with the Texas Commission on Environmental Quality (TCEQ) to appropriate state water from a proposed water reservoir on the North Sulphur River in Fannin, County, Texas, Lake Ralph Hall, in September 2003. The TCEQ declared that application administratively complete in August of 2004 and conducted public hearings in March of 2006. The TCEQ is currently conducting further technical review of the UTRWD's application.

The UTRWD filed an application with the Fort Worth District, U.S. Army Corps of Engineers (USACE) for a Section 404 Permit for the proposed Lake Ralph Hall in November of 2007. The USACE issued notice in February of 2008 and conducted a Public Scoping Meeting in April of 2008. In August of 2008, the USACE informed the UTRWD that an Environmental Impact Statement (EIS) would be required prior to a determination on UTRWD's application.

In October of 2008, the firm of Michael Baker Jr. Inc. (MBI) was retained to prepare an EIS for the proposed Lake Ralph Hall project. In February of 2009, MBI requested additional information to support preparation of its EIS. The following report was prepared to provide additional information to MBI for its use in developing a Draft EIS relative to possible alternative water supply strategies that UTRWD could implement to meet its future water supply needs. Specifically, this report is intended to respond to the following information requested from MBI:

"*Provide all available and the most recent data (i.e. costs, feasibility, yields, timelines, environmental effects, required permits, agreements, etc.) related to each one of UTRWD's recommended strategies identified in the 2006 Region C Plan.*"

The Texas Legislature has mandated a comprehensive long range water supply planning initiative for sixteen regions in the State. Lake Ralph Hall and the UTRWD's service area are located in Region C. The Region C Planning Group completed its latest round of planning in 2006. That plan was incorporated into the 2007 State Water Plan, a plan that was accepted by the Texas Legislature in 2007.

The 2006 Region C Water Plan identified the following recommended water management strategies for UTRWD:

- Conservation
- Additional supplies from DWU under current contract
- Lake Chapman indirect reuse
- Additional supplies from DWU linked to Lake Chapman reuse
- Lake Ralph Hall
- Indirect reuse of return flows from Lake Ralph Hall
- Marvin Nichols Reservoir
- Additional DWU supplies
- Oklahoma water

- Water treatment plant and distribution system improvements

These recommended strategies, which were developed in accordance with the legislatively mandated regional planning process, are the water supply projects that will allow UTRWD to meet its future projected water needs. In addition to the recommended water management strategies, the Region C Water Plan identified the following alternative water management strategies for UTRWD that might be pursued in lieu of certain recommended strategies, to the extent that any of these can be proven practicable:

- Toledo Bend Reservoir
- Wright Patman Lake
- Lake Texoma
- George Parkhouse Reservoir (North)
- George Parkhouse Reservoir (South)
- Additional Reuse

In its evaluation of Lake Ralph Hall, the UTRWD has considered other strategies, including: i) developing supplies from the Gulf of Mexico, the Cypress Creek basin in East Texas, and/or Lake Livingston; ii) ground water imports from Roberts and Brazos counties; supplies from proposed impoundments including the Lower Bois d' Arc and Fastrill reservoirs; and iii) cloud seeding and precipitation enhancement. As presented later in this report, these strategies are not considered as viable alternatives at this time to meet UTRWD's future water supply needs.

In keeping with the purpose of this report, the following discussion provides detailed information related to the status of implementation, or potential implementation, of each of the above listed water supply strategies. Exhibit 1, attached hereto, provides a map of the Region and locates the projects described in this report.

1. Currently Implemented Strategies

The UTRWD has implemented the following water supply strategies listed in the 2006 Region C Water Plan as recommended strategies for UTRWD:

- Conservation,
- Additional supplies from DWU under current contract,
- Lake Chapman indirect reuse, and
- Additional supplies from DWU linked to Lake Chapman reuse.

The following sections provide more detailed discussions of the status of each strategy in terms of the projected available supply amounts, schedule, costs, cultural and environmental impacts, legal and permit issues, agreements, and other pertinent issues.

1.1 Conservation

The 2006 Region C Water Plan defines conservation as a strategy to address long-term demands, as opposed to emergency management or drought measures, which address short-term needs. Conservation is assumed to include the direct and indirect reuse of treated effluent, where appropriate. Indirect reuse strategies include Lake Chapman and Lake Ralph Hall reuse, discussed in paragraphs 1.3 and 2.1, respectively. UTRWD also currently supplies 897 acre-feet per year of direct reuse to Denton County FWSD #1. Mandated conservation measures, i.e. plumbing code implementation, are identified in reduced water use projections. These reductions are considered as additional conservation. Based on the measures recommended in the Region C conservation plan, conservation by all UTRWD customers, both current and future, is expected to supply 850 acre-feet per year of year 2010 demands, and up to 11,762 acre-feet of the projected year 2060 demands. This assumes no increase in direct reuse above the current supply of 897 acre-feet per year.

1.1.1 Projected Water Supply

The projected water supply available from conservation above and beyond that obtained from mandated measures (i.e., low flow plumbing fixtures) through year 2060 is shown in Table 1.1.1.

TABLE 1.1.1
Projected Water Supply from Conservation
Source: 2006 Region C Water Plan

Year	2010	2020	2030	2040	2050	2060
Annual Supply (acre-feet)	850	3,070	4,933	7,196	9,643	11,762

1.1.2 Status of Implementation

As UTRWD does not supply water directly to end users, UTRWD can only implement those strategies related to public education and system operations and maintenance. However, as a condition to its water supply contracts, UTRWD requires that its customers develop their own water conservation plans. UTRWD recently prepared an update to its water conservation plan (UTRWD 2009) which states the following goals:

- Maintain the level of unaccounted-for water in the System below ten percent (10%) annually;
- Maintain a program of universal metering of Customers, meter calibration, and meter replacement and repair;
- Maintain a program of leak detection and repair;
- Continue to utilize wastewater reuse as a major source of future water supply;
- Continue to recycle wash-water from Upper Trinity water treatment plants, where feasible;
- Continue to implement other in-house water conservation efforts;
- Raise public awareness of water conservation and encourage responsible public behavior through a coordinated public education program;
- Expand public education about the need to protect water quality through a continuing program for watershed protection; and
- Maintain average per capita water use in the system at 175 gpcd over the next ten years.

The specific strategies that UTRWD currently implements consist of the following:

- Accurate source supply metering;
- Monitoring and record management of water deliveries, sales, and losses;
- Program for leak detection and repair and water loss accounting;
- Requiring the development of water conservation plans by wholesale customers;
- Reservoir system operations plan; and
- Coordination with Region C Water Planning group.

Additional conservation strategies that UTRWD is implementing include the following:

- Reuse and recycling of reclaimed wastewater;
- Public education programs;
- Maintenance of a water conservation landscaping demonstration garden;
- Pressure control to conserve energy; and
- Watershed protection education.

Each of the above strategies is discussed in more detail in the UTRWD Water Conservation Plan (UTRWD 2009) which is attached to this report. The plan also provides a model water conservation plan for adoption by UTRWD's customers.

1.1.3 Schedule of Implementation

The UTRWD water conservation plan will be evaluated through annual water conservation reports. The annual reports will each include a summary of water conservation reports prepared by UTRWD's customers. The water conservation plan will be modified and updated as needed or every five years beginning in May 2009 as required by TCEQ.

1.1.4 Projected Costs

There are no capital costs associated with UTRWD's Conservation Program, but UTRWD does include the costs of its various initiatives in its annual operations budget.

1.1.5 Legal and Permit Issues

There are no permits required for UTRWD to implement its water conservation plan. Additional indirect reuse supplies will require permit considerations; direct use requires a notification to TCEQ and TCEQ approval. Direct Reuse also requires the utility to maintain records that documents regulatory compliance.

1.1.6 Agreements

UTRWD's wholesale customer agreements encourage the use of conservation as a water supply strategy by requiring customers to develop and implement water conservation plans. Additional direct reuse supplies will require contractual agreements for sale of the water.

1.1.7 Other Issues

None.

1.2 Additional Supplies from DWU Under Current Contract

UTRWD has a raw water purchase agreement with Dallas Water Utilities (DWU). This contract allows UTRWD to withdraw raw water from either Lewisville Lake or Ray Roberts Lake, but UTRWD currently only has infrastructure in place to withdraw from Lewisville Lake The DWU Contract allows UTRWD to purchase a maximum quantity of water equal to that needed by several specific customers designated in the contract in Denton County as well as an additional 10 million gallons per day to meet the needs of other UTRWD customers.

Based on the UTRWD's projected water demands for the specific customers that UTRWD currently supplies in whole or in part, this contract is projected to supply a total of 49,806 acre-feet per year by year 2060. The contract expires in 2023, but an extension is assumed in UTRWD's, DWU and the Region C Water Plans.

1.2.1 Projected Water Supply

The total projected water supply available to UTRWD from additional supplies from DWU under the current contract through year 2060 is shown in Table 1.2.1.

TABLE 1.2.1
Projected Water Supply from Additional Supplies from DWU Under Current Contract
Source: 2006 Region C Water Plan

Year	2010	2020	2030	2040	2050	2060
Annual Supply (acre-feet)	30,834	37,430	44,016	46,222	48,093	49,806

1.2.2 Status of Implementation

The contracts and agreements required to utilize this water supply source are in place.

1.2.3 Schedule of Implementation

UTRWD plans to use this full amount available from DWU as needed to meet its water supply requirements.

1.2.4 Projected Costs

There is no additional capital cost required for UTRWD to develop this supply; however, modifications and improvements to the existing treatment and distribution system would be required in order to utilize the additional supply. The additional supply will be purchased from DWU at the current contract rate of $0.48 per 1,000 gallons, or $156 per acre-foot. This rate is subject to change annually depending on DWU's cost of service.

1.2.5 Legal and Permit Issues

The permits required to utilize this water supply source are in place.

1.2.6 Agreements

The agreement required to utilize this water supply source is in place through 2023.

1.2.7 Other Issues

There are no other known issues with this water supply strategy.

1.3 Lake Chapman Indirect Reuse

UTRWD reached an agreement with the water rights holders in Lewisville Lake, DWU and the City of Denton that allows the UTRWD to reuse return flows that are derived from the Lake Chapman supply. UTRWD has obtained the water reuse permit needed to utilize this supply, making it available to UTRWD (TCEQ Water Use Permit No. 5778). This permit allows UTRWD to reuse up to 60 percent of its return flows originating from Lake Chapman through existing diversion, treatment and distribution facilities.

1.3.1 Projected Water Supply

The projected water supply available to UTRWD from Lake Chapman indirect reuse through year 2060 is shown in Table 1.3.1.

TABLE 1.3.1
Historic and Projected Water Usage and Supply from Lake Chapman Indirect Reuse
Source: 2006 Region C Water Plan and UTRWD

Year	2006	2007	2008			
Historical Usage (acre-feet)	745	2,091	3,568			
Year	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**

Projected Annual Supply (acre-feet)	8,441	8,301	8,161	8,021	7,882	7,743

This supply provides projected additional 8,441 acre-feet per year in 2010; however, this amount is projected to diminish to 7,743 acre-feet per year by 2060, due to the projected diminished yield of Chapman Lake due to sedimentation in the lake.

1.3.2 Status of Implementation

The agreements required to utilize this water supply source are in place.

1.3.3 Schedule of Implementation

UTRWD has implemented this strategy and plans to use this full amount as needed to meet its water supply requirements.

1.3.4 Projected Costs

There is no projected capital cost for UTRWD to develop this supply; however, modifications and improvements to the existing treatment and distribution system may be required in order to utilize the additional supply. UTRWD is required to pay an operational fee for the Pass-Through Agreement with Denton to facilitate reuse at a rate of 0.0238 cents per 1,000 gallons of water.

1.3.5 Legal and Permit Issues

The contract and permits required to utilize this water supply source are in place.

1.3.6 Agreements

The agreements required to utilize this water supply source are in place.

1.3.7 Other Issues

This water supply source may be subject to future rules and standards regarding indirect reuse.

1.4 Additional Supplies from DWU Linked to Lake Chapman Reuse

In addition to the documented return flows that are derived from the Chapman Lake supply, DWU has agreed to allow UTRWD to purchase up to 40 percent of the quantity of water imported from Chapman Lake under the same terms that UTRWD purchases water from DWU under the existing DWU/UTRWD water supply agreement

1.4.1 Projected Water Supply

The projected water supply available to UTRWD from additional supplies from DWU linked to Lake Chapman reuse through year 2060 is shown in Table 1.4.1.

TABLE 1.4.1
Projected Water Supply from Additional Supplies from DWU Linked to Lake Chapman Reuse

Source: 2006 Region C Water Plan

Year	2010	2020	2030	2040	2050	2060
Annual Supply (acre-feet)	5,627	5,534	5,441	5,348	5,254	5,162

This supply would provide an additional 5,627 acre-feet per year in 2010; however, this amount is projected to diminish to 5,162 acre-feet per year by 2060, due to projected diminished yield due to sedimentation in the Chapman Lake

1.4.2 Status of Implementation

The contracts and agreements required to utilize this water supply source are in place.

1.4.3 Schedule of Implementation

UTRWD plans to use this full amount as needed to meet its water supply requirements.

1.4.4 Projected Costs

There is no projected capital cost for UTRWD to develop this supply; however, modifications and improvements to the existing treatment and distribution system would be required in order to utilize the additional supply. The additional supply would be purchased from DWU at the current contract rate of $0.48 per 1,000 gallons, or $156 per acre-foot. This rate is subject to change depending on DWU's cost of service.

1.4.5 Legal and Permit Issues

The contract and permits required to utilize this water supply source are in place.

1.4.6 Agreements

The agreements required to utilize this water supply source are in place.

1.4.7 Other Issues

None.

1.5 Currently Implemented Strategies Compared to Water Demands

Figure 1 represents the projected water demands for UTRWD in comparison to projected supply with only existing sources as well as with future sources outlined in this report. As shown in the figure, the existing sources alone do not provide sufficient yields to be able to support future water demands. If all proposed future sources are utilized, the area demands may be met.

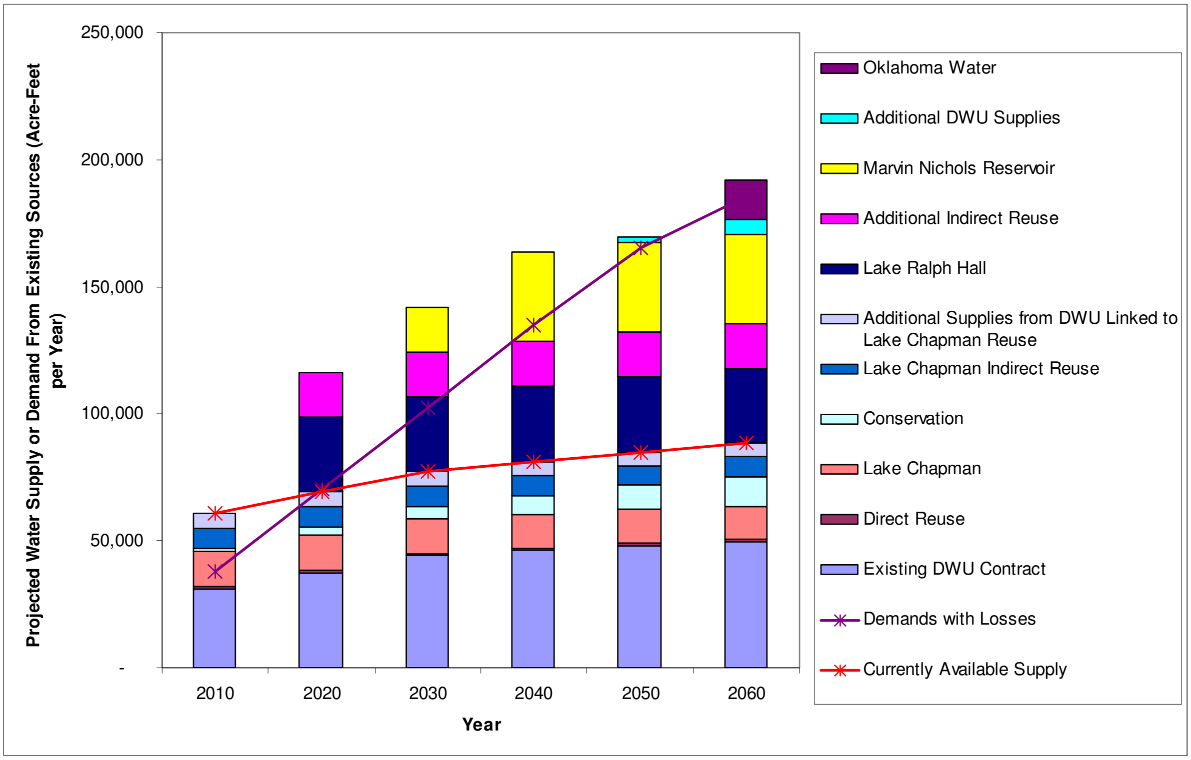

Figure 1. UTRWD Projected Supply and Demand for Currently Implemented Strategies (Source: 2006 Region C Water Plan)

2. Future Supply Strategies for UTRWD

Future water supply strategies, both recommended and alternative, that are discussed in the Region C Water Plan for UTRWD, but are not currently implemented by UTRWD, include the following:

- Lake Ralph Hall,
- Indirect reuse of return flows from Lake Ralph Hall,
- Marvin Nichols Reservoir,
- Additional DWU supplies,
- Oklahoma water,
- Toledo Bend Reservoir,
- Wright Patman Lake,
- Lake Texoma,
- George Parkhouse Reservoir (North),
- George Parkhouse Reservoir (South), and
- Additional reuse.

The following sections provide more detailed discussions of the status of implementation for each strategy, except for Lake Ralph Hall, in terms of the projected available supply amounts, schedule, costs, cultural and environmental impacts, legal and permit issues, agreements, and other pertinent issues. This document is intended to focus on the alternative water supply strategies that the UTRWD has to Lake Ralph Hall. Details on the status, and impacts of Lake Ralph Hall are discussed in a separate document.

2.1 Indirect Reuse of Return Flows from Lake Ralph Hall

Assuming that Lake Ralph Hall is completed, UTRWD intends to apply for the rights to reuse the return flows from the use of this supply, in the same manner as it currently reuses return flows resulting from the use of water diverted from Lake Chapman.

2.1.1 Projected Water Supply

Based upon a return flow factor UTRWD has identified over a course of years, the allowable reuse of return flows from the Lake Ralph Hall project is assumed to be 60 percent of the supply from the project, or approximately 17,800 acre-feet per year. The projected water supply available from the indirect reuse of return flows from Lake Ralph Hall through year 2060 is shown in Table 2.1.1.

TABLE 2.1.1
Projected Water Supply from Indirect Reuse of return Flows from Lake Ralph Hall
Source: 2006 Region C Water Plan

Year	2010	2020	2030	2040	2050	2060
Annual Supply (acre-feet)		17,760	17,760	17,760	17,760	17,760

2.1.2 Status of Implementation

UTRWD has applied for a water rights permit for the proposed Lake Ralph Hall and has not applied for a reuse permit.

2.1.3 Projected Schedule of Implementation

The proposed Lake Ralph Hall water supply is currently scheduled for completion in the year 2020 timeframe. Utilization of the reuse supply will depend on approval of Lake Ralph Hall permits and the timeline for approval of reuse permits.

2.1.4 Projected Costs

There is no projected additional capital cost for UTRWD to develop this supply other than the costs to develop the Lake Ralph Hall supply; however, modifications and improvements to the existing treatment and distribution system may be required in order to utilize the additional supply.

2.1.5 Legal and Permit Issues

The implementation of indirect reuse of return flows from Lake Ralph Hall will require a water use permit, and a bed and banks permit to transfer the water from the discharge point to the intake structure.

2.1.6 Agreements

Implementation of this strategy may require amendments to the existing agreements with the City of Denton and DWU.

2.1.7 Other Issues

According to the Region C Water Plan, development and the associated reuse of Lake Ralph Hall is considered to be highly reliable with medium level impacts on the environment, agriculture, other natural resources, third parties, and key water parameters.

2.2. Marvin Nichols Reservoir

The strategy of obtaining supply from the proposed Marvin Nichols Reservoir is summarized in the 2006 Region C Water Plan as follows:

> "The proposed Marvin Nichols Reservoir is located on the Sulphur River in the Sulphur River Basin in Senate Bill One Planning Region D, the North East Texas Region. The proposed reservoir is about 115 miles from the Metroplex. Development of Marvin Nichols Reservoir was a major strategy for Region C in the 2001 *Region C Water Plan*, called Marvin Nichols I Reservoir North in that plan." (Gooch et al., 2006)

2.2.1 Projected Water Supply

The UTRWD's share of the supply available from the proposed Marvin Nichols Reservoir project is assumed to be 35,000 acre-feet per year in the 2006 Region C Water Plan. The projected water supply available from the Marvin Nichols Reservoir through year 2060 is shown in Table 2.2.1.

TABLE 2.2.1
Projected Water Supply from the Marvin Nichols Reservoir
Source: 2006 Region C Water Plan

Year	2010	2020	2030	2040	2050	2060
Annual Supply (acre-feet)			16,350	32,700	32,700	32,700

The basis for calculating the overall reservoir yield estimate is summarized in the 2006 Region C Water Plan as follows:

> "Using the Sulphur River Basin Water Availability Model and assuming that the proposed Lake Ralph Hall is in place as a senior water right, the estimated yield of Marvin Nichols Reservoir is 612,300 acre-feet per year after allowing for downstream water rights and environmental releases as required by the Texas Water Development Board's environmental flow criteria. (The yield analysis assumes that the reservoir will be operated as a system with Wright Patman Lake, protecting Wright Patman Lake's senior water right while minimizing impacts on the yield of Marvin Nichols Reservoir.) […] The yield is slightly less than the 619,100 acre-feet per year estimated in the 2001 *Region C Water Plan* because Lake Ralph Hall is

> assumed to be in place as a senior water right. (If Lake Ralph Hall were not developed, the yield of Marvin Nichols Reservoir would be 640,800 acre-feet per year operated as a system with Wright Patman Lake, based on the Sulphur River Basin WAM – somewhat higher than estimated in the 2001 *Region C Water Plan*.) Assuming that 20 percent of the yield is used to provide water in Region D and 80 percent is made available to Region C, Marvin Nichols Reservoir will provide 489,840 acre-feet per year of additional water supply for Region C." (Gooch et al., 2006)

The more recent TWDB Report 370 (Kretzschmar et al., 2008) estimates an overall firm yield of 602,000 acre-feet for the proposed reservoir with a conservation pool level at 328 feet. The report estimates that environmental flow requirements will be 12,800 acre-feet per year and that, if Lake Ralph Hall is in place as a senior water right, the available yield will be further reduced by 17,900 acre-feet, leaving a firm yield of 571,300 acre-feet/year. Assuming that 20 percent of the yield will be used to provide water in Region D and 80 percent is available for Region C, the revised supply for Region C is 457,040. UTRWD's share of the revised supply is estimated to be 32,700 in 2040 and beyond.

2.2.2 Status of Implementation

Marvin Nichols is listed in the 2006 Region C Water Plan as a primary water supply strategy for UTRWD, NTMWD, TRWD, and The City of Irving. It is listed as an alternate strategy for The City of Dallas. The Marvin Nichols Site IA is designated by The Texas Legislature as a unique reservoir site. The Marvin Nichols Reservoir has been studied at the reconnaissance level. No detailed field studies have been completed and no permit applications have been filed. Current Regional Planning and the planning of UTRWD's partner agencies call for implementation of the Marvin Nichols Reservoir after 2020 but before 2030. UTRWD's status as a minority partner in the Marvin Nichols project affords it little control over the timing of the project implementation.

2.2.3 Projected Schedule of Implementation

The projected availability of this supply is estimated to be no earlier than 2030; however, no permit applications have been filed nor have any detailed studies been initiated on Marvin Nichols Reservoir.

2.2.4 Projected Costs

The 2006 Region C Water Plan estimates the total capital cost of the project, including transmission to the Metroplex, to be $2.16 billion, of which $143 million is associated with UTRWD. In the Region C Water Plan, the cost of the reservoir itself is estimated at $493 million. The more recent TWDB Report 370 estimates a slightly higher cost for the reservoir construction, at $510 million (in year 2005 dollars). The unit cost for raw water supply (including reservoir and conveyance) to UTRWD is estimated to be $1.27 per 1,000 gallons, or $414 per acre-foot, during the term of debt service.

2.2.5 Legal and Permit Issues

Development of the Marvin Nichols Reservoir will require a new water rights permit, an interbasin transfer, and a 404 permit from the United States Army Corps of Engineers (USACE) in order to transfer the water from the Sulphur River Basin to the Trinity River

Basin. Due to the relative size of the project, permitting and mitigation development could take significant time. As such, water suppliers would need to begin the permitting process far in advance of the water needs date. No permit applications have been filed for Marvin Nichols Reservoir.

2.2.6 Agreements

Development of this supply will require agreement among the potential project partners. In addition, this supply potentially requires negotiations between the operators of Marvin Nichols Reservoir and the City of Texarkana, which holds a water right in Wright Patman Lake, and possibly other local entities.

2.2.7 Other Issues

According to the 2006 Region C Water Plan, development of the Marvin Nichols Reservoir is considered to be highly reliable with high level impacts on the environment, agriculture, and third parties and with medium level impacts on key water parameters and other natural resources. TWDB Report 370 provides a summary of environmental considerations:

> "The Marvin Nichols IA Reservoir is not located on an ecologically significant stream segment but is approximately 29 river miles upstream of one identified by the Texas Parks and Wildlife Department (TPWD, 1999). The Sulphur River downstream of the Interstate 30 bridge in Morris County is considered an ecologically significant stream based on biological function associated with bottomland hardwood forests and the presence of paddlefish, which is a state listed threatened species. The Region D Water Planning Group did not identify the Sulphur River as ecologically unique in its 2006 Regional Water Plan.
>
> Marvin Nichols IA Reservoir will inundate approximately 67,300 acres. The U.S. Fish and Wildlife Service has classified some of this acreage as Priority 1 bottomland hardwoods, which are considered "excellent quality bottomlands of high value to key waterfowl species" (USFWS, 1985). Previous studies have also identified surface lignite deposits within the project area. At this time, there are no lignite mining areas. […] Landcover is dominated by largely contiguous bottomland hardwood forest (39 percent), with sizeable areas of upland deciduous forest (20 percent) and grassland (19 percent). Marsh, swamp, and open water total about 13 percent of the reservoir area" (Kretzschmar et al., 2008). The landcover by type of the area is shown in Figure 1.

The studies listed in Report 370 represent reconnaissance level surveys, not detailed field studies that are necessary to accurately quantify the environmental resources, cultural resources, or other impacts the Marvin Nichols Project might cause. However, given its magnitude (67,300 inundated acres), it is reasonable to assume that the Marvin Nichols Reservoir will have greater impacts than the Lake Ralph Hall Project (7,500 inundated acres).

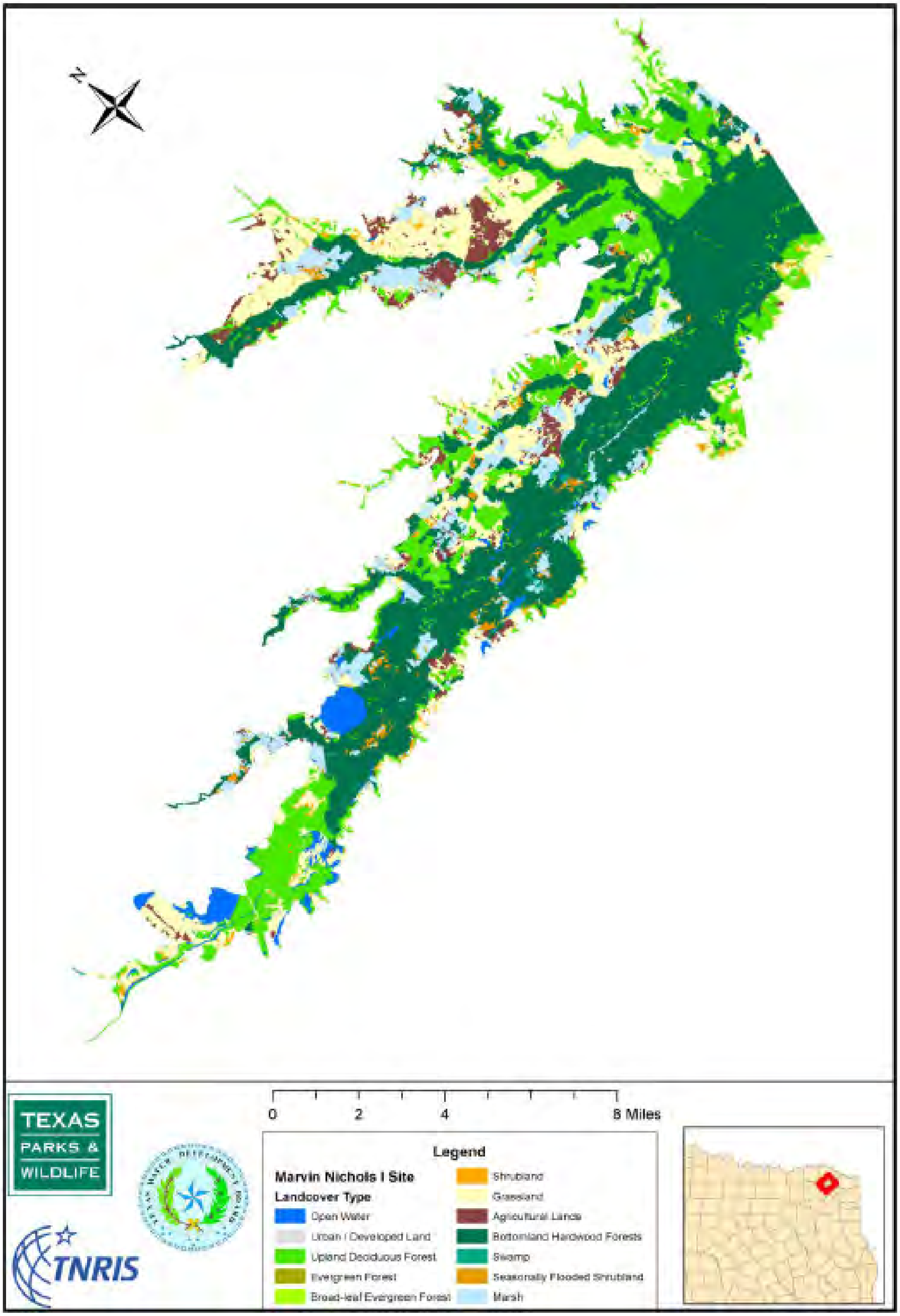

Figure 2. Marvin Nichols Reservoir Landcover by Type (Kretzschmar et al. 2008)

2.3 Additional DWU Supplies

DWU has included supplies for Denton County in its long range water supply plans for decades. Likewise, both the 2003 and the 2007 Region C Water Supply Plans call for DWU providing water supplies to Denton County and UTRWD specifically beyond the current contract expiration date (2023) and in excess of the quantities specified in the current agreement (Ref. Section 1.2 of this report).

UTRWD is in on-going discussions with DWU to extend the current contract and to increase the quantity of raw water it will purchase from DWU. The quantity of additional water and terms of the purchase have not been finalized to date. The best estimate of a quantity of additional supplies that UTRWD will obtain from DWU is listed in the Region C Plan. That Plan projects that UTRWD will add an additional supply of up to 6,000 acre-feet per year to the existing contract with DWU by 2060.

2.3.1 Projected Water Supply

The projected water supply available from additional DWU supplies through year 2060 is shown in Table 2.3.1.

TABLE 2.3.1
Projected Water Supply from Additional DWU Supplies
Source: 2006 Region C Water Plan

Year	2010	2020	2030	2040	2050	2060
Annual Supply (acre-feet)					2,200	6,000

2.3.2 Status of Implementation

DWU currently has water supplies in Lewisville Lake and Ray Roberts Lake, but projected future demands for DWU, its wholesale customers, the City of Denton, and UTRWD exceed the firm yield of this water supply system. DWU will have to develop additional resources to maintain adequate supplies to meet its projected demands and sell additional water to UTRWD. A portion of these additional supplies will have to be connected to Lewisville Lake and/or Ray Roberts Lake for UTRWD to be able to purchase additional water from DWU. The Region C Water Plan lists a number of strategies forDWU, including connecting Lake Palestine, developing Lake Fastrill, obtaining other Sulphur River water supplies, and obtaining water from Toledo Bend. All of these strategies that DWU is pursuing will have their own impacts.

2.3.3 Projected Schedule of Implementation

The current raw water supply contract between UTRWD and DWU is scheduled to be renegotiated prior to 2023. UTRWD is in on-gong discussions to extend the contract beyond its current term and to increase the quantity available to UTRWD.

2.3.4 Projected Costs

There is no capital cost to UTRWD associated with obtaining this supply, but DWU will incur additional capital costs to develop the additional supplies it needs to meet its projected demands plus the additional water it would sell to UTRWD. The cost of purchasing the additional water will be negotiated with DWU. The current rate is $0.48 per 1,000 gallons, or $156 per acre-foot. This rate is subject to change depending on DWU's cost of service and will likely increase due to debt service from DWU's capital investment in additional supplies.

2.3.5 Legal and Permit Issues

UTRWD will not have to seek additional permits to implement this supply, but DWU will have to obtain water rights permits, interbasin transfer permits and a Section 404 permit for the additional supplies it will need to meet its demands.

This water supply will also require a new contract, or amendment of the existing contract, between DWU and UTRWD.

2.3.6 Agreements

Additional supplies from DWU will require agreement between DWU and UTRWD for modifications to the existing contract.

2.3.7 Other Issues

This supply will only be as reliable as Dallas' supply. As previously discussed, Dallas will have to develop additional supplies to support its water demands and those of its wholesale customers, including UTRWD. Each of the strategies that DWU is pursuing will have potential impacts equal to or in excess of those from Lake Ralph Hall.

2.4 Oklahoma Water

Importing water from southeastern Oklahoma is a water management strategy that is recommended for several North Texas suppliers in the Region C Water Plan.

2.4.1 Projected Water Supply

The 2006 Region C Water Plan estimates that 15,000 acre-feet would be available to UTRWD by year 2060.

2.4.2 Status of Implementation

UTRWD is actively pursuing this strategy. UTRWD has filed three applications with the Oklahoma Water Resources Board seeking up to 115,000 acre-feet per year from some combination of the Kiamichi River, Boggy Creek, and Red River (Lake Texoma). However, Oklahoma has imposed a moratorium on any permits or contracts authorizing the sale of water to users outside of the state.

Tarrant Regional Water District (TRWD) and the City of Hugo Oklahoma have both filed actions in Federal Court to overturn Oklahoma's moratorium. Those actions are pending.

Additionally, TRWD, North Texas Municipal Water District (NTMWD) and the City of Irving have filed permit applications or entered into agreement with other water rights holders for water in the same basins as UTRWD's applications. There are no detailed studies that have been completed that quantify the amount of water available from these basins.

2.4.3 Projected Schedule of Implementation

The timeline for developing this water source depends on the resolution of various legal issues mentioned above and planning studies and that are out of the control of UTRWD.

2.4.3 Projected Costs

The 2006 Region C Water Plan states that the strategy of obtaining raw water from Oklahoma would have an overall capital cost to North Texas users of about $500 million, of which UTRWD's share is estimated to be about $50 million. The unit cost for delivery to UTRWD is estimated to be $1.36 per 1,000 gallons, or $443 per acre-foot, during the term of debt service.

These costs are not based on detailed studies and could increase if additional storage infrastructure is required to increase the quantity of available water during dry periods.

2.4.4 Legal and Permit Issues

UTRWD has filed three permit applications for a combined 115,000 acre-feet per year in the Kiamichi River, Muddy Boggy Creek, and Red River (Texoma) basins. Additionally, several other North Texas suppliers have submitted permit applications for water rights in Oklahoma. In some cases other entities have made application for water in the same basins as UTRWD. The quantity of water in Oklahoma available to meet the needs of the various applicants and how that water will be allocated is yet to be resolved.

The Oklahoma Water Resources Board (ORWRB) is waiting on the outcome of the various legal actions discussed above before it considers any of the applications for water from applicants in Texas.

In addition to the legal actions discussed above, the Chickasaw and Choctaw Indian Nations have also asserted legal claims to water in southeastern Oklahoma. Neither tribe has asserted their claims in court, but may do so depending on the outcome of the other actions previously discussed. Those legal actions will likely further delay use of water in Oklahoma by UTRWD or other Texas entities.

Oklahoma City has also filed permit applications for water from the Kiamichi River basin. The OWRB and possibly the courts will have to assess the impact of intrastate needs in conjunction with the interstate permit applications filed by UTRWD and other Texas entities.

In addition to permits from the OWRB, the use of Oklahoma water in Texas has no precedence in Texas Water law or TCEQ rules. Therefore, the role of TCEQ in the use of interstate water in Texas is unknown.

Construction of the infrastructure to capture and convey Oklahoma water to UTRWD and other Texas entities will require a Section 404 permit from the USACE. The scope of that permit, be it an individual permit, a nationwide permit, or regional general permit, will depend on the scope of the infrastructure required. The infrastructure requirements to capture and convey Oklahoma water will be defined by detailed feasibility studies, but such studies will likely not be conducted until after the various legal issues are resolved.

2.4.5 Agreements

Conveyance to the Metroplex area would have to be developed in partnership with other suppliers. Potential partners include DWU, the City of Irving, North Texas Municipal Water District (NTMWD) and Tarrant Regional Water District (TRWD). In addition, agreements may need to be negotiated with the State of Oklahoma and the Native American tribes who assert claims to the water.

2.4.6 Other Issues

According to the 2006 Region C Water Plan, raw water from Oklahoma is assumed to have high reliability with relatively low environmental impacts as the proposed supply amounts are based on the use of existing sources. This option is also assumed to have low to medium low level impacts on agriculture, other natural resource, third parties, and key water quality parameters.

Applications filed by UTRWD and other North Texas entities for water in Oklahoma are all based on “spilt water”, water that flows into the Red River from Oklahoma streams. These permit applications do not seek any rights to stored water in Oklahoma. Hydrologic and system operations studies are required to establish the quantity of water that might be available during drought periods and the impact of that supply on the overall yield of the water supply system.

2.5 Toledo Bend Reservoir

The strategy of obtaining supply from the existing Toledo Bend Reservoir is summarized in the 2006 Region C Water Plan as follows:

> “Toledo Bend Reservoir is an existing impoundment located in the Sabine River Basin on the border between Texas and Louisiana. It was built in the 1960s by the Sabine River Authority of Texas (SRA) and the Sabine River Authority of Louisiana. The yield of the project is split equally between the two states, and Texas’ share of the yield is slightly over 1,000,000 acre-feet per year. The SRA holds a Texas water right to divert 750,000 acre-feet per year from Toledo Bend and is seeking the right to divert an additional 293,300 acre-feet per year.” (Gooch et al., 2006)

2.5.1 Projected Water Supply

The projected water supply from the reservoir is summarized in the 2006 Region C Water Plan as follows:

> “The SRA and Metroplex water suppliers have been investigating the possibility of developing substantial water supplies from Toledo Bend Reservoir, with up to 100,000 acre-feet per year delivered to SRA customers in the upper Sabine River Basin (Region D, the North East Texas Region) and up to 600,000 acre-feet per year delivered to Region C.” (Gooch et al., 2006)

Of the 600,000 acre-feet per year to Region C, 48,000 acre-feet per year could be allocated to UTRWD as an alternative supply.

2.5.2 Status of Implementation

Toledo Bend Reservoir is an existing water supply source; however, no transmission facilities currently exist to deliver this water to the Dallas/Fort Worth area. UTRWD is not currently a partner in the project. If UTRWD were to become a partner, it would be a minority partner and, as such, cannot dictate the schedule for developing this supply. The current schedule for the project does not meet UTRWD's need for additional supply in the 2020's. UTRWD will remain vigilant with regards to the project and seek a partnership if such a partnership can feasibly provide a reliable and timely water supply for UTRWD.

2.5.3 Projected Schedule of Implementation

Development of the Toledo Bend Reservoir as a supply strategy for UTRWD is not projected to occur within the Year 2060 timeframe.

2.5.4 Projected Costs

Due to the 200-mile distance between the reservoir and Region C, development of this supply will require significant water transmission facilities, making the reservoir an expensive option. For the recommended 600,000 acre-feet per year Region C supply, transmission facilities to deliver water from the Toledo Bend Reservoir have an estimated capital cost of $2.4 billion. The cost to UTRWD of its 48,000 acre-feet share is estimated to be $213 million. The unit price for delivery to UTRWD facilities is estimated to be $1.66 per 1,000 gallons, or $541 per acre-foot, during the term of debt service.

2.5.5 Legal and Permit Issues

Development of this supply would require an interbasin transfer permit from the Sabine River Basin to the Trinity River Basin and a Section 404 permit from the USACE. No permit applications have been filed.

2.5.6 Agreements

Due to the magnitude of the capital costs and the cost of conveying this supply to the Metroplex area, development of this supply would require cost-sharing agreements and cooperation with one or more of the major water suppliers in the region. The 2006 Region C Water Plan lists the Toledo Bend Reservoir supply as a recommended water strategy for NTMWD and TRWD and as an alternative strategy for DWU. The development of this supply will also require a water purchase agreement with the Sabine River Authority. No agreements for the development of Toledo Bend Reservoir are in place.

2.5.7 Other Issues

According to the 2006 Region C Water Plan, supply from the Toledo Bend Reservoir is assumed to have high reliability with low level impacts on agriculture, other natural resources, and key water quality parameters since it is already an existing source. Medium low level impacts could occur on the environment and third parties.

The studies listed above represent reconnaissance level surveys, not detailed field studies that are necessary to accurately quantify the environmental resources, cultural resources, or other impacts the Toledo Bend Reservoir Project might cause.

2.6 Wright Patman Lake

The strategy of obtaining additional supply from the existing Wright Patman Lake is summarized in the 2006 Region C Water Plan as follows:

> "Wright Patman Lake is an existing reservoir on the Sulphur River in the Sulphur River Basin, about 150 miles from the Metroplex. It is located in Region D, the North East Texas Region, and owned and operated by the U.S. Army Corps of Engineers. […] There are three different ways in which water could be made available from Wright Patman Lake for water suppliers in Region C:
>
> - Water could be purchased from the City of Texarkana under its existing water right.
> - Flood storage in Wright Patman Lake could be converted to conservation storage, and the increased yield could be used in Region C.
> - Wright Patman Lake could be operated as a system with Jim Chapman Lake (formerly Cooper Lake) upstream to further increase yield." (Gooch et al., 2006)

2.6.1 Projected Water Supply

The purchase option could provide an additional 100,000 acre-feet per year to the Region C supply. The conversion option could provide an additional 180,000 acre-feet per year to the Region C supply. The system operation option could provide 390,000 acre-feet per year to the Region C water supply. The 2006 Region C Water Plan assumes that 38,000 acre-feet per year could be available to UTRWD by Year 2060.

2.6.2 Status of Implementation

For the purchase option, the City of Texarkana currently has water rights of 180,000 acre-feet per year, 135,000 acre-feet per year of which is allocated to industrial use (more than their projected water demand). Texarkana potentially could sell 100,000 acre-feet per year and still meet projected needs.

For the conversion option, a recent study for the Corps of Engineers (Freese & Nichols) reported that:

> "increasing the top of conservation storage in Wright Patman Lake to elevation 228.64 feet msl and allowing diversions as low as elevation 215.25 feet msl would increase the yield of the project to about 364,000 acre-feet per year. It was assumed that 180,000 acre-feet per year of the additional supply developed could be made available to water suppliers in the Metroplex. The yield of Wright Patman Lake could be increased to much more than 364,000 acre-feet per year by converting additional flood storage to conservation storage and increasing the top of conservation storage. However, increases beyond elevation 228.64 feet msl will inundate portions of the White Oak Creek mitigation area, located upstream from Wright Patman Lake." (Gooch et al., 2006)

For the system operation option,

> "The recent study conducted for the Corps of Engineers indicated that system operation of Wright Patman Lake and Jim Chapman Lake could increase the yield from the two projects by about 108,000 acre-feet per year. It was assumed that the combination of purchasing water from Texarkana, converting flood storage to conservation storage, and system operation with Jim Chapman Lake could make 390,000 acre-feet per year available for Region C from Wright Patman Lake." (Gooch et al., 2006)

2.6.3 Projected Schedule of Implementation

Development of additional supplies from Wright Patman Lake as a supply strategy for UTRWD is not projected to occur within the Year 2060 timeframe.

2.6.4 Projected Costs

The Region C share of the capital cost for the *purchase option* is estimated at approximately $5 million with a unit cost of about $1 per 1,000 gallons of water. This cost does not include the cost of conveyance facilities.

The Region C share of the capital cost for the *conversion option* is estimated at approximately $9 million with a unit cost of about $1.50 per 1,000 gallons of water. This cost does not include the cost of conveyance facilities.

The Region C share of the capital cost for the *system operation option* is estimated at approximately $1.9 billion with a unit cost of about $1.66 per 1,000 gallons of water.

For the potential supply allocation to UTRWD of 38,000 acre-feet per year, UTRWD's share of the capital cost of these projects is estimated at $183 million. The unit price of delivery to UTRWD is estimated at $1.64 per 1,000 gallons, or $534 per acre-foot, during the term of debt service.

2.6.5 Legal and Permit Issues

Development of the purchase option would require a contract with the City of Texarkana and the Corps of Engineers for additional conservation storage and pump station improvements as well as an interbasin transfer permit from the TCEQ.

Development of the conversion option would require an interbasin transfer permit from the TCEQ, a contract with the Corps of Engineers, and a new water rights permit from the TCEQ.

Development of the system operations option would require an interbasin transfer permit from the TCEQ, a contract with Texarkana and the Corps of Engineers, and a newwater rights permit from the TCEQ.

Any of the options will require a Section 404 permit from the USACE.

2.6.6 Agreements

Development of this supply requires agreement between the potential suppliers, the City of Texarkana, and the Corps of Engineers.

2.6.7 Other Issues

The 2006 Region C Water Plan notes the following issues with regards to each option for additional supply from Wright Patman Lake:

- The purchase option would require environmental studies and mitigation as well as improvements to the City of Texarkana's pump station. This option is assumed to be highly reliable with low impacts on environment, agriculture, and other natural resources and medium low impacts on third parties and key water quality parameters.
- The conversion option is assumed to be highly reliable with medium impacts on environment, low impacts on agriculture, and medium low impacts on other natural resources, third parties, key water quality parameters.
- The system operations option is assumed to be highly reliable with medium impacts on environment, other natural resources, and third parties, low impacts on agriculture, and medium low impacts on key water quality parameters.

The studies listed above represent reconnaissance level surveys, not detailed field studies that are necessary to accurately quantify the environmental resources, cultural resources, or other impacts Wright Patman Lake might cause. However, given its magnitude, it is reasonable to assume that the options relating to Wright Patman Lake will cause greater impacts than the Lake Ralph Hall Project (7,500 inundated acres) The conversion option and the system operation option will possibly permanently inundate up to 12,000 more acres than are currently inundated by Lake Wright Patman.

2.7 Lake Texoma

The strategy of obtaining supply from the existing Lake Texoma is summarized in the 2006 Region C Water Plan as follows:

> "Lake Texoma is an existing Corps of Engineers reservoir on the Red River on the border between Texas and Oklahoma. Under the terms of the Red River Compact, the yield of Lake Texoma is divided equally between Texas and Oklahoma. Lake Texoma is used for water supply, hydropower generation, flood control, and recreation. Lake Texoma is only about 50 miles from the Metroplex. The lake has elevated levels of dissolved solids, and the water must be blended with higher quality water or desalinated for municipal use. Blending water from Lake Texoma with water from other sources provides an inexpensive supply for Region C. Desalination provides treated water but is a more expensive strategy and there are considerable uncertainties in the long-term costs." (Gooch et al., 2006)

2.7.1 Projected Water Supply

According to the 2006 Region C Water Plan:

> "Further reallocation of hydropower storage to water supply in Lake Texoma would provide additional yield. According to the Corps of Engineers, the firm yield of Lake Texoma with all hydropower storage reallocated to water supply would be 1,088,500 acre-feet per year. Texas' share would be 544,250 acre-feet per year, leaving about 220,000 acre-feet per year of additional supply available to Texas by the reallocation

> of more hydropower storage to municipal use (beyond the supplies already contracted for and the currently authorized reallocation). Further reallocation would require a new authorization by Congress." (Gooch et al., 2006)

Development of the blending option would provide about 220,000 acre-feet per year to Region C.

Development of the desalination option would provide about 207,000 acre-feet per year of treated water to Region C.

The 2006 Region C Water Plan assumes that 25,000 acre-feet of this supply could be allocated to UTRWD.

2.7.2 Status of Implementation

According to the 2006 Region C Water Plan:

> "The U.S. Congress has passed a law allowing the Corps to reallocate an additional 300,000 acre-feet of storage in Lake Texoma from hydropower use to water supply, 150,000 acre-feet for Texas and 150,000 acre-feet for Oklahoma. The North Texas Municipal Water District is negotiating to purchase 100,000 of the 150,000 acre-feet of storage for Texas and has applied for a Texas water right to divert an additional 113,000 acre-feet per year from Lake Texoma. The remaining 50,000 acre-feet of storage was reserved by Congress for the Greater Texoma Utility Authority." (Gooch et al., 2006)

UTRWD has filed for a water rights permit from Lake Texoma from the Oklahoma Water Resources Board (OWRB). The OWRB is not ruling on this and other out of state permits pending the outcome related to lawsuits (see Section 2.4.4).

2.7.3 Projected Schedule of Implementation

Development of additional supplies from Lake Texoma is dependent on the resolution of legal and permit issues related to Oklahoma water.

2.7.4 Projected Costs

Region C capital costs for the *blending option* would be approximately $183 million with a unit cost of about $1.07 per 1,000 gallons of water.

Region C capital costs for the *desalination option* would be approximately $621 million with a unit cost of about $2.17 per 1,000 gallons of water. In addition, since most of the large desalination facilities built to date are on or near the coast, the development of a 100 million gallon per day or larger plant on Lake Texoma (the largest inland facility in the world) would create several cost uncertainties. For example, the method and cost of brine disposal would be uncertain and could potentially increase the estimated desalination cost significantly. Additional studies would be necessary to evaluate the true cost of this option.

2.7.5 Legal and Permit Issues

Lake Texoma water supply (both blend and desalinate) for Region C requires an interbasin transfer permit, state water rights, possible Congressional authorization, and a contract with

USACE. In addition, desalination would require a brine discharge permit or deep well injection.

The State of Oklahoma does retain the right to a significant quantity of water allocated to municipal and industrial use. To date, Oklahoma has issued permits for only a fraction of that water, but Oklahoma's moratorium on exporting water also applies to its Texoma water. As discussed in Section 2.4, UTRWD has applied for up to 115,000 acre feet per year from any combination of three sources in Oklahoma, including Lake Texoma. The same legal and political issues apply to the Texoma application as discussed in Section 2.4

This supply would require a Section 404 permit from the USACE.

2.7.6 Agreements

Development of this supply requires agreement of water rights stakeholders in Texas – NTMWD, GTUA, City of Denison, TXU, and the Red River Authority – together with Oklahoma and the Corps of Engineers.

2.7.7 Other Issues

Since the method and cost of brine disposal are uncertain for an inland facility of this magnitude, brine disposal could significantly increase the estimated cost and complexity of desalination.

Blending and desalination both are assumed to be highly reliable with medium level impacts on the environment (due to high dissolved solids concentrations in Lake Texoma), other natural resources, third parties, and key water quality parameters. In addition, low agricultural impacts could occur.

The information listed above represent reconnaissance level surveys, not detailed field studies to accurately quantify the environmental resource, cultural resource or other impacts that the Lake Texoma alternative might cause.

2.8 George Parkhouse Reservoir (North)

George Parkhouse Reservoir (North), also referred to as Parkhouse II Lake, is a potential reservoir on the North Sulphur River located downstream of the proposed Lake Ralph Hall in Lamar and Delta Counties (Region D). Most of the demand for the reservoir's water would be from Region C.

2.8.1 Projected Water Supply

The 2006 Region C Water Plan estimates that the reservoir yield would be 148,700 acre-feet per year, based on a conservation pool level of 410 feet, 118,960 acre-feet per year of which is assumed to be available for Region C, with 35,000 acre-feet per year of that amount allocated to UTRWD. The more recent TWDB Report 370 estimates the firm yield of the proposed reservoir at 144,300 acre-feet per year, and estimates that this would be reduced by 2,500 acre-feet per year for environmental flow requirements and by an additional 26,900 acre-feet per year if Lake Ralph Hall is in place as a senior water right. If all of the other planned reservoirs in the Sulphur Basin were in place, including the Marvin Nichols Reservoir, the yield from George Parkhouse Reservoir (North) is estimated to be only 32,100 acre-feet per year.

2.8.2 Status of Implementation

This potential reservoir site has been studied by Freese and Nichols, Inc. in 1990, 1996, 2000 and 2006. The site was recommended as a potential reservoir site in the 2007 TWDB reservoir site protection study; however, it was not adopted as a recommended water management strategy in the 2007 State Water Plan, nor has it been designated as a unique reservoir site by the State Legislature.

2.8.3 Projected Schedule of Implementation

Development of additional supplies from the proposed George Parkhouse Reservoir (North) as a supply strategy for UTRWD is not projected to occur within the Year 2060 timeframe. Due to the decrease in yield, the project becomes less favorable as other reservoirs are completed in the Sulphur Basin.

2.8.4 Projected Costs

The 2006 Region C Water Plan estimates that the capital cost for this project, including conveyance to the Metroplex, is approximately $363 million, with UTRWD’s cost share estimated to be $107 million. Of this total, the 2006 Region C Water Plan estimates the cost for construction of the reservoir itself at $206 million. The more recent TWDB Report 370 estimates the cost of the reservoir to be $210 million (in 2005 dollars). The unit costs of raw water (including reservoir and conveyance) from this supply for UTRWD are estimated to be $1.01 per 1,000 gallons of water, or $339 per acre-foot, during the term of debt service.

2.8.5 Legal and Permit Issues

Development of this supply would require a new water rights permit and an interbasin transfer permit from the TCEQ, and a Section 404 permit from the USACE.

2.8.6 Agreements

Development of this supply would require agreement among TRWD, DWU and/or NTMWD. The strategy of obtaining additional water supply from George Parkhouse Reservoir (North) is not a recommended strategy for any Region C supplier, but it is considered an alternative strategy for TRWD, DWU and NTMWD.

2.8.7 Other Issues

According to the 2006 Region C Water Plan, this water supply is assumed to be highly reliable with medium high level impacts on the environment and agriculture, medium level impacts on third parties and other natural resources, and low level impacts on key water quality parameters. TWDB Report 370 provides a summary of environmental considerations:

> “Parkhouse II Lake is not located on an identified ecologically significant stream segment. The Region D Water Planning Group did not identify the Sulphur River as ecologically unique in their 2006 Regional Water Plan. The reservoir site is located some distance upstream of a Priority 1 bottomland hardwood preservation site

> identified as Sulphur River Bottoms West. […] Parkhouse II Lake will inundate approximately 14,400 acres of land at conservation storage capacity. […] Landcover is dominated by grassland (49 percent), with sizeable areas of upland deciduous forest (26 percent) and agricultural land (16 percent). Only about 1.4 percent of this site is classified as bottomland hardwood forest." (Kretzschmar et al., 2008)

The studies listed above represent reconnaissance level surveys, not detailed field studies that are necessary to accurately quantify the environmental resources, cultural resources, or other impacts the George Parkhouse Reservoirs (North) might cause. However, given its magnitude (14,400 inundated acres), it is reasonable to assume that the George Parkhouse Reservoir (North) will cause greater impacts than the Lake Ralph Hall Project (7,500 inundated acres), located upstream.

2.9 George Parkhouse Reservoir (South)

George Parkhouse Reservoir (South), also referred to as Parkhouse I Lake, is a potential reservoir located downstream from Jim Chapman Lake on the South Sulphur River in Hopkins and Delta Counties (Region D).

2.9.1 Projected Water Supply

According to the 2006 Region C Water Plan, George Parkhouse Reservoir (South) could supply 135,600 acre-feet per year based on a conservation pool level of 410 feet. 108,480 acre-feet per year are assumed to be available for Region C, with 35,000 acre-feet per year of that amount assumed to be allocated to UTRWD. Its potential yield would decrease with the development of the Marvin Nichols Reservoir. The more recent TWDB Report 370 estimated the firm yield to be 122,000 acre-feet per year based on a conservation pool elevation of 401 feet. The lower conservation pool elevation was used in this study based on concerns of operational and cost impacts if it were set at a higher level. TWDB report 370 also estimates that environmental flow requirements would be 2,400 acre-feet per year, and notes that the yield will decrease if Lake Ralph Hall is in place as a senior water right. If all of the other proposed reservoirs in the Sulphur Basin were to be completed before George Parkhouse Reservoir (South), the firm yield would be reduced to 48,400 acre-feet per year.

2.9.2 Status of Implementation

This potential reservoir site has been studied by Freese and Nichols, Inc. in 1990, 1996 and 2000. The site was recommended as a potential reservoir site in the 2007 TWDB reservoir site protection study; however, it was not adopted as a recommended water management strategy in the 2007 State Water Plan, nor has it been designated as a unique reservoir site by the State Legislature.

2.9.3 Projected Schedule of Implementation

Development of additional supplies from the proposed George Parkhouse Reservoir (South) as a supply strategy for UTRWD is not projected to occur within the Year 2060 timeframe.

2.9.4 Projected Costs

The 2006 Region C Water Plan estimates the total capital cost for this project, including conveyance to the Metroplex, at approximately $480 million, with UTRWD's share estimated at $155 million. The cost for the reservoir itself is estimated at $328 million. The more recent TWDB report 370 estimates the cost for the reservoir at $291 million (in 2005 dollars). Based on the Region C Water Plan cost estimates, the unit costs of raw water supply (including reservoir and conveyance) to UTRWD are estimated to be $1.34 per 1,000 gallons, or $437 per acre-foot, during the term of debt service.

2.9.5 Legal and Permit Issues

Development of this supply would require a new water rights permit and an interbasin transfer permit from the TCEQ, and a Section 404 permit from the USACE..

2.9.6 Agreements

Development of this supply would require agreements with NTMWD. The project is not a recommended water management strategy for any Region C water supplier; however it is an alternative strategy for NTMWD.

2.9.7 Other Issues

According to the 2006 Region Water Plan, this water supply is assumed to be highly reliable with medium high level impacts on the environment and agriculture, medium level impacts on third parties and other natural resources, and low level impacts on key water quality parameters. TWDB Report 370 provides a summary of the environmental considerations:

> "Parkhouse I Lake is not located on an identified ecologically significant stream segment. The Region D Water Planning Group did not identify the Sulphur River as ecologically unique in their 2006 Regional. The reservoir site is located some distance upstream of a Priority 1 bottomland hardwood preservation site identified as Sulphur River Bottoms West . […] Parkhouse I Lake will inundate approximately 29,000 acres at conservation storage capacity. […] Landcover is dominated by contiguous bottomland hardwood forest (37 percent), with sizeable areas of grassland (16 percent), marsh (16 percent), and agricultural land (16 percent)" (Kretzschmar et al., 2008).

The studies listed above represent reconnaissance level surveys, not detailed field studies that are necessary to accurately quantify the environmental resources, cultural resources, or other impacts the George Parkhouse Reservoir (South) might cause. However, given its magnitude (29,000 inundated acres), it is reasonable to assume that the George Parkhouse Reservoir (South) will cause greater impacts than the Lake Ralph Hall Project (7,500 inundated acres) to be located above the George Parkhouse Reservoir (North).

2.10 Additional Reuse

Additional indirect reuse of return flows from future sources is another alternative strategy for future water supply to UTRWD.

2.10.1 Projected Water Supply

Water supply from additional reuse would be highly dependent on the source, availability, required treatment, and end use of the water. The reuse of the water would be connected to an import source with a reuse to import ratio of approximately 0.6 to 1 in order to ensure the water is reused once before released. The 2006 Region C Water Plan assumes that up to 15,000 acre-feet per year could be available to UTRWD.

2.10.2 Status of Implementation

Since additional reuse requires an import source, the status depends on the existence of the water supply. If the source water already exists, reuse of the source will be much easier and faster to implement.

2.10.3 Projected Schedule of Implementation

The timing of the availability of this potential source of water supply is dependent on the completion of projects to import new water supplies as well as the timeline for permitting of the reuse flows.

2.10.4 Projected Costs

If the water supply already exists, capital cost for additional reuse will be assumed to be $0 with additional unit costs for water treatment and transport.

2.10.5 Legal and Permit Issues

Additional water reuse could require amended water rights permits, renegotiations of existing contracts, interbasin transfer permits, and wastewater discharge permits.

2.10.6 Agreements

Development of additional reuse would require agreement with all parties involved including source/import stakeholders.

2.10.7 Other Issues

Special attention will need to be given to the investigation of possible impacts of the water reuse on the environment, agriculture, other natural resource, third parties, and key water quality parameters.

TABLE 2.11.1
Summary of Future Supply Strategies
Source: 2006 Region C Water Plan

Section #	Strategy	Potential Partners	UTRWD Potential Supply (Acre-Feet per Year) [Total Region C Supply]	UTRWD Share of Capital Cost [Total Region CCost]	UTRWD Unit Cost ($/kgal) [Total Unit Cost]		Reliability	Environmental Factors	Agricultural / Rural Impacts	Other Natural Resources	3rd Party Impacts	Key Water Quality Parameters	Implementation Issues	Comment
					Pre-Amort.	Post-Amort.								
2.1	Indirect Reuse of Return Flows from Lake Ralph Hall	UTRWD	17,760	$0	$0.00	$0.00	High	Low	Low	Medium low	Low	Medium	May require water rights permit.	Develop 202
2.2	Marvin Nichols Reservoir	DWU, Irving, NTMWD, TRWD, & UTRWD	35,000 [489,840]	$142,761,000 [$2,092,720,000]	$1.27 [$1.33]	$0.36 [$0.37]	High	High	High	Medium high	High	Medium	Requires IBT and new water rights permit	Develop 2030 [weighted averag five potential parti
2.3	Additional DWU Water Supplies	DWU and UTRWD	6,000	$0	$0.40	$0.40	High	Low	Low	Medium low	Low	Low		Develop 205
2.4	Oklahoma Water	DWU, Irving, NTMWD, or TRWD	15,000 [165,000 or more; costs based on 115,000]	$60,967,000 [$477,214,000]	$1.36 [$1.40]	$0.45 [$0.47]	High	Low	Low	Low	Medium low	Medium Low	Oklahoma has moratorium for export of water out of state; may require IBT.	Develop 206
2.5	Toledo Bend Reservoir	DWU, NTMWD, SRA, TRWD, & UTRWD	48,000 [600,000]	$212,640,000 [$2,428,789,000]	$1.66 [$1.50]	$0.67 [$0.60]	High	Medium low	Low	Low	Medium low	Low	Requires IBT and agreements with multiple users	Develop 2050 [weighted averag potential partici
2.6	Wright Patman Lake (Purchase)	DWU, Irving, NTMWD, or TRWD	38,000 [100,000]	$182,913,000 [$429,176,000 to $670,735,000]	$1.64 [$1.70 to $2.37]	$0.57 [$0.65 to $0.87]	High	Low	Low	Low	Medium low	Medium low	Requires agreement with Texarkana and IBT	Develop 203
2.6	Wright Patman Lake (Conversion)	DWU, Irving, NTMWD, or TWRD	38,000 [180,000]	$182,913,000 [$825,088,000 to $1,038,329,000]	$1.64 [$1.42 to $1.83]	$0.57 [$0.37 to $0.54]	High	Medium	Low	Medium low	Medium low	Medium low	Requires IBT, contract with USACE and new or amended water right permit.	Develop 203
2.6	Wright Patman Lake (System Operations)	DWU, Irving, NTMWD, TRWD, and UTRWD	38,000 [390,000]	$182,913,000 [$1,891,022,000]	$1.64 [$1.66]	$0.57 [$0.58]	High	Medium	Low	Medium	Medium	Medium low	Requires IBT, contract with USACE, contract with Texarkana, and new or amended water right permit.	Develop 2035 [Cos on 130,000 acre- year for each po participant
2.7	Lake Texoma (Blend)	DWU, TRWD, or UTRWD	25,000 [220,000; costs for 113,000]	$40,396,000 [$182,588,000]	$0.47 [$1.07]	$0.11 [$0.25]	High	Medium low	Low	Medium low	Medium low	Medium	Requires IBT, state water right, Congressional authorization, and contract with USACE	
2.7	Lake Texoma (Desalinate)	DWU or TRWD	25,000 [207,000; costs for 105,000]	$40,396,000 [$621,448,000]	$0.47 [$2.17]	$0.11 [$0.85]	High	Medium	Low	Medium	Medium low	Medium	Requires IBT, Congressional authorization, state water right, contract with USACE and brine discharge permit (or deep well injection)	Delivers treated
2.8	George Parkhouse Reservoir (North)	DWU, NTMWD, and/or UTRWD	35,000 [118,960]	$106,601,000 [$362,322,000 to $365,002,000]	$1.01 [$0.91 to $1.00]	$0.33 [$0.23 to $0.27]	High	Medium high	Medium high	Medium	Medium	Low	Requires new water rights permit and IBT.	[Costs are for NTM DWU]
2.9	George Parkhouse Reservoir (South)	NTMWD and/or UTRWD	35,000 [108,480]	$154,899,000 [$480,099,000]	$1.34 [$1.24]	$0.36 [$0.25]	High	Medium high	Medium high	Medium	Medium	Low	Requires new water rights permit and IBT.	
2.10	Additional Reuse		15,000	$1,000,000	$0.01	$0.00		Low	Low	Medium Low	Low	Medium		

TABLE 2.11.2
Projected Water Supply from Future Supply Strategies (Acre-Feet per Year) for UTRWD
Source: 2006 Region C Water Plan

Section #	Strategy	2010	2020	2030	2040	2050	2060
2.1	Indirect Reuse of Return Flows from Lake Ralph Hall		17,760	17,760	17,760	17,760	17,760
2.2	Marvin Nichols Reservoir			17,500	35,000	35,000	35,000
2.3	Additional DWU Water Supplies					2,200	6,000
2.4	Oklahoma Water						15,000
2.5	Toledo Bend Reservoir						48,000
2.6	Wright Patman Lake						38,000
2.7	Lake Texoma						25,000
2.8	George Parkhouse Reservoir (North)						35,000
2.9	George Parkhouse Reservoir (South)						35,000
2.10	Additional Reuse						15,000

3. Other Future Water Supply Strategies for North Texas

Additional water supply strategies that are discussed in the Region C Water Plan as being potentially applicable for North Texas include the following:

- Gulf of Mexico Desalination,
- Cypress Creek Basin,
- Precipitation Enhancement,
- Ground Water Imports (Robert County),
- Ground Water Imports (Brazos County),
- Lower Bois d'Arc Reservoir,
- Lake Fastrill, and
- Lake Livingston.

These strategies are listed as neither recommended nor alternative water supplies for UTRWD, but are considered potential strategies for future water supplies. They are discussed here in order to provide context relative to the recommended and alternative strategies discussed previously. The following sections provide more detailed discussions of the status of implementation for each strategy in terms of the projected available supply amounts, schedule, costs, cultural and environmental impacts, legal and permit issues, agreements, and other pertinent issues.

3.1 Gulf of Mexico

Several regions of Florida and California have been developing desalinated seawater as a water supply source as the cost of desalination decreases. Under this strategy, the Gulf of Mexico is a future source of water supply for the State of Texas, but it is not a promising source for Region C.

3.1.1 Projected Water Supply

The water supply available from seawater desalination from the Gulf of Mexico is considered to be unlimited.

3.1.2 Status of Implementation

Based on initial studies sponsored by the State of Texas, seawater desalination is considered to be a potential future water supply source for the state; however, desalination is not a favorable strategy for Region C due to the distance from the Gulf of Mexico. The Region C area is more than 200 miles from the Gulf of Mexico and 500 feet or more above sea level. The energy required for desalination and conveyance of raw water from this source would be substantial.

3.1.3 Projected Schedule of Implementation

Development of the Gulf of Mexico as a supply strategy for North Texas is not projected to occur within the Year 2060 timeframe.

3.1.4 Projected Costs

The cost for seawater desalination from the Gulf of Mexico is significantly higher than the other water management strategies for Region C. For a supply of 200,000 acre-feet per year, the 2006 Region C Water Plan estimates a capital cost of approximately $2.8 billion, with a unit cost of about $5.57 per 1,000 gallons of water, or $1,815 per acre-foot.

3.1.5 Legal and Permit Issues

Conveying water from the Gulf of Mexico may require state water rights permits and an interbasin transfer permit from the TCEQ, and a Section 404 permit from the USACE.

3.1.6 Agreements

Due to the magnitude of the capital costs and the cost of conveying this supply to the region, development of this supply would require cost-sharing agreements and cooperation among several of the major water suppliers in the region.

3.1.7 Other Issues

The technology for desalination at this scale is still developing. According to the 2006 Region C Water Plan, using the Gulf of Mexico as a water supply is assumed to have medium level reliability with low level impacts on agriculture, third parties, and key water parameters, medium low level impacts on other natural resources, and medium level impacts on the environment.

The studies listed above represent reconnaissance level surveys, not detailed field studies that are necessary to accurately quantify the environmental resources, cultural resources, or other impacts the Gulf of Mexico Project might cause. However, given the magnitude of transmission to Region C and treatment, it is reasonable to assume that desalination of water from the Gulf of Mexico will cause significantly more environmental other impacts than the Lake Ralph Hall Project.

3.2 Cypress Creek Basin

Lake O′ the Pines is an existing Corps of Engineers reservoir on Cypress Creek in the Cypress Basin (Senate Bill One Water Planning Region D, North East Texas Region). Several Metroplex water suppliers have considered purchasing excess supplies from the Cypress Basin for use in the Metroplex.

3.2.1 Projected Water Supply

According to the 2006 Region C Water Plan, up to 89,600 acre-feet per year could be available to Region C with this strategy.

3.2.2 Status of Implementation

Lake O′ the Pines is an existing reservoir with water rights held by the Northeast Texas Municipal Water District (NETMWD).

3.2.3 Projected Schedule of Implementation

Development of the Lake O' the Pines as a supply strategy for North Texas is not projected to occur within the Year 2060 timeframe.

3.2.4 Projected Costs

Based on the 120 mile distance from the Metroplex, the distance and limited supply make this strategy relatively expensive, and thus is not recommended for Region C. According to the 2006 Region C Water Plan, the total capital cost of this supply is between $257 million to $469 million with unit costs of about $1.25 to $ 1.97 per 1,000 gallons of water, or $407 to $642 per acre-foot.

3.2.5 Legal and Permit Issues

Development of this source would require contracts with NETMWD or other Cypress River Basin water rights holders with excess supplies, an interbasin transfer permit from the TCEQ, and a Section 404 permit from the USACE.

3.2.6 Agreements

Due to the magnitude of the capital costs and the cost of conveying this supply to the Metroplex area, development of this supply would require cost-sharing agreements and cooperation with one or more of the major water suppliers in the region. Lake O' the Pines is listed as an alternative strategy for DWU and NTMWD in the 2006 Region C Water Plan. It is not listed as an alternative water management strategy for UTRWD.

3.2.7 Other Issues

According to the 2006 Region C Water Plan, this supply is assumed to be highly reliable. Since it is an existing source, it is estimated to have low level impacts on the environment, agriculture, and other natural resources and medium low impacts on third parties and key water quality parameters.

3.3 Precipitation Enhancement

The strategy of obtaining supply from precipitation enhancement is summarized in the 2006 Region C Water Plan as follows:

> "Precipitation enhancement involves seeding clouds with silver iodide to promote rainfall. Such programs are generally located within areas where the rainfall is lower than in Region C. Given that Region C has adequate rainfall, and that there are no studies showing what impact precipitation enhancement would have on streamflow and reservoirs in Region C, precipitation enhancement is not recommended as a potentially feasible water management strategy for Region C. However, there may be localized areas in Region C who might benefit from such a management strategy. (Gooch et al., 2006)

3.3.1 Projected Water Supply

The amount of water supply available from this strategy is unknown. Extensive studies would need to be conducted to establish reliable estimates of the potential yield.

3.3.2 Status of Implementation

The 2006 Region C Water Plan does not recommend including precipitation enhancement as a feasible water supply strategy. The plan recommends that interested agencies pursue additional studies and localized pilot studies to better investigate the potential for generating water supply. No known studies are currently underway in North Texas.

3.3.3 Projected Schedule of Implementation

Development of precipitation enhancement as a supply strategy for North Texas is not projected to occur within the Year 2060 timeframe.

3.3.4 Projected Costs

The cost of generating additional water supply from this strategy is unknown. Extensive studies would need to be conducted to establish reliable estimates of the potential yield.

3.3.5 Legal and Permit Issues

There are no known legal or permit issues associated with the strategy of precipitation enhancement. There would be potential liabilities with respect to flood damages that could be directly linked to rainfall events where a water supply agency had utilized precipitation enhancement. It should be noted that the strategy has not been applied in the State of Texas so no precedents have been established.

3.3.6 Agreements

It is not anticipated that additional agreements would be required with other agencies in order to implement precipitation enhancement as a water supply strategy.

3.3.7 Other Issues

Additional study is needed to identify potential environmental impacts associated with precipitation enhancement.

3.4 Ground Water Imports (Roberts County)

The strategy of obtaining supply from the Ogallala aquifer is summarized in the 2006 Region C Water Plan as follows:

> "Mesa Water, Incorporated, is interested in selling groundwater from the Ogallala aquifer in Roberts County to water suppliers in Region C. (Roberts County is in Region A, the Panhandle Region.) Mesa Water controls rights to 150,000 acre-feet per year of groundwater in Roberts County with options for additional supply and has permits from the local groundwater conservation district to export groundwater." (Gooch et al., 2006)

3.4.1 Projected Water Supply

Mesa Water has indicated that they can provide a reliable supply of 200,000 acre-feet per year for Region C through 2060 and beyond.

3.4.2 Status of Implementation

The development of this supply is not a recommended strategy for Region C suppliers. The 2006 Region C Water Plan lists it as an alternative strategy for DWU and NTMWD.

3.4.3 Projected Schedule of Implementation

Use of groundwater from the Ogallala aquifer as a supply strategy for UTRWD is not projected to occur within the Year 2060 timeframe.

3.4.4 Projected Costs

Since the groundwater in Roberts County is relatively far from the Metroplex (250 miles), it would be expensive to bring this supply to Region C. Capital costs for Region C would be about $1.65 to $2 billion with unit costs of about $2.50 per 1,000 gallons of water, or $815 per acre-foot, during the term of debt service.

3.4.5 Legal and Permit Issues

No interbasin transfer permit would be required since this supply is from a groundwater source. This strategy assumes that the water would be supplied through Mesa Water which currently holds permits for the projected supply. This strategy would require a Section 404 permit from the USACE.

3.4.6 Agreements

Due to the magnitude of the capital costs and the cost of conveying this supply to the Metroplex area, development of this supply would require cost-sharing agreements and cooperation with one or more of the major water suppliers in the region. Groundwater from Roberts County is listed as an alternative strategy for DWU and NTMWD in the 2006 Region C Water Plan. It is not listed as an alternative water management strategy for UTRWD.

3.4.7 Other Issues

According to the 2006 Region C Water Plan, this supply is assumed to be highly reliable with medium level impacts on agriculture, other natural resources, and key water parameters, and medium low impacts on environment and third parties.

3.5 Ground Water Imports (Brazos County)

The Carrizo-Wilcox aquifer is summarized in the 2006 Region C Water Plan as follows:

> "The Carrizo-Wilcox aquifer covers a large area of east, central, and south Texas. Organizations and individuals have been studying the development of water supplies in Brazos County and surrounding counties for export. Metroplex water suppliers have been approached as possible customers for the water. (The supplies under discussion are located in Region G, called the Brazos G Region, and these supplies have also been studied for use by communities in that region.) Brazos County is about 150 miles from the Metroplex." (Gooch et al., 2006)

3.5.1 Projected Water Supply

The 2006 Region C Water Plan estimates that approximately 100,000 acre-feet per year could be provided to Region C with this strategy.

3.5.2 Status of Implementation

The development of the Carrizo-Wilcox aquifer as a supply source is not a recommended strategy for Region C suppliers. The 2006 Region C Water Plan lists it as an alternative strategy for NTMWD.

3.5.3 Projected Schedule of Implementation

Use of groundwater from the Carrizo-Wilcox aquifer as a supply strategy for UTRWD is not projected to occur within the Year 2060 timeframe.

3.5.4 Projected Costs

Capital costs for Region C for this supply would be about $550 million with unit costs of about $2.75 per 1,000 gallons, or $896 per acre-foot, during the term of debt service.

3.5.5 Legal and Permit Issues

No interbasin transfer permit would be required since this supply is from a groundwater source. Permits would be required from the controlling groundwater conservation district or districts for terms that equaled or exceeded the debt service requirements for this to be a viable option. This strategy would require a Section 404 permit from the USACE.

3.5.6 Agreements

Due to the magnitude of the capital costs and the cost of conveying this supply to the Metroplex area, development of this supply would require cost-sharing agreements and cooperation with one or more of the major water suppliers in the region. Groundwater from Brazos County is listed as an alternative strategy for NTMWD in the 2006 Region C Water Plan. It is not listed as an alternative water management strategy for UTRWD.

3.5.7 Other Issues

According to the 2006 Region C Water Plan, this supply is assumed to be highly reliable with low level impacts on key water quality parameters, medium level impacts on environment, agriculture, and third parties, and medium high impacts on other natural resources.

3.6 Lower Bois d'Arc Reservoir

The Lower Bois d'Arc Creek Reservoir is located in Region C on Bois d'Arc Creek in Fannin County, upstream from the Caddo National Grasslands.

3.6.1 Projected Water Supply

The 2006 Region C Water Plan estimates the yield of the reservoir at 123,000 acre-feet per year. NTMWD would hold the water rights for the entire yield of the reservoir. The more recent TWDB Report 370 estimates the yield of the reservoir to be 126,280 acre-feet per year at a conservation pool level of 534 feet.

3.6.2 Status of Implementation

Lower Bois d'Arc Creek Reservoir is a recommended water management strategy for NTMWD from the 2001 Region C Water Plan. NTMWD is currently pursuing the development of this reservoir and has filed applications for both water use, interbasin transfer, and Section 404 permits. Additional water, outside of what has been sought by NTMWD, is not available from Lower Bois d'Arc Creek Reservoir. The project has been designated as a unique reservoir site by the State Legislature.

3.6.3 Projected Schedule of Implementation

Obtaining supplies of water from the proposed Lower Bois d'Arc Creek Reservoir as a strategy for UTRWD is not projected to occur within the Year 2060 timeframe.

3.6.4 Projected Costs

The 2006 Region C Water Plan estimates the total capital cost for this project, including conveyance to NTMWD, at $399,190,000 with a unit cost of about $0.87 per 1,000 gallons, or $283 per acre-foot during the term of debt service. The cost of the reservoir itself is estimated to be $170 million. The more recent TWDB Report 370 estimates the total cost of the reservoir at $248 million (in 2005 dollars).

3.6.5 Legal and Permit Issues

Development of this supply would require a water right permit and an interbasin transfer permit from TCEQ, and a Section 404 permit from the USACE.

3.6.6 Agreements

Development of this supply would require an agreement with NTMWD.

3.6.7 Other Issues

According to the 2006 Region C Water Plan, this supply is assumed to be highly reliable with low level impacts on key water quality parameters, medium level impacts on other natural resources and third parties, medium high impacts on environment, and high level impacts on agriculture. TWDB Report 370 provides a summary of the environmental considerations:

> "Lower Bois d'Arc Creek Reservoir is located on an ecologically significant stream as identified by the Texas Parks and Wildlife Department (TPWD, 1999). The designation is based on biological function, hydrologic function, and the presence of a riparian conservation area. The Region C Water Planning Group did not identify this stream segment as ecologically unique in their 2006 Regional Water Plan. Portions of the creek that will be affected by the reservoir were altered (straightened and widened) approximately 80 years ago to reduce localized flooding. The site is located immediately upstream of the Caddo National Grasslands but will have minimal impacts to these lands. The U.S. Fish and Wildlife Service has identified Priority 4 bottomland hardwoods considered "moderate quality bottomlands with minor waterfowl benefits" (USFWS, 1985) in the vicinity of the project.
>
> Lower Bois d'Arc Creek Reservoir will inundate 16,526 acres of land at conservation storage capacity. […] Landcover is dominated by upland deciduous forest (42

> percent), with sizeable areas of grassland (28 percent) and agricultural land (17 percent). Bottomland hardwood forest constitutes only about 2.2 percent of the reservoir area. Marsh, swamp, and open water total about 3.5 percent of the reservoir area." (Kretzschmar et al., 2008)

3.7 Lake Fastrill

Lake Fastrill is a proposed reservoir site being investigated by the Upper Neches River Municipal Water Authority (UNRMWA) and DWU as a potential water supply source.

3.7.1 Projected Water Supply

The 2006 Region C Water Plan estimates the firm yield of the reservoir to be 148,780 acre-feet per year. It is assumed that 112,100 acre-feet per year could be provided to DWU, with the remaining supply being made available for the East Texas Region. The more recent TWDB Report 370 estimates a firm yield of 134,038 acre-feet per year based on a conservation pool elevation of 274 feet.

3.7.2 Status of Implementation

The development of Lake Fastrill is under investigation by DWU and UNRMWA. The project has been designated as a unique reservoir site by the State Legislature.

3.7.3 Projected Schedule of Implementation

Obtaining supplies of water from the proposed Lake Fastrill as a strategy for UTRWD is not projected to occur within the Year 2060 timeframe.

3.7.4 Projected Costs

The 2006 Region C Water Plan estimates the total capital costs for this supply, including conveyance to DWU, at $569,170,000 with a unit cost of about $1.40 per 1,000 gallons, or $456 per acre-foot during the term of debt service. The cost of the reservoir itself is estimated to be $266 million. TWDB Report 370 estimates the cost of the reservoir project at $293 million (in 2005 dollars).

3.7.5 Legal and Permit Issues

Development of this supply will require a new water right permit and an interbasin transfer permit from the TCEQ and a Section 404 permit from the USACE.

3.7.6 Agreements

Development of this supply would require agreements between DWU and/or UNRMWA.

3.7.7 Other Issues

According to the 2006 Region C Water Plan, This supply is assumed to be highly reliable with low level impacts on key water quality parameters, medium level impacts on agriculture and third parties, medium high impacts on other natural resources, and high level impacts on environment. TWDB Report 370 provides a summary of the environmental considerations:

> “Fastrill Reservoir will inundate a portion of Texas Commission on Environmental Quality classified stream segment 0604. The Texas Parks and Wildlife Department listed the entire length of the Neches River below Lake Palestine as ecologically significant (TPWD, 1999). Inundation by or operations of Fastrill Reservoir could have effects relevant to three Texas Parks and Wildlife Department criteria, as follows:
>
> - Biological function—Texas Natural Rivers System nominee for outstandingly remarkable fish and wildlife values; priority bottomland hardwood habitat displays significant overall habitat value
> - High water quality/Exceptional aquatic life/High aesthetic value—National Forest Service wilderness-type area, exceptional aesthetic value
> - Threatened or endangered species/ Unique communities—unique, exemplary, and unusually extensive natural community; paddlefish; creek chubsucker; blue sucker; Neches River rose-mallow
>
> Fastrill Reservoir will inundate 24,948 acres of land at conservation storage capacity. […] Landcover is dominated by bottomland hardwood forest (32 percent), with sizeable areas of evergreen forest (21.5 percent) and upland deciduous forest (18 percent). Marsh, swamp, and open water total about 12 percent of the reservoir area.
>
> The U.S. Fish and Wildlife Service has designated the Neches River National Wildlife Refuge for the purposes of protecting the habitat for migratory birds, bottomland hardwood forests, and wetlands and providing for compatible wildlife-dependent recreation opportunities (USFWS, 2005). The Neches River National Wildlife Refuge includes a segment of the Neches River and its floodplain as well as surrounding upland areas that coincide with the proposed location of Fastrill Reservoir. This refuge site was one among 14 Priority 1 sites identified by the U.S. Fish and Wildlife Service (USFWS, 1985). Priority 1 areas are considered to be excellent quality bottomlands and high value to key waterfowl species including mallards and wood ducks. The Fastrill Reservoir site is also located immediately upstream of a Priority 1 bottomland preservation site identified as Middle Neches River (N-4).” (Kretzschmar et al., 2008)

3.8 Lake Livingston

Lake Livingston is an existing reservoir on the Trinity River (Region H) located about 180 miles downstream from the Metroplex.

3.8.1 Projected Water Supply

The Trinity River Authority (TRA) holds water rights in the reservoir, and has indicated that as much as 200,000 acre-feet per year of water could be supplied to Region C from Lake Livingston.

3.8.2 Status of Implementation

Lake Livingston is an existing reservoir with water rights currently held by the Trinity River Authority (TRA) and the City of Houston. The lake is not a recommended strategy for any

Region C supplier, but it is an alternative strategy for DWU, NTMWD, and TRWD. It is not listed as an alternative water management strategy for UTRWD.

3.8.3 Projected Schedule of Implementation

Obtaining supplies of water from the Lake Livingston as a strategy for UTRWD is not projected to occur within the Year 2060 timeframe.

3.8.4 Projected Costs

According to the 2006 Region C Water Plan, this supply has a capital cost for Region C of approximately $1.2 billion with a unit cost of about $2.20 per 1000 gallons, or $717 per acre – foot, during the term of debt service on the initial construction. As such, the lake is a relatively expensive strategy for Region C suppliers.

3.8.5 Legal and Permit Issues

This supply requires a contract with TRA. No interbasin transfer permit is required since the lake is within the Trinity River Basin. A Section 404 Permit would likely be required for the transmission facilities necessary to transport the water to the Metroplex.

3.8.6 Agreements

Development of this supply may require agreement between the interested parties and Region H, which may be considering other uses for the lake.

3.8.7 Other Issues

According to the 2006 Region C Water Plan, this supply is assumed to be highly reliable. Since it is an existing source, it is estimated to have low level impacts on environment, agriculture, other natural resources, and key water parameters and medium low impacts on third parties.

3.9 Summary of Other Future Water Supply Strategies for North Texas

The additional future water supply strategies that are discussed in the Region C Water Plan as being potentially applicable for North Texas include the following:

- Gulf of Mexico Desalination,
- Cypress Creek Basin,
- Precipitation Enhancement,
- Ground Water Imports (Robert County),
- Ground Water Imports (Brazos County),
- Lower Bois d'Arc Reservoir,
- Lake Fastrill, and
- Lake Livingston.

None of these strategies are considered alternative water management strategy for UTRWD and none are projected for implementation within the Year 2060 timeframe. The strategies are typically more costly than the recommended and alternate future water supply strategies for UTRWD. Most of the projects are a considerable distance from the Metroplex and would require cost-sharing partners to spread the large initial capital investments that would be needed to develop and connect the supplies. The schedules of implementation for the proposed future reservoir sites are out of UTRWD's control. Large-scale desalination and precipitation enhancement would require additional studies and technology development.

Considerations relative to the development of each of these water supply strategies are summarized in Table 3.9.1.

TABLE 3.9.1
Summary of Other Future Water Supply Strategies for North Texas
Source: 2006 Region C Water Plan

Section #	Strategy	Potential Partners	Potential Total Region C Supply (Acre-Feet per Year)	Total Capital Cost	Unit Cost ($/kgal)		Reliability	Environmental Factors	Agricultural/ Rural Impacts	Other Natural Resources	3rd Party Impacts	Key Water Quality Parameters	Implementation Issues	Comments
					Pre-Amort.	Post-Amort.								
3.1	Gulf of Mexico	DWU, NTMWD, or TRWD	Unlimited; costs reflect assumed supply of 200,000 ac-ft./yr.	$2,836,207,000	$5.57	$2.41	Medium	Medium	Low	Medium low	Low	Low	Technology still developing for this application at this scale. May require state water right permit	Costed to central location; capital cost based on one supplier; supply is treated water
3.2	Cyprus Creek Basin	DWU, NTMWD, or TRWD	89,600	$257,192,000 to $469,493,000	$1.25 to $1.97	$0.60 to $0.78	High	Low	Low	Low	Medium low	Low to Medium low	Requires IBT, renegotiating existing contracts, and contract with NETMWD.	
3.3	Precipitation Enhancement	--	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown		
3.4	Ground Water Imports (Roberts County)	DWU, NTMWD, or TRWD	200,000	$1,650,619,000 to $1,994,699,000	$2.40 to $2.83	$0.55 to $0.61	High	Medium low	Medium	Medium	Medium low	Medium	Requires additional water rights	Assumes 400,000 acres of water rights; Currently permitted or contracted for 150,000 acres.
3.5	Ground Water Import (Brazos County)	DWU or NTMWD	100,000	$506,662,000 to $577,413,000	$2.65 to $2.89	$1.24 to $1.28	High	Medium	Medium	Medium high	Medium	Low	Requires coordination with local groundwater districts. Competing uses for water.	
3.6	Lower Bois d'Arc Reservoir	NTMWD	123,000	$399,190,000	$0.87	$0.14	High	Medium high	High	Medium	Medium	Low	Requires new water rights permit and IBT.	
3.7	Lake Fastrill	DWU	112,100	$569,170,000	$1.40	$0.27	High	High	Medium	Medium High	Medium	Low	Requires new water right permit and IBT.	
3.8	Lake Livingston	DWU, NTMWD, or TRWD	200,000	$1,142,917,000 to $1,299,183,000	$1.99 to $2.25	$0.72 to $0.83	High	Low	Low	Low	Medium Low	Low	Requires contract with TRA.	May be competing interest in supply in other region

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Upper Trinity Regional Water District. "Water Conservation Plan." May 2009.

Attachments

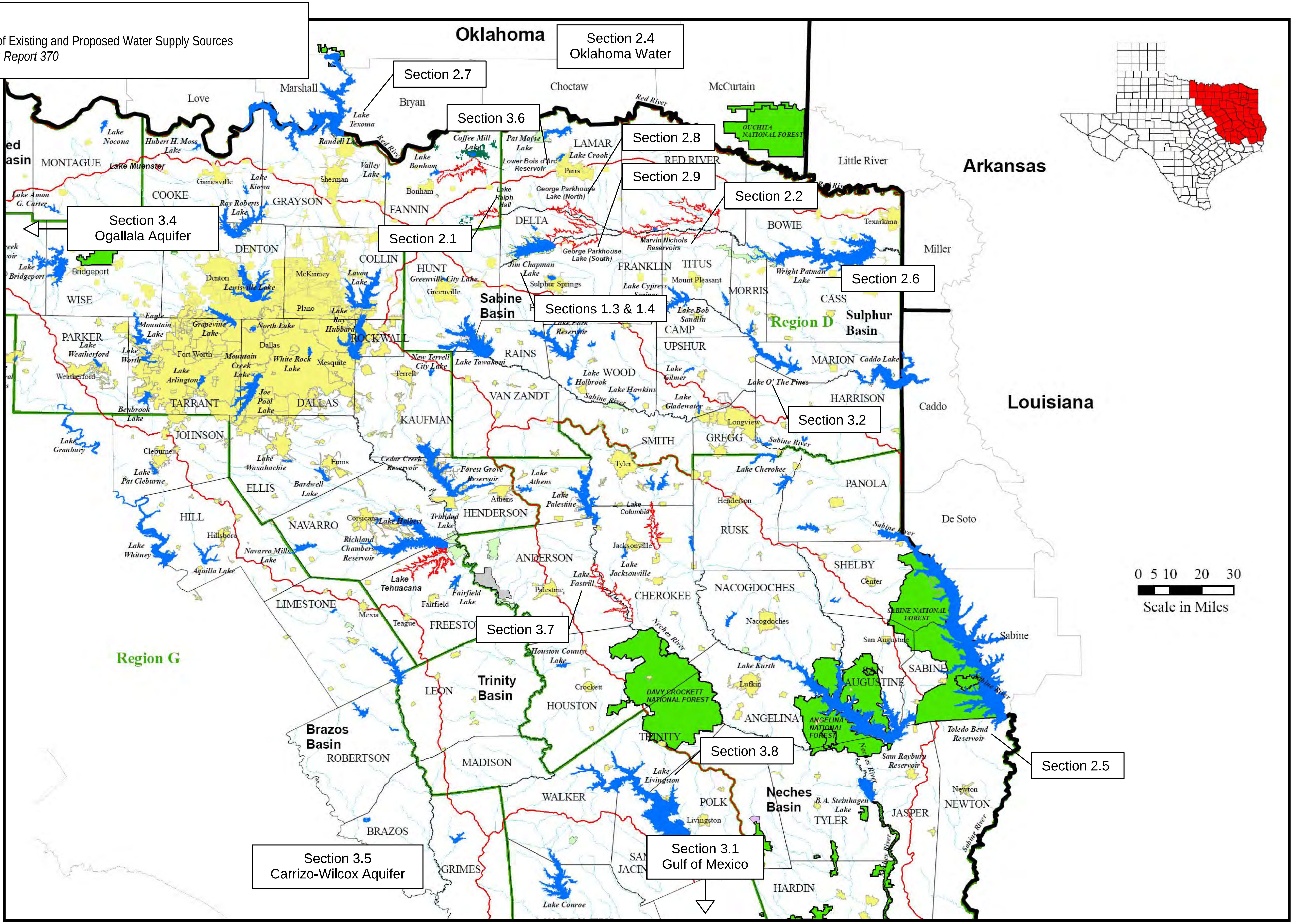
Exhibit 1.

Region C Map (Kretzschmar et al., 2008).

Exhibit 2.

Upper Trinity Regional Water District 2009 Water Conservation Plan.

EXHIBIT 1
Location Map of Existing and Proposed Water Supply Sources
Source: TWDB Report 370



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A-2: Summary of Alternative Dam Site Analysis for Lake Ralph Hall

Summary of Alternative Dam Site Analysis for Lake Ralph Hall

Prepared for

Upper Trinity Regional Water District

Prepared by

CH2MHILL

September, 2009

Summary of Alternative Dam Site Analysis for Lake Ralph Hall

Submitted to

Upper Trinity Regional
Water District

This Document Was Completed
Under The Supervision of

Edward M. Motley, P.E. TX. No. 48243
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Contents

1. Introduction

The Upper Trinity Regional Water District (UTRWD) filed an application with the Texas Commission on Environmental Quality (TCEQ) to appropriate state water from a proposed water reservoir, Lake Ralph Hall, on the North Sulphur River in Fannin, County, Texas, in September 2003. The TCEQ declared the application administratively complete in August of 2004 and conducted public hearings in March of 2006. The TCEQ is currently conducting further technical review of the UTRWD's application.

The UTRWD filed an application with the Fort Worth District, U.S. Army Corps of Engineers (USACE) for a Section 404 Permit for the proposed Lake Ralph Hall in October of 2006. The USACE issued public notice in March of 2008 and conducted a Public Scoping Meeting in April of 2008. In August of 2008, the USACE mandated an Environmental Impact Study (EIS) be performed.

The purpose of this report is to present an evaluation of alternative dam sites for the proposed Lake Ralph Hall. Several dam configurations have been considered for the proposed Lake Ralph Hall. Analysis was performed on each of the dam site alternatives based on size, operation, and impacts on environmental and other resources.

2. Objectives

UTRWD serves one of the fastest growing regions of North Texas. This area whose population is expected to increase to more than 800,000 people -- a four-fold increase within 50 years – will require an anticipated 150 million gallons of water per day.

Presently, UTRWD secures its water from (1) the City of Dallas (Lewisville and Ray Roberts Lakes in Denton County), and (2) Chapman (Cooper) Lake in northeast Texas. These water supply sources appear to be adequate until about the mid 2020's, after which time an estimated 30,000 acre-feet/year of additional supply will be needed.

More conservation and reuse of existing supplies are part of the answer. However, additional water sources are absolutely critical, making proposed Lake Ralph Hall an important strategy to assure future water supplies.

In order to determine the proposed dam site location for Lake Ralph Hall several factors were evaluated in an attempt to minimize the project's impact upon:

- Environmental and cultural resources
- Residents requiring relocation
- Known cemeteries
- Roadway relocations

3. Alternatives Overview

Four possible dam sites have been considered for Lake Ralph Hall (listed from West to East): Dam Site A (west of SH 34), Dam Site B (upstream of Merrill Creek), Dam Site C (downstream of Merrill Creek), and Dam Site D (downstream of Baker Creek).

3.1. Dam Site A (West of SH 34)

Dam Site A is the western most location of the alternatives located about 1,000 feet upstream of SH 34. The proposed location for Dam Site A is shown in Figure 1 of Appendix A.

3.2. Dam Site B (Upstream of Merrill Creek)

Dam Site B is located about 7,500 feet east of Dam Site A or about 6,500 feet east of SH 34. Compared to Dam Site A, Dam Site B offers the advantage of additional storage and yield, but the disadvantage of impacting SH 34. The proposed location for Dam Site B is shown in Figure 2 of Appendix A.

3.3. Dam Site C (Downstream of Merrill Creek)

Dam Site C is located about 6,100 feet east of Dam Site B or about 12,600 feet east of SH 34 and 7,500 feet west of FM 904. Compared to Dam Sites A and B, Dam Site C offers the advantage of additional storage and capturing inflows from Merrill Creek, resulting in more yield. However, it also has the disadvantage of impacting more roadways. The proposed location for Dam Site C is shown in Figure 3 of Appendix A.

3.4. Dam Site D (Downstream of Baker Creek)

Dam Site D is the eastern most location of the alternatives located about 10,800 feet east of Dam Site C or about 2,500 feet east of FM 904. Compared to the other sites, Dam Site D offers the advantage of capturing inflows from Baker Creek, but the disadvantage of impacting FM 904 as well as SH 34. In addition, Dam Site D has additional storage, thus a greater yield, than the other alternatives. The proposed location for Dam Site D is shown in Figure 4 of Appendix A.

4. Alternatives Comparisons

4.1. Dam Site A (West of SH 34)

4.1.1. Description

Dam Site A is 10,650 feet long with an elevation of 570 feet (MSL). The construction of Dam Site A would create a conservation pool with an elevation of 551 feet (MSL) and the smallest storage volume out of the four alternatives at 58,053 acre-feet. The conservation pool has a maximum depth of 61 feet, a surface area of 3,818 acres, and an average depth of 15.2 feet. The 100 year flood pool elevation for Dam Site A is 560 feet (MSL).

4.1.2. Operation Overview

The implementation of Dam Site A would result in an estimated yield of 21,860 acre-ft/year and a unit area firm annual yield of 5.72 acre-ft/year/sq. mile. Dam Site A does not provide the minimum quantity of water required by UTRWD.

4.1.3. Impacts

4.1.3.1. Environmental

Table 1 shows the environmental impacts of Dam Site A. As shown, the footprint of the conservation pool of Dam Site A would inundate about 3,664 acres of land, and the footprint of the project area of Dam A would inundate about 5,418 acres of land.

TABLE 1
Environmental Impacts of Dam Site A

	Dam Site A	
	Conservation Pool	Project Area
Roads/Houses	28	41
Stream Channels	193	226
Cropland	1,177	1,709
Forest	636	823
Grasses	210	272
Parks (Emerging Forests)	338	500
Pasture	436	866
Young Forest	646	981
Total Acres	**3,664**	**5,418**

4.1.3.2. Cultural

The construction of Dam Site A would impact 1 known cemetery (Merrill Cemetery) and 3 other cultural resources including two abandoned farm houses.

4.1.3.3. Roadway

The implementation of Dam Site A would impact 3.35 miles of roadway: 3.32 miles of FM 2990 to be abandoned and 0.03 miles of FM 68.

4.1.3.4. Structures

Dam Site A would impact 296 parcels and 5,418 acres of land. Based on aerial photography, this area includes 11 structures without confirmation of residency.

4.1.3.5. Pipeline Impacts

The raw water pipeline from Dam Site A would be 164,120 linear feet and would require crossing 26 county roads, 11 state highways, and 1 US highway.

4.2. Dam Site B (Upstream of Merrill Creek)

4.2.1. Description

Dam B Site is 12,790 feet long with an elevation of 570 feet (MSL). The construction of Dam Site B would create a conservation pool with the same elevation as Dam Site A of 551 feet (MSL), but a storage volume of 95,903 acre-feet. The conservation pool has a maximum depth of 81 feet, a surface area of 5,309 acres, and an average depth of 18 feet. The 100 year flood pool elevation for Dam Site B is 560 feet (MSL).

4.2.2. Operation Overview

The implementation of Dam Site B would result in an estimated yield of 27,460 acre-ft/year and a unit area firm annual yield of 5.17 acre-ft/year/sq. mile. Dam B does not provide the minimum quantity of water required by UTRWD.

4.2.3. Impacts

4.2.3.1. Environmental

Table 2 shows the environmental impacts of Dam Site B. The footprint of the conservation pool of Dam Site B would inundate about 5,123 acres of land, and the footprint of the project area of Dam Site B would inundate about 7,198 acres of land.

TABLE 2
Environmental Impacts of Dam Site B

	Dam Site B	
	Conservation Pool	Project Area
Roads/Houses	49	68
Stream Channels	220	253
Cropland	1,487	2,041
Forest	811	1,039
Grasses	344	437
Parks (Emerging Forests)	397	607
Pasture	965	1,538
Young Forest	850	1,215
Total Acres	**5,123**	**7,198**

4.2.3.2. Cultural

The construction of Dam Site B would impact no known cemeteries; however, five other cultural resources including two abandoned farm houses would be impacted.

4.2.3.3. Roadway

The implementation of Dam Site B would impact 5.18 miles of roadway: 3.32 miles of FM 2990 to be abandoned, 1.83 miles of SH 34 to be adjusted vertically, and 0.03 miles of FM 68.

4.2.3.4. Structures

Dam Site B would impact 362 parcels and 7,198 acres of land. Based on aerial photography, this area includes 13 structures without confirmation of residency.

4.2.3.5. Pipeline Impacts

The raw water pipeline from Dam Site B would be 163,620 linear feet and would require the same number of crossings as Dam Site C and Dam Site D: 28 county roads, 10 state highways, and 1 US highway.

4.3. Dam Site C (Downstream of Merrill Creek)

4.3.1. Description

Dam Site C is 12,900 feet long with an elevation of 565 feet (MSL). The construction of Dam Site C creates a conservation pool with the same elevation as Dam Sites A and B of 551 feet (MSL), but a storage volume of 160,235 acre-feet. The conservation pool has a maximum depth of 91 feet, a surface area of 7,602 acres, and an average depth of 21.1 feet. The 100 year flood pool elevation for Dam Site C is 560 feet (MSL).

4.3.2. Operation Overview

The implementation of Dam Site C would result in an estimated yield of 34,050 acre-ft/year and a unit area firm annual yield of 4.48 acre-ft/year/sq. mile.

4.3.3. Impacts

4.3.3.1. Environmental

Table 3 shows the environmental impacts of Dam Site C. The footprint of the conservation pool of Dam Site C would inundate about 7,242 acres of land, and the footprint of the project area of Dam Site C would inundate about 9,963 acres of land.

TABLE 3
Environmental Impacts of Dam Site C

	Dam Site C	
	Conservation Pool	Project Area
Roads/Houses	64	91
Stream Channels	294	331
Cropland	1,934	2,589
Forest	1,080	1,374
Grasses	578	748
Parks (Emerging Forests)	550	838
Pasture	1,677	2,491
Young Forest	1,065	1,501
Total Acres	**7,242**	**9,963**

4.3.3.2. Cultural

The construction of Dam Site C would impact no known cemeteries; however, fifteen other cultural resources including two abandoned farm houses would be impacted.

4.3.3.3. Roadway

The implementation of Dam Site C would impact 7.24 miles of roadway: 3.32 miles of FM 2990 to be abandoned, 2.35 miles of SH 34 to be adjusted vertically, 1.54 miles of FM 1550 to be rerouted, and 0.03 miles of FM 68.

4.3.3.4. Structures

Dam Site C would impact 456 parcels and 9,963 acres of land. Based on aerial photography, this area includes 22 structures without confirmation of residency.

4.3.3.5. Pipeline Impacts

The raw water pipeline for Dam Site C would be 161,230 linear feet and would require the same number of crossings as Dam Site B and Dam Site D: 28 county roads, 10 state highways, and 1 US highway.

4.4. Dam Site D (Downstream of Baker Creek)

4.4.1. Description

Dam Site D is 11,780 feet long with an elevation of 565 feet (MSL). The construction of Dam Site D creates a conservation pool with the same elevation as Dam Sites A, B, and C of 551 feet (MSL) and the largest storage volume of 297,596 acre-feet. The conservation pool has a maximum depth of 92 feet, a surface area of 12,245 acres, and an average depth of 24.3 feet. The 100 year flood pool elevation for Dam Site D is 560 feet (MSL).

4.4.2. Operation Overview

The implementation of Dam Site D would result in an estimated yield of 47,370 acre-ft/year and a unit area firm annual yield of 3.87 acre-ft/year/sq. mile.

4.4.3. Impacts

4.4.3.1. Environmental

Table 4 shows the environmental impacts of Dam Site D. The footprint of the conservation pool of Dam Site D would inundate about 11,860 acres of land, and the footprint of the project area of Dam Site D would inundate about 15,636 acres of land.

TABLE 4
Environmental Impacts of Dam Site D

	Dam Site D	
	Conservation Pool	Project Area
Roads/Houses	111	154
Stream Channels	429	476
Cropland	3,360	4,443
Forest	1,746	2,119
Grasses	793	1,030
Parks (Emerging Forests)	764	1,081
Pasture	3,065	4,226
Young Forest	1,592	2,107
Total Acres	**11,860**	**15,636**

4.4.3.2. Cultural

The construction of Dam Site D would impact 1 known cemetery (Lyday Cemetery) and 16 other cultural resources including two abandoned farm houses. In addition, there are 2 cemeteries (Bledsoe Cemetery) and (Bourland Cemetery) that are near the South Abutment of the dam site and could be impacted by the dam construction.

4.4.3.3. Roadway

The implementation of Dam Site D would impact 10.26 miles of roadway: 3.32 miles of FM 2990 to be abandoned, 2.35 miles of SH 34 to be adjusted vertically, 1.54 miles of FM 1550 to be relocated, 3.02 miles of FM 904 to be adjusted vertically, and 0.03 miles of FM 68.

4.4.3.4. Structures

Dam Site D would impact 629 parcels and 15,636 acres of land. Based on aerial photography, this area includes 42 structures without confirmation of residency.

4.4.3.5. Pipeline Impacts

The raw water pipeline from Dam Site D would require the same number of crossings as Dam Sites B and C: 28 county roads, 10 state highways, and 1 US highway.

5. Water Availability Model Results

Figures 5 and 6 provide a summary and comparison of the water availability results for the Lake Ralph Hall dam site alternatives based on simulations with the TCEQ Water Availability Model for the Sulphur River Basin.

Based on the frequency of lake levels in Figure 5, Dam Sites A, B, and C behave similarly in terms of lake level exceedance. Dam Site D does not behave as favorably as the other configurations in terms of lake levels.

Similar behaviors are seen in Figure 6 with monthly lake level variations. Dam Sites A, B, and C behave much more similarly with Dam Site D slightly below the Dam Sites A, B, and C levels.

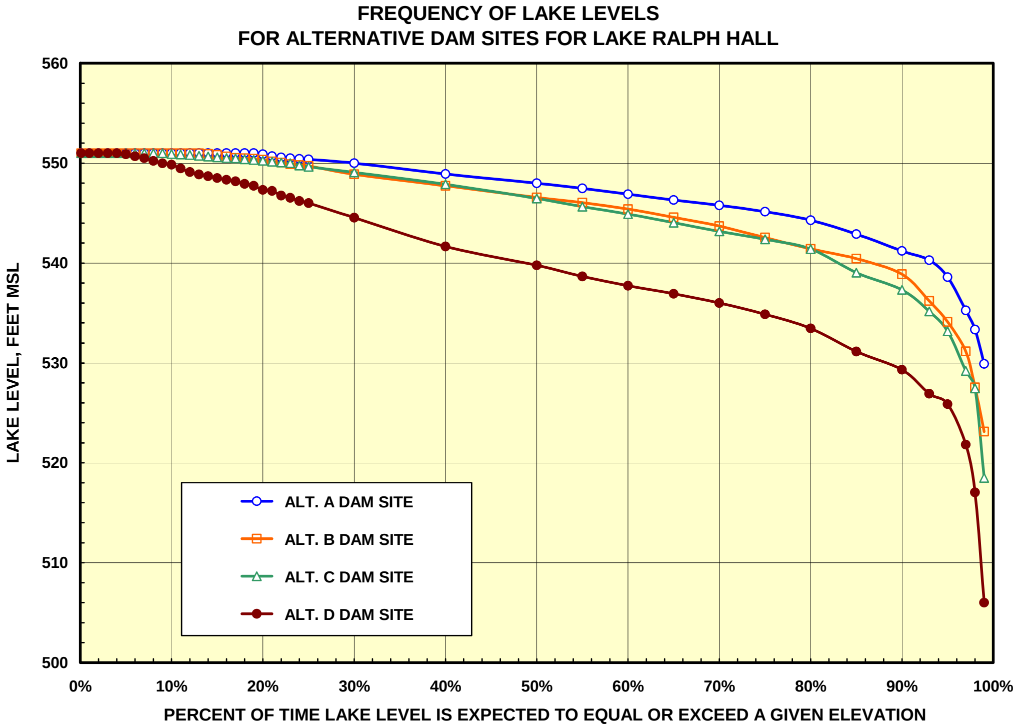

Figure 5. Frequency of Lake Levels for Alternative Dam Sites for Lake Ralph Hall (Brandes, 2009)

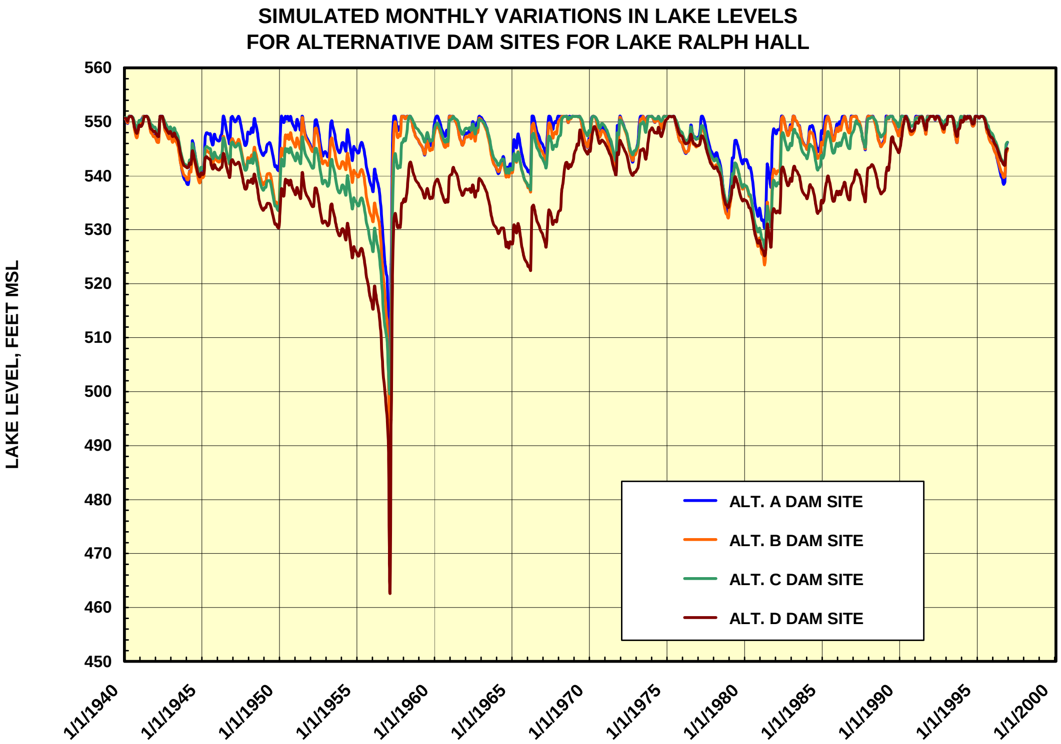

Figure 6. Simulated Monthly Variations in Lake Levels for Alternative Dam Sites for Lake Ralph Hall (Brandes, 2009)

6. Summary of Alternatives

6.1.1. Description

As shown in Table 6, Dam Site A is the shortest lengthwise and results in the smallest conservation pool storage volume, surface area, and maximum depth. Dam Site C has the longest dam and the second largest storage volume. Dam Site D has the largest storage volume, surface area, and maximum depth.

TABLE 6
Site Data for Lake Ralph Hall Alternatives

	Dam Site A	**Dam Site B**	**Dam Site C**	**Dam Site D**
Dam length (ft)	10,650	12,790	12,900	11,780
Dam elevation (ft. msl)	570	570	565	565
Storage volume at conservation pool (acre/feet)	58,053	95,903	160,235	297,596
Conservation pool elev. (ft. msl)	551	551	551	551
Surface area at conservation pool (acre)	3,818	5,309	7,602	12,245
Average Depth (feet)	15.2	18.1	21.1	24.3
Maximum depth at conservation pool (ft)	61	81	91	92

6.1.2. Operation Overview

As shown in Table 7, neither Dam Site A nor Dam Site B provide sufficient yield to meet UTRWD's minimum requirement of 30,000 acre-feet/year. Dam Sites C and D can both provide a yield in excess of UTRWD's minimum requirement.

TABLE 7
Operating Data for Lake Ralph Hall Alternatives

	Dam Site A	**Dam Site B**	**Dam Site C**	**Dam Site D**
Estimated yield (acre-ft/year)	21,860	27,460	34,050	47,370
100 year flood pool elevation (ft. msl)	560	560	560	560

6.1.3. Impacts

In terms of environmental impacts (as shown in Table 8), Dam Site A has the smallest impact overall on each of the land use types, followed by Dam Sites B and C. However, since Dam Sites A and B do not provide sufficient yield to meet UTRWD's minimum requirement of 30,000 acre-feet/year, they are not considered to be favorable alternatives for Lake Ralph Hall. Between Dam Sites C and D, Dam Site D provides only 31% more annual yield with 63% more acres of environmental impact than Dam Site C, making Dam Site D a poor alternative for Lake Ralph Hall.

TABLE 8
Environmental/Land Use Impacts for Lake Ralph Hall Alternatives

	Dam Site A		**Dam Site B**		**Dam Site C**		**Dam Site D**	
	C. Pool*	Project Area	C. Pool*	Project Area	C. Pool*	Project Area	C. Pool*	Project Area
Roads/ Houses	28	41	49	68	64	91	111	154
Stream Channels	193	226	220	253	294	331	429	476
Cropland	1,177	1,709	1,487	2,041	1,934	2,589	3,360	4,443
Forest	636	823	811	1,039	1,080	1,374	1,746	2,119
Grasses	210	272	344	437	578	748	793	1,030
Parks (Emerging Forests)	338	500	397	607	550	838	764	1,081
Pasture	436	866	965	1,538	1,677	2,491	3,065	4,226
Young Forest	646	981	850	1,215	1,065	1,501	1,592	2,107
Total Acres	**3,664**	**5,418**	**5,123**	**7,198**	**7,242**	**9,963**	**11,860**	**15,636**

*C. Pool = Conservation Pool

Table 9 shows other possible impacts the dam sites may have on the area such as on cultural resources, roadways, structures, and pipeline/roadway crossings. Again, since Dam Sites A and B do not provide sufficient yield to meet UTRWD’s minimum requirement of 30,000 acre-feet/year, they are not considered to be favorable alternatives for Lake Ralph Hall despite their lesser impacts. Between Dam Sites C and D, Dam Site D provides only a 31% more annual yield with 1 more cemetery, 1 more other cultural resource, 41% more roadway, 91% more residences, and 38% more land parcels impacted than Dam Site C, making Dam Site D a poor alternative for Lake Ralph Hall.

TABLE 9
Impacts Comparison of Lake Ralph Hall Alternatives

	Dam Site A	**Dam Site B**	**Dam Site C**	**Dam Site D**
Cultural resources				
Cemeteries impacted	1	0	0	1
Other Cultural Resources	3	5	15	16
Roadway				
FM 2990 (miles)	3.32	3.32	3.32	3.32
SH 34	0.00	1.83	2.35	2.35
FM 1550	0.00	0.00	1.54	1.54
FM 904	0.00	0.00	0.00	3.02
FM 68	0.03	0.03	0.03	0.03
Structures				
Apparent residences	11	13	22	42
Number of parcels	296	362	456	629
Acres	5,189	6,925	9,649	15,345
Raw Pipeline/Roadway Crossings				
Pipe Length (linear feet)	164,120	163,620	161,230	171,240
Number of County Roads	26	28	28	28
Number of State Highways	11	10	10	10
Number of US Highways	1	1	1	1

7. Conclusions

Based on the analysis of the alternatives for Lake Ralph Hall, several options seem to have certain deficiencies. Dam Site A and Dam Site B do not provide sufficient yield to meet UTRWD'S minimum requirement of 30,000 acre-feet/year. Although Dam Site D provides more water than the other configurations, its increase in impacts on the environment and other resources is not proportional to the smaller increase in yield, making it an unfavorable alternative for Lake Ralph Hall. In addition, Dam Site D does not demonstrate favorable lake level behavior as the other dam configurations. Based on these findings and analysis, Dam Site C is the most practical alternative in terms of yield, size, and area impacts.

8. References

Brandes, Robert. 2009. Water Availability Model for Sulphur River Basin.

A-3: Lake Ralph Hall Raw Water Pipeline Alignment Study

DRAFT

Lake Ralph Hall Raw Water Pipeline Alignment Study

March 2010

PRELIMINARY PRE-DECISION
NOT SUBJECT TO FREEDOM OF INFORMATION ACT

THIS DOCUMENT IS RELEASED
FOR THE PURPOSE OF INTERIM
REVIEW UNDER THE AUTHORIY OF
JERRY W. SNEAD, P.E., PE NO. 90305
AND
JOHN E. LEVITT, P.E., PE NO. 47714
ON MARCH 2, 2010.
IT IS NOT TO BE USED FOR BIDDING,
PERMITTING OR CONSTRUCTION.

Prepared for:

UPPER TRINITY
REGIONAL WATER DISTRICT

Prepared by:

CP&Y

Firm Registration Number: 1741

and

CH2MHILL

Firm Registration Number: 2297

Contents

I. Introduction

Proposed Lake Ralph Hall

The proposed Lake Ralph Hall is located on the North Sulphur River in Southeastern Fannin County, Texas. The dam and spillway will be constructed west of Farm-to-Market Road (FM) 904 and approximately 3.5 miles northeast of Ladonia. The proposed 7,605-acre reservoir will have a conservation pool elevation of 551.00 feet (mean sea level, msl).

The raw water intake structure and pump station will be constructed within the reservoir footprint. As part of this evaluation, it was assumed that the intake and pump station will be located on the east end of the reservoir near the dam structure, approximately 3.5 miles northeast of Ladonia. The raw water transmission pipeline will convey raw water from the intake/pump station to the Tom Harpool Water Treatment Plant, located in northwest Denton County.

Purpose and Need

Based on current growth rates within the Upper Trinity Regional Water District's (District) service area, the District will need additional water supplies by the year 2020. The proposed Lake Ralph Hall will add approximately 34,000 acre-feet per year to the District's available water supply, helping to ensure a reliable water supply for the District's customers. Water from Lake Ralph Hall will be used by the District to help meet municipal, industrial and agricultural water demand within the District's service area.

Project and Report Description

The District authorized CP&Y, Inc. (CP&Y) on March 1, 2007 to conduct a Raw Water Pipeline Alignment Study to convey raw water from the proposed Lake Ralph Hall, a planned future water supply reservoir on the North Sulphur River in Southeast Fannin County, for the District's use. The work is part of Task Order 6 in which CP&Y and CH2M HILL are to provide professional engineering services to support the Districts efforts to prepare a Draft Environmental Impact Statement (DEIS), secure a Section 404 Permit for the proposed Lake Ralph Hall, and prepare for future property acquisitions and other efforts to develop the proposed lake.

This study focused on a 300-foot wide potential alignment corridor from which a 100-foot wide right-of-way will be selected. The primary objective of this study is to develop and evaluate potential pipeline routes for a raw water transmission pipeline from the proposed Lake Ralph Hall to the city of Irving's existing Chapman Lake Raw Water Pipeline System in Collin County. The evaluations for this primary objective were performed by CP&Y in conjunction with CH2M HILL, Alan Plummer Associates, Inc. (APAI) and AR Consultants, Inc. (ARC) and are included in Section II of this report.

The primary alignment requires an amendment to the District's Raw Water Conveyance Agreement with the City of Irving. The parties have not reached a final agreement on such an amendment; therefore, a secondary set of alignments were also evaluated in the event that the District and the City of Irving fail to reach an agreement on raw water conveyance. Potential secondary alignments from the proposed Lake Ralph Hall to the existing Tom Harpool Water Treatment Plant were evaluated by CH2M HILL in conjunction with APAI and ARC and are included in Section III of this report.

Section IV contains two exhibits. Exhibit 1 shows an aerial view of the primary and secondary alignments that were evaluated. Exhibit 2 shows an aerial view of a single primary and secondary alignment that should be considered for further evaluation.

Section V contains the results of desktop evaluations of cultural resources near the primary and secondary alignments.

Section VI contains the results of desktop evaluations of environmentally sensitive areas near the primary and secondary alignments.

II. Proposed Lake Ralph Hall to Chapman Lake Raw Water Pipeline System

This technical memorandum presents the development of four alternative primary pipeline alignments, the method of evaluation, and the results of the evaluations for each alternative. The study area for the alternative pipeline alignments begins at the proposed Lake Ralph Hall intake/pump station, generally extends between the cities of Ladonia and Merit, and ends at the proposed connection point with Irving's existing Chapman Lake Raw Water Pipeline System. The recommended pipeline alignment, referred to as the "Environmental" alignment, offers several advantages and reasonable compromises of evaluation criteria.

Objectives

The objectives of this alignment study were to:

- Investigate possible pipeline routes to convey raw water from the proposed Lake Ralph Hall near Ladonia, Texas to the Tom Harpool Water Treatment Plant (Harpool WTP) in Denton County, Texas, via Irving's existing Chapman Lake Raw Water Pipeline System,
- Minimize the cost of the proposed pipeline,
- Minimize the environmental impact of the proposed pipeline, and
- Minimize the social impacts of the proposed pipeline. Social impacts include disruption of businesses, displacement of residents, traffic impact, and cultural resources.

Development of Alignments and Evaluation Criteria

Four alignments were evaluated based on the following criteria:

- pipeline length,
- environmental impacts,
- archaeological and cultural resource impacts,
- right-of-way needs,
- community impacts, and
- construction constraints.

The ideal alignment would minimize pipeline length; have minimal impacts to the environment and public community; and preserve any archaeological and cultural resources. However, seldom does one alternative fit the ideal definition, thus it is often necessary to select an alternative that best compromises the evaluation criteria.

Resources that were utilized during preparation of this report include: aerial photography; aerial helicopter video of the "Railroad" alignment, conducted in September 2006; USGS topographic maps; various county appraisal District maps; a preliminary infrastructure study for the lake and raw water pipeline prepared by CP&Y dated February 6, 2004, "Raw Water Infrastructure"; a report prepared by ARC, titled "Archaeological Potential of the Lake Ralph Hall Pipeline Routes, Collin, Hunt, and Fannin Counties, Texas"; and multiple site visits.

Archaeological and Cultural Resources

To assess the impacts to archaeological and cultural resources, CP&Y subcontracted ARC to conduct a desktop survey of the alternative pipeline alignments. The desktop surveys consisted of a literature review and records search to identify sites in the study area. In addition to the desktop surveys, ARC conducted a field reconnaissance (window survey) along major roadways near the proposed pipeline alignments. A report presenting the findings of this evaluation is included in Section V.

Environmental Resources

The potential impacts of any large-diameter pipeline alignment may include the disruption of habitat for threatened or endangered species, temporary alteration of wetlands, and loss of wooded areas. Since the pipeline will be buried, most of these impacts are transitory and do not represent long term alteration of the environment. Avoiding these areas as much as reasonably possible will help minimize the impact of the alignment to the environment. To assess the impacts of each pipeline alignment to environmental resources, CP&Y subcontracted APAI to conduct desktop surveys for each of the pipeline alignment alternatives.

APAI evaluated each of the four pipeline alignments to quantify the impacts to wooded areas, streams, urban/developed areas, agricultural areas, and impervious areas (roads, buildings, paved areas, etc.). Desktop surveys of aerial photography, along with limited site visits, were used to identify and quantify impacts to environmental resources. A report presenting the findings of this evaluation is included in Section VI.

Right-of-Way

Construction of the transmission pipeline will require acquisition of both permanent and temporary right-of-way, which can be time consuming and expensive. In addition to the land, which is proportional to the length of the pipeline, there is a measure of effort associated with the number of property owners with whom the District must negotiate. With this in mind, the recommended alignment should impact as few different owners as reasonably possible, yet maintain a logical alignment. Aerial maps and county district appraisal maps were compared to determine the actual number of property owners impacted for each alternative.

Socioeconomic Impacts

When selecting a pipeline alignment it is typically advantageous to avoid urban and suburban (developed) areas as much as reasonably possible. Construction in urban and suburban areas can be more difficult and costly as there may not be enough right-of-way available to construct the pipeline efficiently and safely; there is the likelihood of more public and private utility conflicts; and land costs are typically higher. Construction in rural areas is likely to occur with fewer conflicts, and farmland used for grazing or crops can usually continue to be used for such purposes after construction. The pipeline alignments were evaluated to assess their socioeconomic impacts and the recommended pipeline alignment should avoid or minimize the disturbance of urbanized or developed areas.

Constructability

Construction related factors are also quite important in the selection of pipeline routing. These factors include site accessibility requirements; roadway, railroad, pipeline and stream crossing assessments; and route topography (i.e. elevations, grade and cross slopes, etc.). Each alignment was evaluated for number of road crossings, known pipeline crossings, topography and available right-of-way. These factors can affect the project's schedule and construction cost.

Alignments

Four alternative pipeline alignments were evaluated. The study area for the alternative pipeline alignments begins at the proposed Lake Ralph Hall intake/pump station, generally extends between Ladonia and Merit, and ends at the proposed connection point with Irving's existing Chapman Lake Raw Water Pipeline System. Each of the four alignments begins at the Lake Ralph Hall raw water intake/pump station, assumed to be located within the reservoir near the dam structure approximately 3.5 miles northeast of Ladonia. All four alignments then follow a common southward route to State Highway (SH) 64. From SH 64, the alignments follow separate routes, generally traveling southwest between Ladonia and Merit. The four alignments come together again less than a mile northeast of Merit and turn westward along a common route, paralleling an existing 72-inch raw water pipeline jointly owned by Irving and the North Texas Municipal Water District (NTMWD), which is part of the Chapman Lake Raw Water Pipeline System. The proposed pipeline then discharges into a proposed balancing reservoir approximately two miles west of Merit near the existing Irving Balancing Reservoir (IBR). The final section of pipeline extends approximately one mile from the proposed balancing reservoir and connects to Irving's existing Chapman Lake Raw Water Pipeline System. Refer to Exhibit 1, Section IV for a sketch of each alignment that was considered.

Alignment Alternative No. 1 – "Railroad" Alignment

The first alignment considered was the "Railroad" alignment. This alignment primarily follows the Atchison, Topeka and Santa Fe Railway (ATSF) abandoned railroad right-of-way that travels southwest through the cities of Ladonia, Wolfe City, Celeste and Merit.

The pipeline alignment begins at the Lake Ralph Hall intake/pump station and extends generally southward to SH 64 until it intersects with the ATSF abandoned railroad right-of-way. From there the alignment follows the abandoned railroad generally southwest through Ladonia, then crossing the Middle Sulphur River. The pipeline then passes through Wolfe City, crossing several streams and the South Sulphur River, then through Celeste. After passing through Celeste, the alignment crosses the Cowleech Fork of the Sabine River. Just prior to entering Merit, the alignment changes direction westward and extends to the proposed balancing reservoir west of Merit, paralleling an existing 72-inch Chapman Lake raw water pipeline, jointly owned by Irving and NTMWD. From the proposed balancing reservoir, the alignment continues westward and connects to Irving's existing Chapman Lake Raw Water Pipeline System.

The abandoned railroad right-of-way typically measures 100-feet wide in rural areas, but sometimes as little as 50-feet wide within portions of the aforementioned cities. The abandoned railroad was initially identified because of the long stretch of available land with no apparent competing uses, and the possibility of acquiring a significant portion of the right-of-way needed for the transmission pipeline from a single property owner, thus simplifying the property acquisition process.

Alignment Alternative No. 2 – "Direct" Alignment

The second alternative is referred to as the "Direct" alignment. The objective of this alternative was to develop an alignment with the shortest route possible.

The pipeline alignment begins at the Lake Ralph Hall intake/pump station and extends generally southward to SH 64. From there, a straight line was drawn to the location approximately one mile northeast of Merit, where all four alignments converge, hence the name "Direct". The preliminary alignment would have a minimum length of 31.9 miles, assuming no consideration is given to any obstacles. The final alignment only deviates from this straight-line alignment to avoid major obstacles, such as houses, ponds and the Webb Hill Country Club golf course. This pipeline alignment also avoids major developed areas, passing approximately seven-tenths of a mile southwest of Ladonia, and approximately 1.5 miles southwest of Wolfe City and Celeste. Along the alignment, the pipeline crosses four state highways (SH 50, SH 11, SH 34 and SH 69) and four intermittent streams (Willow Oak Creek, Middle Sulphur River, South Sulphur River and the Cowleech Fork of the Sabine River). Just prior to entering Merit, the alignment changes direction westward and extends to a proposed balancing reservoir west of Merit, paralleling the existing 72-inch Chapman Lake raw water pipeline, jointly owned by Irving and NTMWD. From the proposed balancing reservoir, the alignment continues westward and connects to Irving's existing Chapman Lake Raw Water Pipeline System.

Alignment Alternative No. 3 – "Modified Direct"

The third alignment is referred to as the "Modified Direct" alignment. This alignment is similar to the "Direct" alignment, but was modified to minimize environmental impacts and follow a more logical course. Typical modifications included minor adjustments to the alignment to minimize stream crossings, impacts to wooded areas and the number of property owners impacted. Aerial maps and county district appraisal maps were compared to align the pipeline. Contiguous property tracts with the same ownership were identified and preferred during the alignment. Large tracts of land were also preferable to several small tracts when placing the alignment.

Alignment Alternative No. 4 – "Environmental" Alignment

The fourth alignment is the "Environmental" alignment. The objective of this alignment was to further minimize the environmental impacts, while maintaining a reasonable length.

This pipeline alignment begins at the Lake Ralph Hall intake/pump station and extends generally southward along the common route to SH 64. From there, the pipeline alignment proceeds generally southwest from Ladonia to Merit, being approximately 1 mile southeast of Ladonia, 2.5 miles southeast of Wolfe City and 1.5 miles southeast of Celeste. Between Ladonia and Celeste, the "Environmental" alignment is located up to approximately one mile southeast of the "Direct" alignment. Along the alignment, the pipeline crosses four state highways (SH 50, SH 11, SH 34 and SH 69) and four intermittent streams (Willow Oak Creek, Middle Sulphur River, South Sulphur River and the Cowleech Fork of the Sabine River). Just prior to entering Merit, the alignment changes direction westward and extends to a proposed balancing reservoir west of Merit, paralleling the existing 72-inch Chapman Lake raw water pipeline, jointly owned by Irving and NTMWD. From the proposed balancing reservoir, the alignment continues westward and connects to Irving's existing Chapman Lake Raw Water Pipeline System.

Alternative Evaluation

Each of the four alignments was evaluated based on the above criteria, and the results are presented in Table 1 below.

Table 1 – Alignment Comparison

Evaluation Criteria	Alternative No. 1 “Railroad” Alignment	Alternative No. 2 “Direct” Alignment	Alternative No. 3 “Modified Direct” Alignment	Alternative No. 4 “Environmental” Alignment
Length of Pipeline	At 32.7 miles, the “Railroad” alignment is one of the longer alignments.	At 32.2 miles, the “Direct” alignment is the shortest alignment	At 33.0 miles, the “Modified Direct” alignment is the longest alignment	At 32.3 miles, the “Environmental” alignment is comparable to the “Direct” alignment
Streams	55 stream crossings with 3,980 linear feet of stream impacts.	58 stream crossings with 7,130 linear feet of stream impacts.	56 stream crossings with 6,789 linear feet of stream impacts	42 stream crossings with 5,058 linear feet of stream impacts
Ponds(1)	0.6 acres of ponds located within the ROW of the “Railroad” alignment	1.6 acres of ponds located within the ROW of the “Direct” alignment	0.5 acres of ponds located within the ROW of the “Modified Direct” alignment	1.2 acres of ponds located within the ROW of the “Environmental” alignment
Wooded Areas(1)	The “Railroad” alignment impacts 269 acres of wooded areas, which includes overgrowth along the abandoned railroad.	The “Direct” alignment impacts 122 acres of wooded areas.	The “Modified Direct” alignment impacts 117 acres of wooded areas.	The “Environmental” alignment impacts 105 acres of wooded areas.
Caddo National Grassland Impacts(1)	The “Railroad” alignment extends across the Caddo National Grasslands, impacting 50.3 acres of national grasslands	The “Direct” alignment extends across the Caddo National Grasslands, impacting 13.3 acres of national grasslands	None	None
Archaeological and Cultural Impacts	High risk of encountering historic sites along “Railroad” alignment. Low risk of encountering archaeological sites along “Railroad” alignment due to pre-disturbance of railroad.	Medium risk of encountering historic sites along “Direct” alignment. Medium risk of encountering archaeological sites along “Direct” alignment near intermittent streams.	Medium risk of encountering historic sites along “Modified Direct” alignment. Medium risk of encountering archaeological sites along “Modified Direct” alignment near intermittent streams.	Medium risk of encountering historic sites along “Environmental” alignment. Medium risk of encountering archaeological sites along “Environmental” alignment near intermittent streams.

Right-of-Way Impacts	The “Railroad” alignment will require property acquisition from 80 property owners, which is the least of the four alternatives. However the railroad could reclaim the ROW and require the pipeline to be relocated in the future.	The “Direct” alignment will require property acquisition from 175 property owners, which is the most of the four alternatives.	The “Modified Direct” alignment was modified to reduce the number of property owners affected to 141.	The “Environmental” alignment will require property acquisition from 156 property owners.
Socioeconomic Impacts(1)	The “Railroad” alignment passes through Ladonia, Wolfe City, and Celeste increasing the impacts and the potential for traffic and utility conflicts. 4 state highway crossings 4 FM roadway crossings 47 street/driveway crossings 29.1 acres of building/road impacts within ROW	The “Direct” alignment follows a rural route and avoids Ladonia, Wolfe City, Celeste and Merit. 4 state highway crossings 6 FM roadway crossings 32 street/driveway crossings 3.2 acres of building/road impacts within ROW	The “Modified Direct” alignment follows a rural route and avoids Ladonia, Wolfe City, Celeste and Merit. 4 state highway crossings 6 FM roadway crossings 32 street/driveway crossings 4.4 acres of building/road impacts within ROW	The “Environmental” alignment follows a rural route and avoids Ladonia, Wolfe City, Celeste and Merit. 4 state highway crossings 7 FM roadway crossings 35 street/driveway crossings 4.7 acres of building/road impacts within ROW
Constructability	The “Railroad” alignment has limited ROW width within urban areas and steep side-slopes along the railroad ROW. Limited access from county roads in rural areas	Limited access from county roads in rural areas	Limited access from county roads in rural areas	Limited access from county roads in rural areas

(1) Impacts measured in acres are based on a 100-foot right-of-way width.

Alternatives Discussion and Preferred Alignment

Four alternative pipeline alignments were evaluated – the "Railroad" alignment, the "Direct" alignment, the "Modified Direct" alignment and the "Environmental" alignment. Based on the evaluations presented in Table 1, each alternative merits consideration for its advantages over the other alternatives. The "Railroad" alignment would impact significantly fewer property owners, thus shortening and simplifying the right-of-way acquisition process, and is less likely to impact any previously undisturbed archaeological areas. The "Modified Direct" alignment is the shortest of the four alignments. The "Environmental" alignment has the least overall impact on environmental resources.

But it is also important to consider the disadvantages of each alignment relative to the other alternatives. The "Railroad" alignment is one of the longest alternatives, passes directly through the middle of three cities, extends into national grasslands, and has the highest risk of encountering historical sites of interest. The "Direct" alignment impacts the greatest number of property owners and environmental resources, and also extends into national grasslands. The "Modified Direct" alignment is the longest of the four alternatives. The "Environmental" alignment impacts a large number of property owners, although not as many as the "Direct" alignment.

Based on these evaluations, the "Environmental" alignment alternative is recommended as the preferred alignment for conveying raw water from Lake Ralph Hall for the District's use. This alignment offers several advantages and reasonable compromises when compared to the other three alternatives. The "Environmental" alignment:

- has the least overall environmental impacts;
- avoids the suburban areas of Ladonia, Wolfe City and Celeste;
- avoids the Caddo National Grasslands protected area
- is only slightly longer than the "Direct" alignment, and is shorter than the other two alignments;
- impacts fewer property owners than the "Direct" alignment;
- greater ease of installation compared to the "Railroad" alignment; and
- has a lower chance of encountering significant historical sites in the alignment right-of-way, which can be avoided reasonably easily, compared to the "Railroad" alignment.

Each of the alignments evaluated are shown in Exhibit 1, Section IV. The "Environmental" alignment, the preferred primary alignment, is shown in Exhibit 2, Section IV.

III. Lake Ralph Hall To Tom Harpool Water Treatment Plant Pipeline Alignment Evaluation

This technical memorandum describes the evaluation of possible secondary alignments to convey raw water from the proposed Lake Ralph Hall to the existing Tom Harpool Water Treatment Plant. The first section describes the objectives of the evaluation. The second section describes the criteria that were used to develop and evaluate each alignment. The third section describes the alignments that were studied and includes a table that allows for a side by side comparison of the relevant features of each. The final section includes a discussion of the alternatives. CH2M HILL's recommended pipeline alignment, referred to as the "Minimum Urban Low Head Alignment" alignment, offers several advantages and reasonable compromises of evaluation criteria.

Objectives

The objectives of this alignment study were to:

- Investigate possible pipeline routes to convey raw water from the proposed Lake Ralph Hall near Ladonia, Texas to the Tom Harpool Water Treatment Plant (Harpool WTP) in Denton County, Texas,
- Minimize the cost of the proposed pipeline,
- Minimize the environmental impact of the proposed pipeline,
- Minimize the social impacts of the proposed pipeline. Social impacts include disruption of businesses, displacement of residents, traffic impact, and cultural resources.

Development of Alignments and Evaluation Criteria

Five alignments were evaluated based on the following criteria:

- pipeline length,
- environmental impacts,
- archaeological and cultural resource impacts,
- right-of-way needs,
- community impacts, and
- construction constraints.

The ideal alignment would minimize pipeline length; have minimal impacts to the environment and public community; and preserve any archaeological and cultural resources. However, seldom does one alternative fit the ideal definition, thus it is often necessary to select an alternative that best compromises the evaluation criteria.

Resources that were utilized during preparation of this report include: aerial photography; USGS topographic maps; various county appraisal District maps; a preliminary infrastructure study for the lake and raw water pipeline prepared by CP&Y dated February 6, 2004, “Raw Water Infrastructure”; a report prepared by ARC, titled “Archaeological Potential of the Lake Ralph Hall Pipeline Routes, Collin, Hunt, and Fannin Counties, Texas”; and multiple site visits.

Archaeological and Cultural Resources

To assess the impacts to archaeological and cultural resources, ARC conducted a desktop survey of the alternative pipeline alignments. The desktop surveys consisted of a literature review and records search to identify sites in the study area. In addition to the desktop surveys, ARC conducted a field reconnaissance (window survey) along major roadways near the proposed pipeline alignments. A report presenting the findings of this evaluation is included in Section V.

Environmental Resources

The potential impacts of any large-diameter pipeline alignment may include the disruption of habitat for threatened or endangered species, temporary alteration of wetlands, and loss of wooded areas. Since the pipeline will be buried, most of these impacts are transitory and do not represent long term alteration of the environment. Avoiding these areas as much as reasonably possible will help minimize the impact of the alignment to the environment. To assess the impacts of each pipeline alignment to environmental resources, APAI conducted desktop surveys for each of the pipeline alignment alternatives.

APAI evaluated each of the pipeline alignments to quantify the impacts to wooded areas, streams, urban/developed areas, agricultural areas, and impervious areas (roads, buildings, paved areas, etc.). Desktop surveys of aerial photography, along with limited site visits, were used to identify and quantify impacts to environmental resources. A report presenting the findings of this evaluation is included in Section VI.

Right-of-Way

Construction of the transmission pipeline will require acquisition of both permanent and temporary right-of-way, which can be time consuming and expensive. In addition to the land, which is proportional to the length of the pipeline, there is a measure of effort associated with the number of property owners with whom the District must negotiate. With this in mind, the recommended alignment should impact as few different owners as reasonably possible, yet maintain a logical alignment.

Socioeconomic Impacts

When selecting a pipeline alignment it is typically advantageous to avoid urban and suburban (developed) areas as much as reasonably possible. Construction in urban and suburban areas can be more difficult and costly as there may not be enough right-of-way available to construct the pipeline efficiently and safely; there is the likelihood of more public and private utility conflicts; and land costs are typically higher. Construction in rural areas is likely to occur with fewer conflicts, and farmland used for grazing or crops can usually continue to be used for such purposes after construction. The pipeline alignments were evaluated to assess their socioeconomic impacts and the recommended pipeline alignment should avoid or minimize the disturbance of urbanized or developed areas.

Constructability

Construction related factors are also quite important in the selection of pipeline routing. These factors include site accessibility requirements; roadway, railroad, pipeline and stream crossing assessments; and route topography (i.e. elevations, grade, cross slopes, etc.). Each alignment was evaluated for number of road crossings, known pipeline crossings, topography and available right-of-way. These factors can affect the project's schedule and construction cost.

Alignments

The areas between the proposed Lake Ralph Hall and the Harpool WTP are rural and largely undeveloped. The majority of the land use appears to be pasture or grazing land, and several small towns are located in the area. The large open areas offered several potential alignments which are shown in Exhibit 1, Section IV and described in the paragraphs below.

Alignment Alternative No. 1. - Straight Line Alignment

The straight line alignment is straight line between the Harpool WTP and the proposed Lake Ralph Hall. The pipeline does not avoid homes, wells, creeks, major highways or cemeteries. While being the shortest distance alignment (approximately 64.2 miles), this alignment goes through Ladonia, Leonard, Anna, Melissa and Prosper, and cuts through the Caddo National Grasslands (near Ladonia) and would disrupt numerous residences, businesses, traffic and cultural resources. The highest ground elevation of this alignment is 785 ft and is located east of Wilson Creek.

Alignment Alternative No. 2. – Modified Straight Alignment

This alignment attempts to follow the straight alignment while avoiding existing developments. The result is that many sections of this alignment are located close to existing developments. It was assumed that these existing developments will continue to expand and create additional conflicts with the alignment prior to acquisition of easements. This possibility makes this alignment choice less attractive than some of the others. The highest ground elevation of this alignment is 770 ft and is located east of Wilson Creek.

Alignment Alternative No. 3. - Least Urban Direct Alignment

In an effort to avoid the developments near the Shortest Direct Route alignment , the alignment was adjusted starting near Bear Creek so that it followed a more Westerly course. This alignment traveled North of Anna, Weston, and Celina before turning south and following Pecan Creek to the Harpool WTP. This alignment avoided many of the developments that were noted in the Shortest Direct Route and had a maximum ground elevation of 800 ft near the drainage divide west of Long Branch Creek.

Alignment Alternative No. 4. - North Alignment

This alignment was developed in an effort to completely avoid developing cities like Leonard, Trenton, Van Alstyne and Celina, and the Caddo National Grasslands. This resulted in a longer route. This alignment crosses fewer lakes and ponds than the Minimal Urban Impact, Least Urban Direct, and Minimal Urban Low Head alignments. The highest ground elevation of this alignment is 788 ft and is located near the Smallwood Cemetery. The ground elevation near US 75 is approximately 782 ft.

Alignment Alternative No. 5. - Minimal Urban Low Head Alignment

This preferred alignment was developed in order to minimize pumping cost thus minimizing operations cost of the proposed pipeline. It is a refinement of the previous alignment and also avoids high points along the Sulphur River and Trinity River watershed boundary. A review of aerial photographs did not reveal any conflicts with homes, schools or ponds. The alignment will cross major roads and railroads at a 90 degree angle and will also minimize the wooded areas crossed. The length of this alignment is approximately 71 miles long. The highest ground elevation of this alignment is 788 ft and is located near the Smallwood Cemetery. The ground elevation near US 75 is approximately 782 ft.

Alternative Evaluation

Each of the five alternative pipeline alignments was evaluated based on the evaluation criteria. The results of those evaluations are presented in Table 2.

Table 2 - Alignment Comparison

Evaluation Criteria	Alternative No. 1 Straight Line Alignment	Alternative No. 2 Modified Straight Alignment	Alternative No. 3 Least Urban Alignment	Alternative No. 4 North Alignment	Alternative No. 5 Minimum Urban Low Head Alignment
Length of Pipeline (miles)	64.2	66.3	70.5	71.1	71.1
Number of Stream Crossing	27	27	26	27	25
Ponds	Numerous small ponds	Numerous small ponds	Numerous small ponds	Crosses fewer ponds than alignments 3, and 5;	Numerous small ponds
Wooded Areas	This criteria was not calculated for this alignment	This criteria was not calculated for this alignment	This criteria was not calculated for this alignment	This criteria was not calculated for this alignment	This alignment impacts 107 acres of wooded areas
Caddo National Grassland Impacts	Goes through Caddo Natl. Grasslands	No Conflict	No Conflict	No Conflict	No Conflict
Archaeological and Cultural Impacts	This alignment was ruled out before this study was performed	This alignment was ruled out before this study was performed	This alignment was ruled out before this study was performed	This alignment was ruled out before this study was performed	High risk of encountering historic sites along this alignment. High risk of encountering archaeological sites along this alignment near intermittent streams.
Acres of R.O.W.[1]	778	803	854	862	862

Socioeconomic Impacts	Extensive; Goes through numerous cities and includes 8 highway crossings and 3 railroad crossings Impacted acreage within ROW of this alignment was not calculated	Significant; Adjacent to numerous developed/developing areas and includes 10 highway crossings and 3 railroad crossings Impacted acreage within ROW of this alignment was not calculated	Avoids urban areas and includes 10 highway crossings and 3 railroad crossings Impacted acreage within ROW of this alignment was not calculated	Avoids urban areas and includes 10 highway crossings and 3 railroad crossings Impacted acreage within ROW of this alignment was not calculated	Avoids pending development near Celina; and includes 8 highway crossings and 3 railroad crossings 27.2 acres of developed area impacts within ROW
Constructability/Comments	Not Applicable/ Not a realistic alignment but a baseline to evaluate other options.	Construction challenges should be anticipated near developed areas/highest ground elev is 770 ft.	No significant construction challenges idenfitifed/highest ground surface of all alignments of 800 ft.	No significant construction challenges idenfitifed/highest ground elev is 788 ft.	No significant construction challenges idenfitifed/highest ground elev is 788 ft.

[1] 100 ft wide R.O.W. assumed

Alternatives Discussion and Preferred Alignment

A total of five secondary alignments were investigated to deliver raw water from the Lake Ralph Hall to the Harpool WTP. The study began with the straight line alignment and then progressed to the other four alignments as we investigated pipe corridors that would satisfy the evaluation criteria. The Modified Straight Alignment is adjacent to many developed and developing areas which may create conflicts during further evaluation. The Least Urban Direct alignment avoids developed areas but includes the highest point of all the alignments which is expected to increase design, construction and operating costs.

The remaining 2 alignments are North and Minimum Urban Low Head. The North alignment is located further away from future development in the vicinity of Celina by following a more northerly route near the west end. This alignment is anticipated to have a slightly higher cost due to the fact that it crosses more streams and roads. The Minimum Urban Low Head Alignment appears to be a viable corridor for conveying water from Lake Ralph Hall to the Harpool WTP and is considered to be the preferred secondary alignment.

Based on these evaluations, CH2M HILL recommends the “Minimum Urban Low Head Alignment” alignment alternative as the preferred secondary alignment for conveying raw water from Lake Ralph Hall for the District’s use. This alignment offers several advantages and reasonable compromises when compared to the other four secondary alternatives. The “Minimum Urban Low Head Alignment” alignment:

- has the least number of stream crossings;
- avoids the suburban areas of Ladonia, Wolfe City, Leonard, Weston and Celina;
- avoids the Lyndon B. Johnson National Grasslands protected area
- has fewer highway crossings than the other viable alignments;
- will minimize pumping cost by avoiding high points along the Sulphur River and Trinity River watershed boundary; and
- is routed further away from developed/developing areas, and thus less anticipated construction challenges, compared to the “Modified Straight ” alignment.

IV. Exhibits

PRELIMINARY PRE-DECISION
NOT SUBJECT TO FREEDOM
OF INFORMATION ACT
February 4, 2010

Lake Ralph Hall Alignment Study

Exhibit 1

Alignment Alternatives

N

0 1 2 3 4 Miles

Legend

▬	Proposed Collin County Outer Loop
●	Cemeteries
🟩	Grasslands

CH2MHILL

Chiang, Patel & Yerby, Inc.

UPPER TRINITY REGIONAL WATER DISTRICT

PRELIMINARY PRE-DECISION
NOT SUBJECT TO FREEDOM
OF INFORMATION ACT
February 4, 2010

CH2MHILL

CP&Y
Chiang, Patel & Yerby, Inc.

UPPER TRINITY
REGIONAL WATER DISTRICT

Lake Ralph Hall Alignment Study

Exhibit 2

Recommended Alignments

N

0 1 2 3 4 Miles

Legend

Proposed Collin County Outer Loop
● Cemeteries
🟩 Grasslands

VI. Desktop Evaluations of Environmentally Sensitive Areas

ALAN PLUMMER
ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS • DESIGNERS • SCIENTISTS

0346-004-03

December 18, 2009

Mr. Jerry Snead, P.E.
CH2M Hill
12377 Merit Drive, Suite 100
Dallas, Texas 75251

RE: Proposed Land Cover and Stream Assessment for the Minimum Urban Low Head Pipeline Alignment

Dear Mr. Snead:

Representatives from Alan Plummer Associates, Inc. (APAI) conducted a desk top land cover and stream/lake assessment for the proposed Minimum Urban Low Head (MULH) pipeline alignment, which would transport raw water from the proposed Lake Ralph Hall directly to a location near the Upper Trinity Regional Water District's Harpool Water Treatment Plant north of Lewisville Lake. The proposed MULH alignment is approximately 64 miles in length spanning Fannin, Collin, and Denton Counties, Texas. The proposed pipeline would be situated in the Sulphur and Trinity River Basins. Specifically, the proposed pipeline would encounter the following hydrologic unit codes: 12030103 associated with the Elm Fork Trinity River, 12030106 associated with the East Fork Trinity River, and 11140301 associated with the Sulphur River. Rather than parallel existing transportation and utility corridors, the proposed pipeline alignment takes a direct, cross-county approach to minimize the length of pipeline.

In November 2009, APAI was tasked to assess current land cover and potential stream and lake impacts associated with the proposed pipeline. Geographic Information Systems specifically the Arc GIS suite (ArcView, ArcCatalog, and ArcToolbox) was used to perform the assessment. Base layer files were obtained from the Texas Natural Resources Information System's Geospatial Database, the Texas Water Development Board's Geospatial Database, and from CH2M Hill. Files obtained included the 2008 National Agriculture Imagery Program's Digital Orthoimagery 0.5 Meter Resolution aerial photographs for Fannin, Collin, and Denton Counties, the National Hydrography Dataset, the transportation dataset (road networks), the various datasets associated with political

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boundaries, the hydrologic unit code dataset, the United States Geologic Survey topographic quadrangle maps pertinent to the proposed project area, and the proposed pipeline alignment. All files were referenced to the North American Datum 1983 State Plane North Central Texas in Feet.

Once the base files were uploaded to ArcView, the proposed alignment was buffered to represent a proposed 100-foot permanent easement. After the proposed easement boundary was established, polygons and polylines representing land cover types were drawn based on the signatures observed in the aerial photographs, the National Hydrography Dataset, and what was shown on the USGS topographic quadrangle maps. Land cover types included the following categories: streams, on-channel ponds, upland ponds, developed areas, forest, park-like, cropland, and pasture. These categories were based on the categories identified in the Texas Parks and Wildlife Department's Wildlife Habitat Appraisal Procedure. The polygons and polylines were then cropped using the proposed easement polygon to provide the following analysis of land cover within the proposed easement area:

Stream Channels (Linear Feet)	On-channel Ponds (Acres)	Upland Ponds (Acres)	Developed Areas (Acres)	Forest (Acres)	Park-like (Acres)	Cropland (Acres)	Pasture (Acres)
16,919	7.2	1.9	25.8	107.0	16.4	245.2	368.4

The proposed pipeline alignment received from CH2M Hill did not continue directly to the Harpool Water Treatment Plant. Instead the pipeline alignment terminated at a location south of FM 428 and Pecan Creek in Denton County. Based on previous information received from CH2M Hill, APAI drew in the alignment from the aforementioned terminus to the Harpool Water Treatment Plant and followed the same protocols mentioned above to discern the land cover types (described below) along this segment.

Stream Channels (Linear Feet)	On-channel Ponds (Acres)	Upland Ponds (Acres)	Potential Wetlands (Acres)	Developed Areas (Acres)	Forest (Acres)	Park-like (Acres)	Cropland (Acres)	Pasture (Acres)
2,587	1.4	0.0	0.5	1.4	22.0	7.0	3.9	27.7

Should you have questions or need further clarifications, please do not hesitate to phone me at (817) 806-1700. We appreciate the opportunity to provide our services on this project.

Sincerely,

Alan Plummer Associates, Inc.

Jason Voight

ALAN PLUMMER
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ENVIRONMENTAL ENGINEERS • DESIGNERS • SCIENTISTS

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0346-004-03

February 5, 2010

Mr. John Levitt, P.E.
CPY
1820 Regal Row, Suite 200
Dallas, Texas 75235

RE: Proposed Land Cover and Surface Water Assessment for the Proposed Pipeline Alignments Associated with the Intake at Lake Ralph Hall Reservoir (Dam C Intake) to a Proposed Balancing Reservoir Location along the Lake Chapman Raw Water Transmission Pipeline

INTRODUCTION

Representatives from Alan Plummer Associates, Inc. (APAI) conducted a desk top land cover and surface water assessment for four potential pipeline alignments that would transport raw water from the proposed intake at Lake Ralph Hall to a proposed location west of the existing balancing reservoir associated with the Lake Chapman Raw Water Transmission Pipeline in northeastern Collin County. The following narratives detail the methodology used for determining the types of land cover and surface water as well as summarize the potential impacts to land cover and surface waters within the proposed pipelines' 100-foot easements.

METHODOLOGY

This assessment used Geographic Information Systems, specifically the Arc GIS suite (ArcView, ArcCatalog, and ArcToolbox), to map land cover and surface water features within the proposed easements associated with the alternative alignments. Base layer files were obtained from the Texas Natural Resources Information System's Geospatial Database, and the Texas Water Development Board's Geospatial Database. Files obtained included the 2008 National Agriculture Imagery Program's Digital Orthoimagery 0.5 Meter Resolution aerial photographs for Fannin, Collin, and Denton Counties, the National

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Hydrography Dataset, the transportation dataset (road networks), the various datasets associated with political boundaries, the hydrologic unit code dataset, the United States Geologic Survey topographic quadrangle maps pertinent to the proposed project area, and the proposed pipeline alignment. All files were referenced to the North American Datum 1983 State Plane North Central Texas in Feet.

Once the base files were uploaded to ArcView, the proposed alignment was buffered to represent a proposed 100-foot permanent easement. After the proposed easement boundary was established, polygons and polylines representing land cover types and surface water features were drawn based on the signatures observed in the aerial photographs, the National Hydrography Dataset, and what was shown on the USGS topographic quadrangle maps. Land cover types included the following categories: streams, on-channel ponds, upland ponds, developed areas, forests, park-like areas, cropland, and pasture. These categories were based on the categories identified in the Texas Parks and Wildlife Department's Wildlife Habitat Appraisal Procedure. The polygons and polylines representing the different land cover and surface water categories were cropped using the proposed easement polygon in order to determine the quantity of a specific land cover category within the easement.

RESULTS

Direct Alignment

The Direct Alignment is approximately 31.50 miles long and would be located in portions of Fannin, Hunt, and Collin Counties. The pipeline would originate in the Sulphur River Basin and cross the upper portion of the Sabine River Basin before terminating in the East Fork Trinity River Basin. Specifically, the proposed pipeline would encounter the following hydrologic unit codes: 11140301 associated with the Sulphur River, 12010001 associated with the Sabine River, and 12030106 associated with the East Fork Trinity River. The Direct Alignment was designed to provide the most direct route from the proposed intake at Lake Ralph Hall to the proposed "tie in" at the Lake Chapman Raw Water Transmission Pipeline. The alignment generally parallels existing utility and transportation rights-of way in order to minimize environmental, infrastructure, and property impacts. Table 1 below shows the results of the land cover and surface water assessment for the Direct Alignment.

TABLE 1: DIRECT ALIGNMENT LAND USE Approximately 31.50 Mile Length and 100-foot Easement Width	
DEVELOPED AREAS (ACRES)	3.18
FOREST (ACRES)	115.13
PARK LIKE (ACRES)	7.08
CROPLAND (ACRES)	66.46
PASTURE (ACRES)	189.74
8 STOCK TANKS (ACRES)	1.64
ON-CHANNEL POND	--
TOTAL STREAM CROSSINGS	58
STREAM LENGTH (FEET)	7,130

Modified Direct Alignment

The Modified Direct Alignment is approximately 32.25 miles long and would follow the same general course as the Direct Alignment from the Lake Ralph Hall intake to the proposed "tie in" with the Lake Chapman Raw Water Transmission Pipeline. The Modified Direct Alignment would be located in the same counties and river basins as the Direct Alignment. Table 2 below shows the results of the land cover and surface water assessment for the Modified Direct Alignment.

TABLE 2: MODIFIED DIRECT ALIGNMENT LAND USE Approximately 32.25 Mile Length and 100-foot Easement Width	
DEVELOPED AREAS (ACRES)	4.44
FOREST (ACRES)	107.02
PARK LIKE (ACRES)	9.88
CROPLAND (ACRES)	78.83
PASTURE (ACRES)	191.52
5 STOCK TANKS (ACRES)	0.51
ON-CHANNEL POND	--
TOTAL STREAM CROSSINGS	56
STREAM LENGTH (FEET)	6,789

Environmental Alignment

The Environmental Alignment is approximately 31.75 miles long and would follow the same general course as the Direct and Modified Direct Alignments from the Lake Ralph Hall intake to the proposed "tie in" with the Lake Chapman Raw Water Transmission Pipeline. The Environmental Alignment would be located in the same counties and river basins as the

Direct and Modified Direct Alignments. The routing of this alignment was prepared in a way that would limit environmental impacts by avoiding and minimizing impacts to heavily wooded areas and surface water features. Table 3 below shows the results of the land cover and surface water assessment for the Environmental Alignment.

TABLE 3: ENVIRONMENTAL ALIGNMENT LAND USE **Approximately 31.75 Mile Length and 100-foot Easement Width**	
DEVELOPED AREAS (ACRES)	4.66
FOREST (ACRES)	81.78
PARK LIKE (ACRES)	23.08
CROPLAND (ACRES)	61.63
PASTURE (ACRES)	212.69
6 STOCK TANKS (ACRES)	1.17
ON-CHANNEL POND	--
TOTAL STREAM CROSSINGS	42
STREAM LENGTH FEET	5,058

Rail Alignment

The Rail Alignment is approximately 31.5 miles long and would generally follow the abandoned Topeka Santa Fe Railroad alignment for the majority of its length. This alignment would originate at the same point as the alignments mentioned above, and terminate at the same location as the aforementioned alignments. The Rail Alignment would be located in the same counties and river basins as the Direct and Modified Direct Alignments. By following the former railroad right of way, the Rail Alignment limits environmental, infrastructure, and property impacts. Table 4 below shows the results of the land cover and surface water assessment for the Rail Alignment.

TABLE 4: RAIL ALIGNMENT LAND USE **Approximately 31.5 Mile Length and 100-foot Easement Width**	
DEVELOPED AREAS (ACRES)	29.14
FOREST (ACRES)	108.24
PARK LIKE (ACRES)	161.18
CROPLAND (ACRES)	5.18
PASTURE (ACRES)	114.45
STOCK TANK (ACRES)	0.27
7 ON-CHANNEL PONDS (ACRES)	0.302
TOTAL STREAM CROSSINGS	55
STREAM LENGTH FEET	3,980

Should you have questions or need further clarifications, please do not hesitate to phone me at (817) 806-1700. We appreciate the opportunity to provide our services on this project.

Sincerely,

Alan Plummer Associates, Inc.

Jason Voight

A-4: Cost Estimates

Toledo Bend to Merit Pipeline Cost
Pipeline and Pump Station Costs for Alternatives Analysis

Overview

This memorandum documents the development of construction, operation and maintenance costs involved to build and operate a pipeline to convey water from Toledo Bend to UTRWD's terminal storage area near Merit, Texas. The cost includes the cost of raw water, electricity, pipeline construction cost, associated Right of Way (ROW) acquisition, Pump station and balancing reservoirs costs.

The costs are grouped into two major categories:

1. Construction Cost
2. Annual Operation, Maintenance and Repair Cost

Assumptions

The assumptions made to develop the cost estimates are listed below:

1. Peak flows would be 45,000 acre-feet /year (ac-ft/yr)
2. Average flows would be 34,050 ac-ft/yr
3. The intake for the pipeline would be located on the Texas side of the Toledo Bend Reservoir
4. The intake works are located at 160 ft Mean Sea Level (MSL) elevation
5. The life of the pipeline is 30 years
6. The terminal is located at 710 ft MSL elevation
7. The pipeline Hazen Williams Roughness coefficient is 120 (mature cement-mortar lined pipe)
8. The pump efficiency is 80%
9. The maximum pipeline pressure is 150 pounds per square inch gage (psig)
10. The pipeline would not cross any major river systems (additional bridge cost)
11. Annual rate of return on investment is 6%
12. Annual rate of inflation is 2%

Methodology

Lift- Also known as static head difference- This is the difference in elevation between the Intake works at Toledo Bend Reservoir and the Terminal, and is computed as 550 feet.

Velocity head: This is the energy contained in a stream of water due to its velocity. The energy is lost when the water is discharged. The amount of work required to produce this velocity is equivalent to picking this water up high enough so it would attain the required velocity in falling. This value, referred to as velocity head, is on the order of 0.5 foot, and can be considered negligible for a long pipe line.

Pressure losses - Pressure losses are calculated using Hazen-Williams equation using a roughness coefficient of 120, and additional criteria laid out in the document titled "Proposed Lake Ralph Hall Pipeline and Pump Criteria for Alternative Analysis" prepared by CH2M Hill in June 2015.

A 219 mile pipeline will be required from Toledo Bend to Merit. See **Figure 1** for the alignment assumed for this exercise.

Other alignments are possible, but this one was selected for being the shortest distance. A feasibility study would help determine the most constructible pipeline route.

Figure 1: Preliminary Alignment for Pipeline from Toledo Bend to Merit, TX

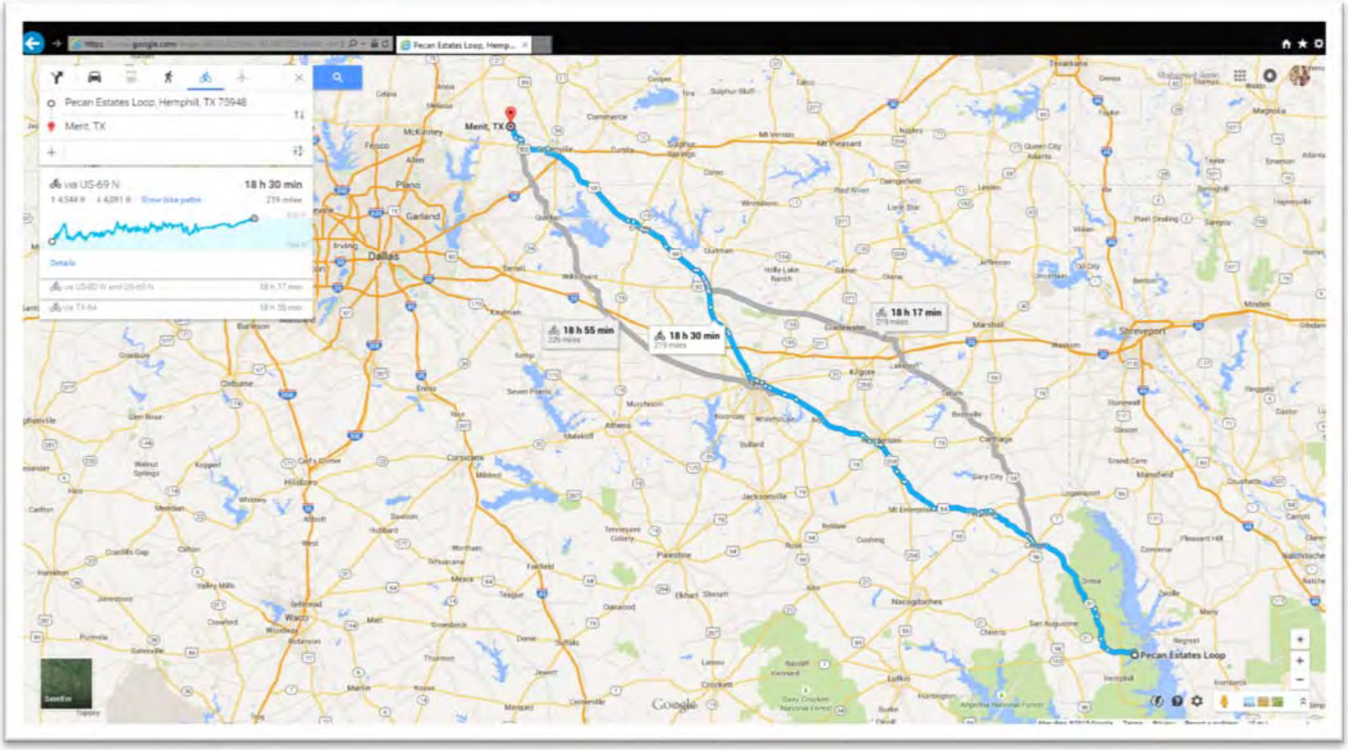


Figure 2 shows the terrain along the selected 219 mile pipeline alignment. For headloss calculations, the equivalent pipeline length is assumed to be 30% larger to account for in-pipe losses due to enlargements, contractions, elbows and couplings. For headloss calculation, therefore, the equivalent length used is 284.7 miles.

Figure 2: Terrain Profile along the Selected 219 mile Pipeline Alignment

Six alternatives are evaluated, and are summarized in **Table 1** below.

Table 1: Alternatives Evaluated

Alternative	**1**	**2**	**3**	**4**	**5**	**6**
Annual Flow (ac-ft) used	45,000	45,000	45,000	34,050	34,050	34,050
Pipe Size (in)	48	52	56	48	42	52

Capital Costs

Unit Costs- December 2012 unit costs for Lake Ralph Hall were escalated to 2015 costs using a construction cost escalation (CCE) based on Engineering News Record (ENR) Construction Cost Indexes from both years. The resulting CCE was computed as 1.0296. The Unit costs used in this analysis are listed below in **Table 2**:

Table 2: Unit Costs

Item	Unit	2012 Cost	2015 Cost
Pipeline Construction	FT	$300	$309
Pipeline ROW	FT	$5.51	$5.67
Pump Station Construction	LS/EA	$10,500,000	$10,810,000
Balancing Reservoir	LS/EA	$1,500,000	$1,544,400
Water Cost	/1000 gal	$0.56	$0.56
Electricity	/KwH	$0.08	$0.08

Capital Costs for construction are assumed to occur within 1 year. They include costs for Pipeline construction, ROW cost, Pump Station Cost, Cost of Balancing Reservoirs, and added contingency (see **Table 3**).

Table 3: Capital Construction Costs for Each Alternative

Alternative	1	2	3	4	5	6
Pipeline Construction Cost	$357,164,121.60	$357,164,121.60	$357,164,121.60	$357,164,121.60	$357,164,121.60	$357,164,121.60
ROW Cost	$6,559,914.37	$6,559,914.37	$6,559,914.37	$6,559,914.37	$6,559,914.37	$6,559,914.37
Pump Station Cost	$97,297,200.00	$75,675,600.00	$64,864,800.00	$64,864,800.00	$108,108,000.00	$54,054,000.00
Cost of Balancing Reservoirs	$12,000,000.00	$9,000,000.00	$7,500,000.00	$7,500,000.00	$13,500,000.00	$6,000,000.00
Total Capital Cost	$473,021,235.97	$448,399,635.97	$436,088,835.97	$436,088,835.97	$485,332,035.97	$423,778,035.97
Add contingency	1.3	1.3	1.3	1.3	1.3	1.3
Total Construction Cost	$614,927,606.76	$582,919,526.76	$566,915,486.76	$566,915,486.76	$630,931,646.76	$550,911,446.76

Operation, Maintenance and Repair Costs

As shown in **Table 4**, Operation, Maintenance and Repair (OM&R) include costs of purchasing water from the Toledo Bend Reservoir and electricity required to operate the pump stations. See **Table 2** above for the unit costs adopted for this exercise. A 10% contingency is added to the operations cost for maintenance and repair.

Table 4: OM&R Costs

Alternative	1	2	3	4	5	6
Water HorsePower Required (hp)	21683.68	15940.41	12289.12	10973.66	18328.69	8380.65
Total Cost of Electricity	$14,170,196.69	$10,416,993.87	$8,030,889.66	$7,171,246.17	$11,977,723.22	$5,476,723.59
Total Water Cost	$8,217,009.96	$8,217,009.96	$8,217,009.96	$6,217,610.19	$6,217,610.19	$6,217,610.19
Add 10% for repair & maint costs	$2,238,720.67	$1,863,400.38	$1,624,789.96	$1,338,885.64	$1,819,533.34	$1,169,433.38
Annual Operating Cost	$24,625,927.32	$20,497,404.22	$17,872,689.59	$14,727,742.00	$20,014,866.75	$12,863,767.17
Assume % rate of inflation	0.02	0.02	0.02	0.02	0.02	0.02
Assume annual rate of return (%)	0.06	0.06	0.06	0.06	0.06	0.06
Assume Life Cycle of Pipeline (yrs)	30	30	30	30	30	30
Net Present Value (using int rate)	$388,321,809.70	$323,219,871.53	$281,831,218.66	$232,239,105.73	$315,610,825.01	$202,846,421.89

Present value life cycle cost estimate was developed and applied to the annual OM&R costs to allow for a "normalized" (i.e. "apples to apples") comparison of the options. The life cycle cost analysis includes the capital construction cost and the OM&R costs over a 30-year period of time.

All construction is assumed to occur within a year; therefore, the associated construction costs are presented at present value. The OM&R life cycle cost is calculated at present value using Engineering Economic Analyses practices. The future value of the OM&R costs include estimating the annual average OM&R cost then summing it over 30 years by assuming a 2% increase every year due to inflation, and is calculated using the following formula:

$$FV = \frac{A * [(1+i)^n - 1]}{i}$$

FV = Future Value
A = Annual Cost
i = interest rate
n = number of years

To determine the present value, the future value is brought to the present value by assuming a 6% rate of return on the investment using the following formula:

$$PV = \frac{FV}{(1+i)^n}$$

PV = Present Value
FV = Future Value
i = interest rate
n = number of years

The detailed OM&R cost and life cycle estimates are summarized in **Table 4** above**.**

Results:

Costs were derived for 6 alternatives (see **Table 5**). Capital Costs were estimated to occur within the next 12 months. Annual OM&R costs were estimated over a 30 year life cycle and reported as present costs using an 8% annual rate of return and a 2% annual rate of inflation. A 48 inch pipeline carrying 45,000 ac-ft/yr from Toledo Bend to Merit would cost $1,003,249,416 in 2015 dollars. In comparison, a 48 inch pipeline carrying 34,050 ac-ft/yr over the same distance would cost $799,154,592 in 2015 dollars.

Table 5: Costs in Present Value Format

Alternative	**1**	**2**	**3**	**4**	**5**	**6**
Annual Flow (ac-ft)	45,000	45,000	45,000	34,050	34,050	34,050
Pipe Size (in)	48	52	56	48	42	52
Total Capital Cost	$473,021,235.97	$448,399,635.97	$436,088,835.97	$436,088,835.97	$485,332,035.97	$423,778,035.97
Annual Operating Cost	$24,625,927.32	$20,497,404.22	$17,872,689.59	$14,727,742.00	$20,014,866.75	$12,863,767.17
Total Present Costs for Pipeline	$1,003,249,416.46	$906,139,398.29	$848,746,705.41	$799,154,592.48	$946,542,471.76	$753,757,868.65

Next, the present value of capital construction and OM&R costs for the Lake Ralph Hall dam and reservoir and a pipeline to convey water to UTRWD's terminal storage area near Merit, Texas is computed. UTRWD's 2012 capital costs for construction are used as a starting point for capital construction costs and the 2012-2015 CCE Index value of 1.0296 is applied to determine 2015 capital construction costs.

Table 6: Lake Ralph Hall Capital Costs

PROJECTED 2012 COSTRUCTION COSTS Adjusted to 2015

CONSTRUCTION COSTS	**Quantity**	**Unit**	**Unit Price**	**2012 Cost**	**CCE (2012 - 2015)**	**2015 Cost**
Mobilization and Demobilization	1	LS	$5,187,750	$5,187,750	1.0296	$5,341,307
Storm water Prevention	1	LS	$611,935	$611,935	1.0296	$630,048
Clearing & Grubbing	450	AC	$2,500	$1,125,000	1.0296	$1,158,300
Demolition	1	LS	$1,000,000	$1,000,000	1.0296	$1,029,600
Care of Water	1	LS	$250,000	$250,000	1.0296	$257,400
Relocations						
Roadways	25,000	LF	$300	$7,500,000	1.0296	$7,722,000
Roadway Embankments	330,329	CY	$6.00	$1,981,974	1.0296	$2,040,640
Major Bridges	5,100	LF	$2,900	$14,790,000	1.0296	$15,227,784
Minor Bridges	1,450	LF	$2,000	$2,900,000	1.0296	$2,985,840
Utility Relocations:						
AT& T	24,000	LF	$30	$720,000	1.0296	$741,312
Oncor	67,000	LF	$45	$3,015,000	1.0296	$3,104,244
Fiber Optic	19,000	LF	$30	$570,000	1.0296	$586,872
Miscellaneous Relocations	1	LS	$1,000,000	$1,000,000	1.0296	$1,029,600
Embankment Random Fill	3,476,415	CY	$6.00	$20,858,490	1.0296	$21,475,901
Embankment Core	906,016	CY	$6.50	$5,889,104	1.0296	$6,063,421
Principal Spillway Reinf. Conc.	22,471	CY	$300	$6,741,300	1.0296	$6,940,842
Emergency Spillway Mass/Reinf. Conc.	38,980	CY	$250	$9,745,000	1.0296	$10,033,452
Rock Riprap	394,202	SY	$75	$29,565,150	1.0296	$30,440,278
Raw Water Pump Station/Outlet Works	1	LS	$10,500,000	$10,500,000	1.0296	$10,810,800
Booster PS Improvements	1	LS	$1,500,000	$1,500,000	1.0296	$1,544,400
Balancing Reservoir	1	LS	$1,500,000	$1,500,000	1.0296	$1,544,400
Raw Water Pipeline	170,544	LF	$300	$51,163,200	1.0296	$52,677,631
CONSTRUCTION TOTAL				**$178,113,903**		**$183,386,075**
Contingencies*, Professional Services & Permitting	1	LS	$53,434,000	$53,434,000	1.0296	$55,015,646
Land Acquisition & Mitigation	1	LS	$42,251,000	$42,251,000	1.0296	$43,501,630
Pipeline Easements	170,544	LF	$5.51	$939,697	1.0296	$967,512
TOTAL COST				**$274,738,600**		**$282,870,863**

OM&R costs are then calculated for the LRH-Merit Pipeline (see **Table 7**) using the same assumptions as the Toledo Bend-Merit Pipeline, with the exception of water cost- it is assumed here that there would be no cost for the water. OM&R costs are based on UTRWD's proposed alignment #4, which is 32.3 miles long.

Table 7: LRH OM&R Costs

Alternative	**1**	**2**	**3**	**4**	**5**	**6**
Volume (ac-ft)	**45000**	**45000**	**45000**	**34050**	**34050**	**34050**
Pipe length (UTRWD's proposed Alignment # 4) (mi)	32.3	32.3	32.3	32.3	32.3	32.3
dh = inside or hydraulic diameter (inches)	**48**	**52**	**56**	**48**	**42**	**52**
Head Loss (ft/mi)	8.86	6.00	4.18	5.29	10.13	3.58
Terminal Elevation (provided)	710	710	710	710	710	710
LRH Elevation (estimated)	509	509	509	509	509	509
Velocity Head (ft)	0.38	0.28	0.21	0.22	0.37	0.16
Total Head Required (ft)	573.73	453.52	377.09	423.39	626.82	351.66
Pump Efficiency	80%	80%	80%	80%	80%	80%
Horse Power Required (hp)	5052.36	3993.75	3320.70	2821.23	4176.79	2343.29
Total Dynamic Pumping Head (ft)	581.4161115	458.7056107	380.6922295	427.9862889	635.6697751	354.7675152
Operating Cost						
Energy Needed(kwh)	33,495,557.12	26,426,168.25	21,931,793.88	$18,656,690.28	27,709,986.10	15,464,952.56
Unit Cost of Electricity	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08
Total Cost of Electricity	**$2,679,644.57**	**$2,114,093.46**	**$1,754,543.51**	**$1,492,535.22**	**$2,216,798.89**	**$1,237,196.20**
Add 10% for repair & maintenance costs	$267,964.46	$211,409.35	$175,454.35	$149,253.52	$221,679.89	$123,719.62
Annual Operating Cost	**$2,947,609.03**	**$2,325,502.81**	**$1,929,997.86**	**$1,641,788.74**	**$2,438,478.78**	**$1,360,915.82**

Table 8: LRH Combined Costs at Present Value

Alternative	**1**	**2**	**3**	**4**	**5**	**6**
Annual Operating Cost	$2,947,609	$2,325,502	$1,929,997	$1,641,788	$2,438,478	$1,360,915
Assume rate of inflation (increased costs per yr)	0.02	0.02	0.02	0.02	0.02	0.02
Assume annual rate of return	0.06	0.06	0.06	0.06	0.06	0.06
Assume Life Cycle of Pipeline	30	30	30	30	30	30
Net Future Value of Future Costs (with inflation)	$266,959,237	$210,616,272	$174,796,149	$148,693,603	$220,848,288	$123,255,482
Net Present Value (using assumed interest rate)	$46,480,307	$36,670,426	$30,433,780	$25,889,062	$38,451,924	$21,460,028
Capital Cost Calculated Above	$274,738,600	$274,738,600	$274,738,600	$274,738,600	$274,738,600	$274,738,600
Total Present Costs for Pipeline	$329,351,170	$319,541,289	$313,304,643	$308,759,925	$321,322,787	$304,330,891

When the present value of capital and OM&R costs for a Toledo Bend-Merit Pipeline is compared to the present value of capital and OM&R costs for construction of Lake Ralph Hall and a pipeline to convey water to UTRWD's terminal storage area near Merit, Texas, the costs for the Toledo Bend-Merit Pipeline are approximately thrice as much in present day value.

Desalination Plant in Texas City and Pipeline to Merit Costs for Alternatives Analysis

Overview

This memorandum documents the development of construction, operation and maintenance costs involved to build and operate a desalination plant on the Gulf Coast and a pipeline to convey the treated water from the plant to UTRWD's terminal storage area near Merit, TX. Merit is selected as the terminal storage area for the pipeline because the life cycle costs for Lake Ralph Hall (see below) also consider a pipeline that terminates at Merit. The costs include the cost of constructing and operating the desalination plant over 30 years, pipeline construction and operation cost, associated Right of Way acquisition, pump station and balancing reservoir costs. The 30-year life cycle is used with the understanding that after a 30 year life, the plant and/or the pipeline would have to undergo rehabilitation.

The costs are grouped into two major categories:

1. Construction Cost
2. Annual Operation, Maintenance and Repair Cost

Assumptions

The assumptions made to develop the cost estimates are listed below:

1. Average flows would be 34,050 ac-ft /yr
2. The intake works and desalination plant are located at 0 ft MSL elevation at Texas City, and coordinates are 29°19'N, 94°54'W
3. The pipeline would be 320 miles long.
4. The life of the desalination plant and the pipeline is 30 years.
5. The terminal is located at 710 ft MSL elevation
6. The pipeline Hazen Williams Roughness coefficient is 120 (mature cement-mortar lined pipe)
7. The pump efficiency is 80%
8. The maximum pipeline pressure is 150 psig
9. The pipeline would not cross any major river systems (additional bridge cost)
10. Annual rate of return on investment is 6%
11. Annual rate of inflation is 2%

Methodology

Lift- Also known as static head difference- This is the difference in elevation between the proposed desalination plant at Texas City and the UTRWD Terminal, and is computed as 710 feet.

Velocity head: This is the energy contained in a stream of water due to its velocity. The energy is lost when the water is discharged. The amount off work required to produce this velocity is equivalent to picking this water up high enough that it would attain the required velocity in falling. This value, referred to as velocity head, is on the order of 0.5 foot, and can be considered negligible for a long pipe line.

Pressure losses - Pressure losses are calculated using Hazen-Williams equation using a roughness coefficient of 120, and additional criteria laid out in the document titled "Proposed Lake Ralph Hall Pipeline and Pump Criteria for Alternative Analysis" prepared by CH2M Hill in June 2015.

A 320 mile pipeline would be required from Texas City to Merit. See Figure 1 for the alignment assumed for this exercise. Other alignments are possible, but this one was selected for being the shortest distance. A feasibility study would help determine the most constructible pipeline route.

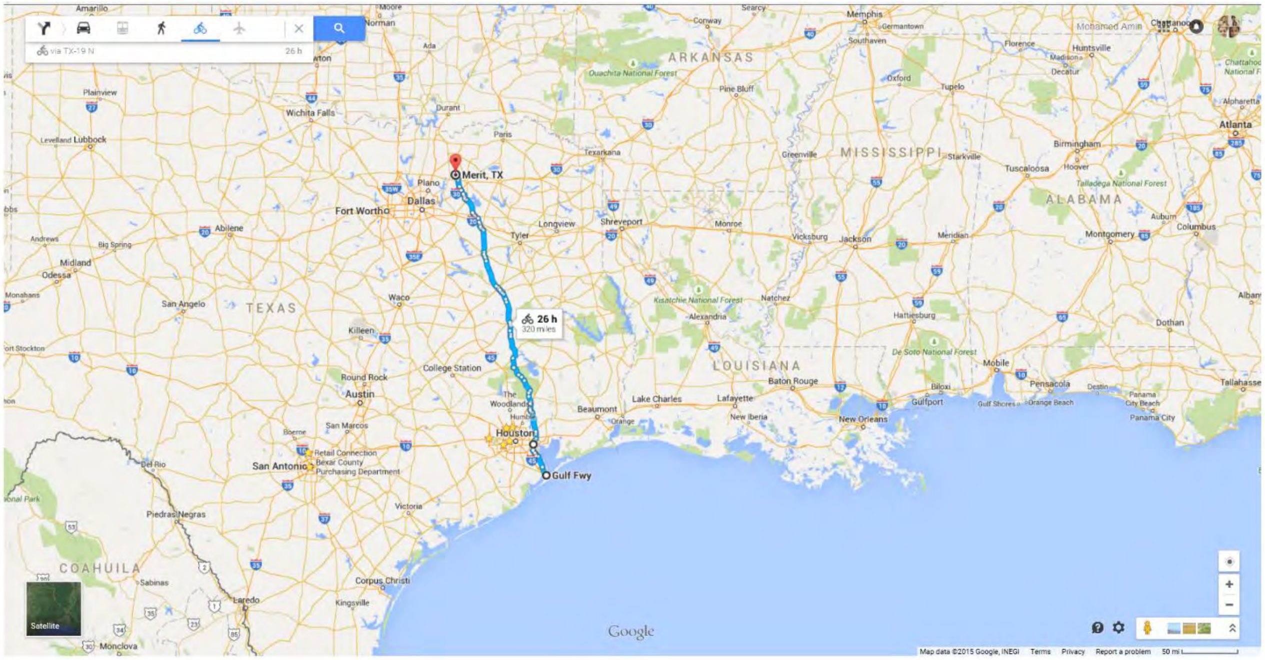
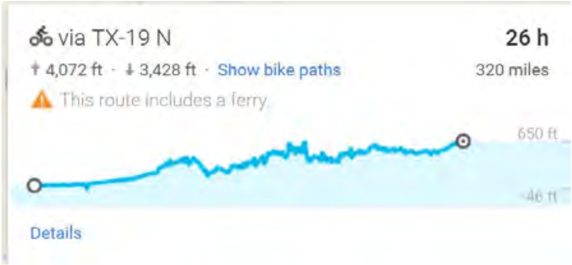


Figure 1: Preliminary Alignment for Pipeline from Texas City to Merit, TX

Figure 2 shows the terrain along the selected 320 mile pipeline alignment.



via TX-19 N 26 h

↑ 4,072 ft · ↓ 3,428 ft · Show bike paths 320 miles

This route includes a ferry

For headloss calculations, the equivalent pipeline length is assumed to be 30% larger to account for in-pipe losses due to enlargements, contractions, elbows and couplings. For headloss calculation, therefore, the equivalent length used is 416 miles, which is 30% higher than the 320 mile pipeline length.

The desalination plant construction and annual operating costs were estimated by CH2M Hill using their Parametric Cost Estimation System. The capital construction and Operating costs computed in the CH2M Hill study have been adopted as elements of this analysis after a cursory review for logic and reasonability. The pipeline construction and annual operating costs are determined using the Proposed Lake Ralph Hall Pipeline and Pump Criteria for Alternative Analysis prepared by CH2M Hill in June 2015.

Six alternatives are evaluated and are summarized in Table 1 below. These six alternatives represent unique combinations of possible annual flow volumes that would be required and pipe line diameters that can be used to carry these flows. The maximum annual flow is 45,000 ac-ft/yr, and the average annual flow is 34,050 ac-ft/yr. Pipe diameters have been varied from 42” to 56”. A 42” diameter pipeline may be cheaper to purchase but more expensive to operate over its life span because of higher energy costs to pump water; conversely a larger diameter pipeline may be more expensive to install, but would cost less to operate over a 30 year life span because of lower energy costs to pump water through it.

Table 1: Alternatives Evaluated

Alternative	**1**	**2**	**3**	**4**	**5**	**6**
Annual Flow (ac-ft) used	45,000	45,000	45,000	34,050	34,050	34,050
Pipe Size (in)	48	52	56	48	42	52

Capital Costs

Unit Costs- December 2012 unit costs for Lake Ralph Hall were escalated to 2015 costs using a construction cost escalation (CCE) based on ENR Construction Cost Indexes from both years. The resulting CCE was computed as 1.0296. The Unit costs used in this analysis are listed below:

Table 2: Unit Costs

Item	**Unit**	**2012 Cost**	**2015 Cost**
Pipeline Construction	FT	$300	$309
Pipeline ROW	FT	$5.51	$5.67
Pump Station Construction	LS/EA	$10,500,000	$10,810,000
Balancing Reservoir	LS/EA	$1,500,000	$1,544,400
Water Cost	/1000 gal	$0.56	$0.56
Electricity	/KwH	$0.08	$0.08

Capital Costs for construction are assumed to occur within 1 year. They include costs for Pipeline construction, ROW cost, Pump Station Cost, Cost of Balancing Reservoirs, and added contingency.

Table 3: Capital Construction Costs for each alternative

Alternative	1	2	3	4	5	6
Desalination Plant Cost*	$409,890,000.00	$409,890,000.00	$409,890,000.00	$409,890,000.00	$409,890,000.00	$409,890,000.00
Pipeline Construction Cost	$521,883,648.00	$521,883,648.00	$521,883,648.00	$521,883,648.00	$521,883,648.00	$521,883,648.00
ROW Cost	$9,585,263.00	$9,585,263.00	$9,585,263.00	$9,585,263.00	$9,585,263.00	$9,585,263.00
Pump Station Cost	$140,540,400.00	$108,108,000.00	$86,486,400.00	$97,297,200.00	$162,162,000.00	$75,675,600.00
Cost of Balancing Reservoirs	$18,000,000.00	$13,500,000.00	$10,500,000.00	$12,000,000.00	$21,000,000.00	$9,000,000.00
Total Capital Cost	$1,099,899,311.00	$1,062,966,911.00	$1,038,345,311.00	$1,050,656,111.00	$1,124,520,911.00	$1,026,034,511.00
Add contingency	1.3	1.3	1.3	1.3	1.3	1.3
Total Construction Cost	$1,429,869,104.30	$1,381,856,984.30	$1,349,848,904.30	$1,365,852,944.30	$1,461,877,184.30	$1,333,844,864.30

*- See CH2M Hill Parametric Cost Estimates for this cost.

Operation, Maintenance and Repair Costs

These include costs of running the desalination plant, chemicals, labor costs for operating the desalination plant, and electricity required to operate the pump stations. There is no cost of purchasing water under this alternative. See Table 2 above for the unit costs adopted for this exercise. A 10% contingency is added to the operations cost for maintenance and repair.

Table 4: OM&R Costs

Alternative	1	2	3	4	5	6
Desalination Plant Annual Cost*	$51,700,000.00	$51,700,000.00	$51,700,000.00	$51,700,000.00	$51,700,000.00	$51,700,000.00
Total Cost of Electricity	$20,273,680.18	$14,789,548.21	$11,303,003.25	$10,151,933.14	$17,175,095.95	$7,675,918.42
Total Water Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Add 10% for repair & maintenance costs	$2,027,368.02	$1,478,954.82	$1,130,300.32	$1,015,193.31	$1,717,509.60	$767,591.84
Annual Operating Cost	$74,001,048.20	$67,968,503.03	$64,133,303.57	$62,867,126.45	$70,592,605.55	$60,143,510.26

*- See CH2M Hill Parametric Cost Estimates for this cost.

Present value life cycle cost estimate was developed and applied to the annual operating, maintenance and repair costs to allow for a "normalized" (i.e. "apples to apples") comparison of the options. The life cycle cost analysis includes the capital construction cost and the M&R costs over a 30-year period of time.

All construction is assumed to occur within a year; therefore, the associated construction costs are presented at present value. The OM&R life cycle cost is calculated at present value using Engineering Economic Analyses practices. The future value of the OM&R costs include estimating the annual average OM&R cost then summing it over 30 years by assuming a 2% increase every year due to inflation, and is calculated using the following formula:

$$FV = \frac{A * [(1+i)^n - 1]}{i}$$

FV = Future Value
A = Annual Cost
i = interest rate
n = number of years

To determine the present value, the future value is brought to the present value by assuming a 6% rate of return on the investment using the following formula:

$$PV = \frac{FV}{(1+i)^n}$$

PV = Present Value
FV = Future Value
i = interest rate
n = number of years

The rate of return is included to define how much money the project owners would need to have available today to pay for the construction, operation and maintenance over the entire life cycle of the project. This enables an apples-to-apples comparison between various alternatives using present value, which is a common baseline.

The detailed OM&R cost and life cycle estimates are provided in in the attached table and are summarized in **Table 5 below.**

Results:

Costs were derived for 6 alternatives. Capital Costs were estimated to occur within the next 12 months. Annual operations, maintenance and repair costs were estimated over a 30 year life cycle and reported as present costs using a 6% annual rate of return and a 2% annual rate of inflation. A desalination plant in Texas City and a 48-inch pipeline carrying 45,000 ac-ft. a year from the desalination plant to Merit would cost **$2,596,778,314** in 2015 dollars. In comparison, the same desalination plant in Texas City and a 48-inch pipeline carrying the average flow of 34,050 ac-ft. per year over the same distance would cost **$2,357,193,344.52** in 2015 dollars. The difference is the present value of the higher cost of electricity and the additional pump stations and balancing reservoirs required to deliver water to Merit if the higher flow is needed.

Table 5: Costs in present value format

Alternative	1	2	3	4	5	6
Volume	45000	45000	45000	34050	34050	34050
Pipe Size (in)	48	52	56	48	42	52
Total Construction Cost	$1,429,869,104.30	$1,381,856,984.30	$1,349,848,904.30	$1,365,852,944.30	$1,461,877,184.30	$1,333,844,864.30
Annual Operating Cost	$74,001,048.20	$67,968,503.03	$64,133,303.57	$62,867,126.45	$70,592,605.55	$60,143,510.26
Total Present Costs	**$2,596,778,313.85**	**$2,453,640,074.16**	**$2,361,155,423.74**	**$2,357,193,344.52**	**$2,575,039,274.79**	**$2,282,237,050.70**

Next, the present value of capital construction and OM&R costs for the Lake Ralph Hall dam and reservoir and a pipeline to convey water to UTRWD's terminal storage area near Merit, TX is computed. UTRWD's 2012 capital costs for construction are used as a starting point for capital construction costs, and the 2012-2015 CCE Index value of 1.0296 is applied to determine 2015 capital construction costs.

Table 6: Lake Ralph Hall Capital Costs

PROJECTED 2012 COSTRUCTION COSTS Adjusted to 2015						
CONSTRUCTION COSTS	**Quantity**	**Unit**	**Unit Price**	**2012 Cost**	**CCE (2012 - 2015)**	**2015 Cost**
Mobilization and Demobilization	1	LS	$5,187,750	$5,187,750	1.0296	$5,341,307
Storm water Prevention	1	LS	$611,935	$611,935	1.0296	$630,048
Clearing & Grubbing	450	AC	$2,500	$1,125,000	1.0296	$1,158,300
Demolition	1	LS	$1,000,000	$1,000,000	1.0296	$1,029,600
Care of Water	1	LS	$250,000	$250,000	1.0296	$257,400
Relocations						
Roadways	25,000	LF	$300	$7,500,000	1.0296	$7,722,000
Roadway Embankments	330,329	CY	$6.00	$1,981,974	1.0296	$2,040,640
Major Bridges	5,100	LF	$2,900	$14,790,000	1.0296	$15,227,784
Minor Bridges	1,450	LF	$2,000	$2,900,000	1.0296	$2,985,840
Utility Relocations:						
AT& T	24,000	LF	$30	$720,000	1.0296	$741,312
Oncor	67,000	LF	$45	$3,015,000	1.0296	$3,104,244
Fiber Optic	19,000	LF	$30	$570,000	1.0296	$586,872
Miscellaneous Relocations	1	LS	$1,000,000	$1,000,000	1.0296	$1,029,600
Embankment Random Fill	3,476,415	CY	$6.00	$20,858,490	1.0296	$21,475,901
Embankment Core	906,016	CY	$6.50	$5,889,104	1.0296	$6,063,421
Principal Spillway Reinf. Conc.	22,471	CY	$300	$6,741,300	1.0296	$6,940,842

PROJECTED 2012 COSTRUCTION COSTS Adjusted to 2015

CONSTRUCTION COSTS	**Quantity**	**Unit**	**Unit Price**	**2012 Cost**	**CCE (2012 - 2015)**	**2015 Cost**
Emergency Spillway Mass/Reinf. Conc.	38,980	CY	$250	$9,745,000	1.0296	$10,033,452
Rock Riprap	394,202	SY	$75	$29,565,150	1.0296	$30,440,278
Raw Water Pump Station/Outlet Works	1	LS	$10,500,000	$10,500,000	1.0296	$10,810,800
Booster PS Improvements	1	LS	$1,500,000	$1,500,000	1.0296	$1,544,400
Balancing Reservoir	1	LS	$1,500,000	$1,500,000	1.0296	$1,544,400
Raw Water Pipeline	170,544	LF	$300	$51,163,200	1.0296	$52,677,631
CONSTRUCTION TOTAL				**$178,113,903**		**$183,386,075**
Contingencies*, Professional Services & Permitting	1	LS	$53,434,000	$53,434,000	1.0296	$55,015,646
Land Acquisition & Mitigation	1	LS	$42,251,000	$42,251,000	1.0296	$43,501,630
Pipeline Easements	170,544	LF	$5.51	$939,697	1.0296	$967,512
TOTAL COST				**$274,738,600**		**$282,870,863**

Operations, Maintenance and Repair costs are then calculated for the LRH-Merit Pipeline using the same assumptions as the Texas City- Merit Pipeline, including the assumption regarding water cost- it is assumed here that there would be no cost for the water. OM&R Costs are based on UTRWD's proposed alignment #4, which is 32.3 miles long.

Table 7: LRH OM&R Costs

Alternative	**1**	**2**	**3**	**4**	**5**	**6**
Volume (ac-ft)	**45000**	**45000**	**45000**	**34050**	**34050**	**34050**
Pipe length (UTRWD's proposed Alignment # 4) (mi)	32.3	32.3	32.3	32.3	32.3	32.3
dh = inside or hydraulic diameter (inches)	**48**	**52**	**56**	**48**	**42**	**52**
Head Loss (ft/mi)	8.86	6.00	4.18	5.29	10.13	3.58
Terminal Elevation (provided)	710	710	710	710	710	710
LRH Elevation (estimated)	509	509	509	509	509	509
Velocity Head (ft)	0.38	0.28	0.21	0.22	0.37	0.16
Total Head Required (ft)	573.73	453.52	377.09	423.39	626.82	351.66
Pump Efficiency	80%	80%	80%	80%	80%	80%
Horse Power Required (hp)	5052.36	3993.75	3320.70	2821.23	4176.79	2343.29
Total Dynamic Pumping Head (ft)	581.41	458.70	380.69	427.98	635.66	354.76
Operating Cost						
Energy Needed(kwh)	33,495,557.12	26,426,168.25	21,931,793.88	$18,656,690.28	27,709,986.10	15,464,952.56
Unit Cost of Electricity	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08
Total Cost of Electricity	**$2,679,644.57**	**$2,114,093.46**	**$1,754,543.51**	**$1,492,535.22**	**$2,216,798.89**	**$1,237,196.20**
Add 10% for repair & maintenance costs	$267,964.46	$211,409.35	$175,454.35	$149,253.52	$221,679.89	$123,719.62
Annual Operating Cost	**$2,947,609.03**	**$2,325,502.81**	**$1,929,997.86**	**$1,641,788.74**	**$2,438,478.78**	**$1,360,915.82**

The present value costs are then computed using the same formulae to calculate future value of all operating costs over a 30 year lifespan, assuming a 2% inflation rate, and a 6% annual rate of return, and then adjusting the future value of operating costs to present day value. Capital construction costs are then added in. See Table 8 below for the present day value of costs for each alternative.

Table 8: LRH Combined Costs at Present Value

Alternative	**1**	**2**	**3**	**4**	**5**	**6**
Volume (ac-ft)	**45000**	**45000**	**45000**	**34050**	**34050**	**34050**
Pipe Diameter	**48**	**52**	**56**	**48**	**42**	**52**
Annual Operating Cost	$2,947,609	$2,325,502	$1,929,997	$1,641,788	$2,438,478	$1,360,915
Assume rate of inflation (increased costs per yr)	0.02	0.02	0.02	0.02	0.02	0.02
Assume annual rate of return	0.06	0.06	0.06	0.06	0.06	0.06
Assume Life Cycle of Pipeline	30	30	30	30	30	30
Net Future Value of Future Costs (with inflation)	$266,959,237	$210,616,272	$174,796,149	$148,693,603	$220,848,288	$123,255,482
Net Present Value (using assumed interest rate)	$46,480,307	$36,670,426	$30,433,780	$25,889,062	$38,451,924	$21,460,028
Capital Cost Calculated Above	$274,738,600	$274,738,600	$274,738,600	$274,738,600	$274,738,600	$274,738,600
Total Present Costs for Pipeline	$329,351,170	$319,541,289	$313,304,643	$308,759,925	$321,322,787	$304,330,891

When the present value of capital and OM&R costs for a desalination plant at Texas City and a pipeline carrying treated water to Merit TX is compared to the present value of capital and OM&R costs for construction of Lake Ralph Hall and a pipeline to convey water to UTRWD’s terminal storage area near Merit, TX, the costs for the Desalination Plant are approximately 8 times as much in present day value. Considering Alternative 4 in both cases – LRH Alternative 4 would cost **$308,759,925,** while Alternative 4 for the desalination plant in Texas City, and a pipe line to Merit, TX would cost **$2,357,193,344.52**.

A-5: Typical Reservoir Development Schedule

Michael Baker
INTERNATIONAL

We Make a Difference

MEMO

To: **Mr. Chandler Peter, U.S. Army Corps of Engineers, Fort Worth District**

From: **Matt Barkley**

Subject: Toledo Bend Alternative Practicability Analysis

Michael Baker International (MBI) is currently in the process of preparing a Draft Environmental Impact Statement (DEIS) for the proposed Lake Ralph Hall (LRH) in accordance with the National Environmental Policy Act (NEPA). The DEIS is in support of the Fort Worth District U.S. Army Corps of Engineers' (USACE) consideration of the Upper Trinity Regional Water District's (UTRWD's) application for a Section 404 Individual Permit.

MBI is evaluating the practicability of alternatives to LRH that might meet UTRWD's water supply requirements as established by the Purpose and Need for the proposed action. One such alternative involves the conveyance of raw water from the Toledo Bend Reservoir to UTRWD. The Toledo Bend Pipeline Alternative would include transferring 34,050 acre-feet (ac-ft) of water per year from Toledo Bend Reservoir to a balancing reservoir near Merit, Texas through a 219-mile newly constructed pipeline. From the balancing reservoir, the raw water would be conveyed to UTRWD's existing raw water treatment system via an existing pipeline.

MBI provided USACE with a document titled, "*Lake Ralph Hall Environmental Impact Statement NEPA, Public Interest Review and Clean Water Act Section 404 (b)(1) Alternatives Analysis Toledo Bend Alternative (e.g., pipeline) Practicability Analysis*" (transmitted to USACE's Mr. Chandler Peter via e-mail on November 2, 2015). The document included analyses of water availability, environment impacts, costs and a timeline for developing a Toledo Bend Pipeline Alternative. Based on the results of the practicability analyses, MBI concluded that the Toledo Bend Pipeline Alternative required further study and consideration as an alternative to LRH.

At the direction of UTRWD, CH2M Hill, Inc. (CH2M) provided supplemental information and analyses specific to the Toledo Bend Pipeline Alternative via a technical memorandum dated June 8, 2016. The technical memorandum focused primarily on a critique of the schedule to develop this alternative provided by MBI and concluded that MBI's proposed timeline for developing this alternative should be modified. Specifically, CH2M suggested the following schedule revisions:

- Extend the water rights permit timeline from ~5.5 years to ~7.7 years;

- Extend the design timeline from ~2 years to ~5.5 years (The water rights permitting process can range from one year to greater than ten years depending on project complexity and whether or not the application is contested[1]);
- Initiate design after the water rights permit is issued rather than conducting these activities with some overlap;
- Extend the Section 404 Individual Permit timeline from 6 months to 9 months;
- Increase the construction duration from 3 years to 5 years.

The schedule modifications proposed by the CH2M technical memorandum would extend the schedule for developing this alternative from MBI's estimate of approximately 8.5 years to almost 19 years. Given the substantial difference between the two estimates, MBI re-evaluated the timeline for developing this alternative. The following paragraphs provide a summary of the findings of the re-evaluation.

Section 404 Individual Permit

Per direction from USACE, the duration for the Individual 404 permit remains at 6 months. However, MBI recommends that the 404 permit task start after the water rights permit is obtained. Currently, the State water rights and the Federal 404 permitting processes differ substantially in terms of technical requirements and the level of design details required. While there are efforts underway to streamline both processes, the existing differences between them do not lend well to conducting the permitting processes concurrently, particularly when considering a pipeline project like the Toledo Bend Pipeline Alternative. It is reasonable to assume that an Applicant like UTRWD would not incur costs to design and pursue a 404 permit until after they receive their water rights permit from the State of Texas given the risks involved in the water rights process.

Final Design and ROW Acquisition

Both the Final Design and ROW acquisition tasks would require significant investment from the Applicant. It is reasonable to assume that an Applicant like UTRWD could advance some ROW acquisition and design work at risk (prior to the water rights permit), but the majority of these tasks would not be conducted until after receipt of the water rights permit.

Construction Schedule

It is highly unlikely that an Applicant like UTRWD would initiate construction in advance of obtaining the water rights permit. While an Applicant could begin construction before obtaining a water right, such action would include risk at a level that would be contrary to sound stewardship of public funds. As indicated by TCEQ, the water rights permit application process timeframe varies greatly, especially when the application is contested. Several recent pipeline projects identified by CH2M and further examined by MBI are summarized below:

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[1] Email from Kim Wilson March 31, 2016

1. Tarrant Regional Water District (TRWD) and the City of Dallas Water Utilities have partnered to finance, plan, design, construct, and operate the Integrated Pipeline (***IPL Project***). The IPL Project is an integrated water delivery transmission system connecting Lake Palestine to Lake Benbrook with connections to Cedar Creek and Richland-Chambers Reservoir. The project consists of 150 miles of pipeline, three new lake pump stations, and three new booster pump stations delivering a required capacity of 350 million gallons per day of water to North Central Texas. The first phase of the project includes the construction of 68 miles of pipeline. The construction of Phase I began in May 2014 and is scheduled to be completed in October 2020. The pipeline is scheduled to be operational in 2021.[2]
2. The 41-mile ***Mary Rhodes Phase II Pipeline Project*** will connect the Colorado River to the Mary Rhodes Phase I Pipeline. The project was designed and permitted in 4 years and required a 2-year construction period. The design phase of the project was completed in October 2013. The City of Corpus Christi completed bidding in January 2014 and awarded construction contracts in February 2014. Construction of the project started in April 2014 and was scheduled to be completed in summer of 2015.[3] However, heavy rains delayed the completion to early 2016 when commissioning of the pipeline began.[4]
3. Due to ongoing drought conditions and the presence of the zebra mussel in Lake Texoma, the North Texas Municipal Water District (NTMWD) constructed the 48-mile ***Lake Texoma Pipeline*** from Lake Texoma to the Wylie Water Treatment Plant. The design phase for this project began in 2011 and construction was completed in 2014. The project did not require additional water rights.[5]

After reviewing construction schedules for other similar projects, MBI recommends the duration of the construction task for the Toledo Bend Pipeline Alternative be increased from 3 years to 5 years to better reflect actual construction durations of recently completed or on-going pipeline construction projects in Texas.

These revisions to the schedule would increase Toledo Bend Pipeline Alterative project implementation timeline to approximately 16 years with a completion date in 2032. As a result, the Toledo Bend Pipeline Alternative is not practicable for UTRWD to pursue as an alternative to LRH since UTRWD need is 34,050 ac-ft/yr by 2024.

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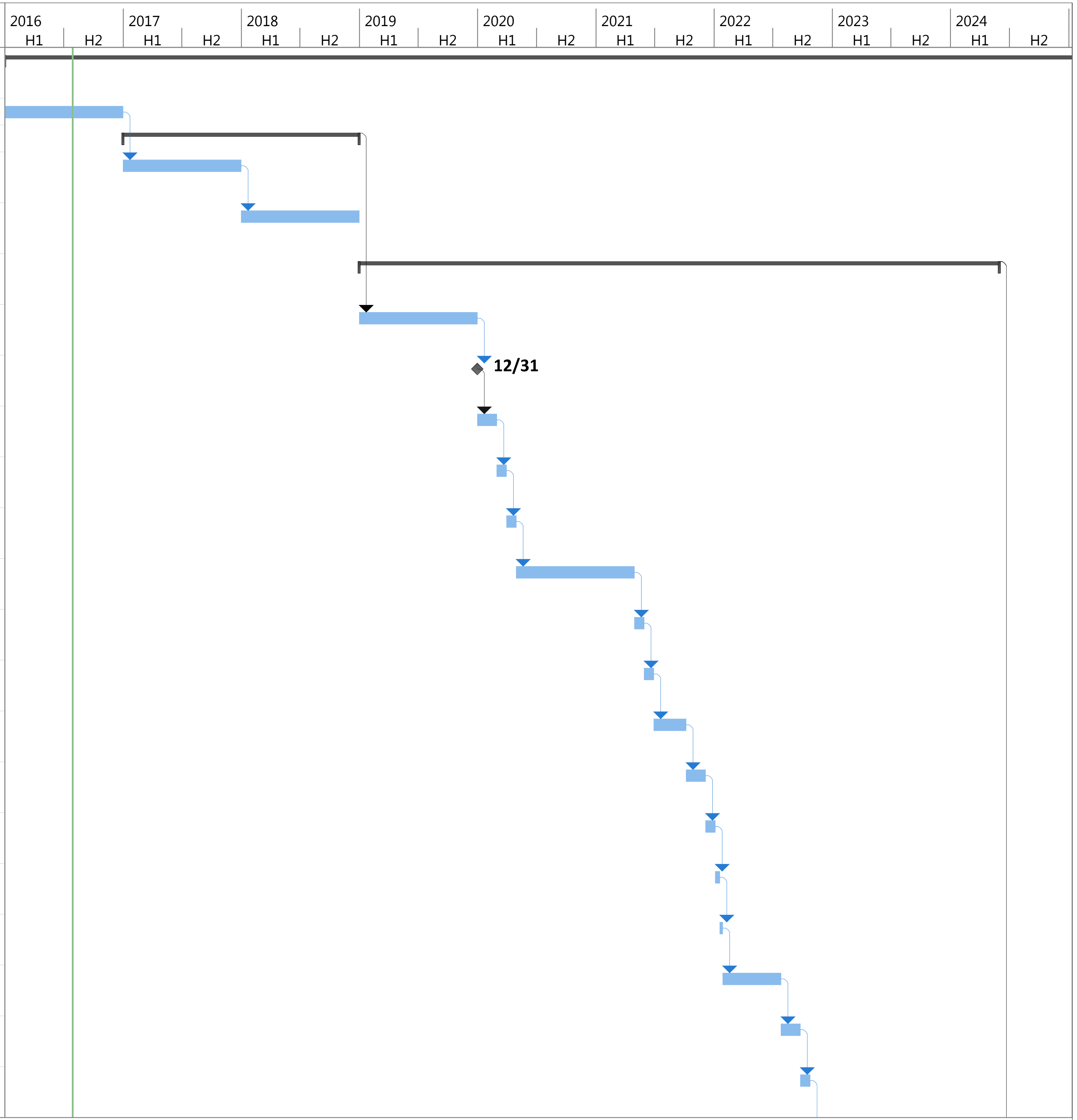
[2] Tarrant Regional Water District (TRWD). 2016. Integrated Pipeline. http://www.iplproject.com/. Accessed July 2016.

[3] City of Corpus Christi. 2016. Mary Rhodes Pipeline. http://engineercc.com/mary-rhodes-pipeline. Accessed July 2016.

[4] San Patricio Municipal Water District. 2016. Mary Rhodes Pipeline Phase 2 Nearing Completion. http://sanpatwater.com/news%204.7.16%20MRP2.php. Accessed July 2016.

[5] North Texas Municipal Water District. 2016. About Our Water System. https://www.ntmwd.com/watersystem.html. Accessed July 2016.

ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
1			**Toledo Bend Pipeline Alternative**	**4281 days**	**Fri 1/1/16**	**Sat 5/29/32**
2	📅		**Negotiate and Execute Contract for Purchase**	365 edays	Fri 1/1/16	Sat 12/31/16
3			**Project Definition Studies**	**520 days**	**Sat 12/31/16**	**Mon 12/31/18**
4			Route Studies	365 edays	Sat 12/31/16	Sun 12/31/17
5			Schematic Design	365 edays	Sun 12/31/17	Mon 12/31/18
6			**Water Right**	**1414 days**	**Mon 12/31/18**	**Fri 5/31/24**
7			Prepare Application	365 edays	Mon 12/31/18	Tue 12/31/19
8			Application filed	0 days	Tue 12/31/19	Tue 12/31/19
9			TCEQ determination of administrative completeness	60 edays	Tue 12/31/19	Sat 2/29/20
10			Initial public notice	30 edays	Sat 2/29/20	Mon 3/30/20
11			Deadline for comments on the application	30 edays	Mon 3/30/20	Wed 4/29/20
12			TCEQ determination of technical completeness	365 edays	Wed 4/29/20	Thu 4/29/21
13			Second public notice	30 edays	Thu 4/29/21	Sat 5/29/21
14			Deadline for comments on the draft permit	30 edays	Sat 5/29/21	Mon 6/28/21
15			TCEQ will prepare a response to comments (RTC)	100 edays	Mon 6/28/21	Wed 10/6/21
16			Letter to requestors	60 edays	Wed 10/6/21	Sun 12/5/21
17			Deadline for applicant and others to file responses to hearing requests	30 edays	Sun 12/5/21	Tue 1/4/22
18			Deadline for requesters to file replies to responses for hearing requests	14 edays	Tue 1/4/22	Tue 1/18/22
19			Meeting of the Commissioners	9 edays	Tue 1/18/22	Thu 1/27/22
20			preliminary hearing to proposal for a decision	180 edays	Thu 1/27/22	Tue 7/26/22
21			hearing request is granted, new public notice (newspaper) of the preliminary hearing is required	60 edays	Tue 7/26/22	Sat 9/24/22
22			Preliminary hearing	30 edays	Sat 9/24/22	Mon 10/24/22



Project: Toledo Bend Revised
Date: Fri 7/29/16

Task	▬	Project Summary	⊓	Manual Task	▬	Start-only	[	Deadline	⇩
Split	┈	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	─
Milestone	◆	Inactive Milestone	◇	Manual Summary Rollup	▬	External Tasks	▬	Manual Progress	─
Summary	⊓	Inactive Summary	⊓	Manual Summary	⊓	External Milestone	◆		

ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
23			hearing on the merits (i.e., the trial) is held by a SOAH ALJ	180 edays	Mon 10/24/22	Sat 4/22/23
24			court reporter prepares the transcript of the hearing.	10 edays	Sat 4/22/23	Tue 5/2/23
25			Filing of written final arguments	30 edays	Tue 5/2/23	Thu 6/1/23
26			Parties file responses to final written arguments of others	15 edays	Thu 6/1/23	Fri 6/16/23
27			Recommendation of the ALJ(s) to the TCEQ Commissioners	60 edays	Fri 6/16/23	Tue 8/15/23
28			Deadline to file exceptions to the PFD	20 edays	Tue 8/15/23	Mon 9/4/23
29			Deadline to respond to exceptions of others	10 edays	Mon 9/4/23	Thu 9/14/23
30			Commissioners’ meeting to consider the proposal for decision and exceptions and replies,	90 edays	Thu 9/14/23	Wed 12/13/23
31			Written order of the Commission is mailed to all parties	30 edays	Wed 12/13/23	Fri 1/12/24
32			Deadline to file motion for rehearing to ask the Commission to reconsider the decision	20 edays	Fri 1/12/24	Thu 2/1/24
33			Commission grants or denies motion for rehearing	90 edays	Thu 2/1/24	Wed 5/1/24
34			If the motion is denied, deadline to file appeal to court	30 edays	Wed 5/1/24	Fri 5/31/24
35			**Individual 404 Permit**	180 edays	Fri 5/31/24	Wed 11/27/24
36			**Final Design**	730 edays	Fri 5/31/24	Sun 5/31/26
37			**ROW Acquisition**	1095 edays	Fri 5/31/24	Mon 5/31/27
38			**Construction**	1825 edays	Sun 5/31/26	Fri 5/30/31
39			**Commissioning**	365 edays	Fri 5/30/31	Sat 5/29/32

Task	▬	Project Summary	⎴	Manual Task	▬	Start-only	[	Deadline	⇩
Split	┈	Inactive Task	▭	Duration-only	▬	Finish-only	]	Progress	─
Milestone	◆	Inactive Milestone	◇	Manual Summary Rollup	▬	External Tasks	▬	Manual Progress	─
Summary	⎴	Inactive Summary	⎴	Manual Summary	⎴	External Milestone	◆		

A-6: Correspondence

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF

February 9, 2015

Regulatory Division

Mr. Walt Sears Jr.
Executive Director
Northeast Texas Municipal Water District
P.O. Box 955
Hughes Springs, TX 75656

Dear Mr. Sears:

The United States Army Corps of Engineers, Fort Worth Regulatory Division (USACE) is preparing a Draft Environmental Impact Statement (DEIS) for the proposed Lake Ralph Hall project located in Fannin County, Texas. The project proponent, Upper Trinity Regional Water District (UTRWD), submitted an application to the USACE for a Department of the Army permit under Section 404 of the Clean Water Act (CWA), to discharge dredged and fill material into waters of the United States (U.S.) for the purpose of constructing the proposed Lake Ralph Hall project.

UTRWD is legally obligated, as requested, to provide treated wholesale water to retail water providers within UTRWD's planning area, including Denton County and small portions of Collin, Grayson, Wise and Cooke counties to the extent that Denton County Customers' service areas extend outside the County. UTRWD presently obtains its supplies by purchasing water from the Sulphur River Water District and Commerce out of Lake Chapman, and raw water from Denton and DWU and reuse. According to the 2011 Region C Water Plan, UTRWD's currently available supplies range between 33,158 and 63,463 acre-feet per year from 2010 to 2060 and they need to develop an additional 100,520 acre-feet per year by 2060. To meet part of the growing demands of its customers, UTRWD proposes to develop the Lake Ralph Hall reservoir and consequently, the 2011 Region C Plan identifies it as a recommended water management strategy for UTRWD.

Pursuant to the National Environmental Policy Act of 1969 (NEPA) and Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR 230), USACE is undertaking an independent evaluation and screening process of alternatives initially considered by UTRWD as well as others. One such alternative is the Lake O' the Pines. In our effort to independently evaluate the Lake O' the Pines alternative, we request the following information from Northeast Texas Municipal Water District (NETMWD):

1. The amount of uncommitted (e.g., contracted and/or permitted but unused) raw water available from the Lake O' the Pines for distribution to any wholesale water suppliers in any planning area, including entities like UTRWD in the Texas Water Development Board Region C Group's planning area;

2. Any new information that you may have specific to the data gaps relevant to the Lake O' the Pines identified in the *Region C Study Commission – Final Report – Phase I and II* (Espey Consultants 2010), specifically:

   a. What volume of water is available from Lake O' the Pines, including permitted water that has not been contracted below 228.5 feet above mean sea level?
   b. Are there any other considerations for existing water rights holders (including contracts that may not be fully utilized), anticipated local needs over the term of a contract period, unexpected local need and retained local excess surplus supply for drought protection?

3. A detailed description/schedule for the steps that it would take for NETMWD to contract and sale any uncommitted raw water to a wholesale water supplier like UTRWD; and

4. A detailed description/NETMWD's understanding of any conveyance mechanism required to transfer any uncommitted Lake O' the Pines raw water to Region C, specifically to UTRWD.

If you have any questions concerning this matter or the preparation of the DEIS and information being gathered for it, please contact Mr. Chandler Peter at 817-886-1736 or at Chandler.J.Peter@usace.army.mil .

Sincerely,

for Stephen L. Brooks
Chief, Regulatory Division
Fort Worth District

Copies furnished:

Larry Patterson
Upper Trinity Regional Water District
900 N. Kealy
P.O. Drawer 305
Lewisville, TX 75067

Matt Barkley
Michael Baker International
810 Hester's Crossing, Suite 163
Round Rock, TX 78681

NORTHEAST TEXAS MUNICIPAL WATER DISTRICT

2003-336

February 17, 2015

Stephen L. Brooks, Chief, Regulatory Division
Corps of Engineers, Fort Worth Division
PO Box 17300
Fort Worth, Texas 76102-0300

Dear Mr. Brooks,

In reply to the questions included in your letter dated February 9, 2015, I have provided the answers as follows:

1. The amount of uncommitted (e.g., contracted and/or permitted but unused) raw water available from the Lake O' the Pines for distribution to any wholesale water suppliers in any planning area, including entities like UTRWD in the Texas Water Development Board Region C Group's planning area:

   Answer: NETMWD possesses a water right in the amount of 203,800 acre feet. A portion of that volume is allocated to municipal water uses and a portion is allocated to industrial uses. A portion of this water is authorized to be used in the Sabine River Basin (up to 47,000 acre feet annually). The remainder is authorized for use in the Cypress Creek Basin. No water has been authorized for use outside of the regional water planning area that NETMWD is located in. If a possible customer wanted water that is indisputably 100% reliable, an amount of 26,000 acre feet could be considered uncommitted water.

2. Any new information that you may have specific to the data gaps relevant to the Lake O' the Pines identified in the *Region C Study Commission – Final Report – Phase I and II (Espey Consultants 2010)*, specifically:

   A. What volume of water is available from Lake O' the Pines, including permitted water that has not been contracted below 228.5 feet above mean sea level?

   Answer: NETMWD does not have any new information specific to the data gaps mentioned above. Starting with the volume of 203,800 acre feet and subtracting all contractual commitments results in a volume of 17,800 to 50,300 acre feet, depending on how one interprets the supply contracts. It should be noted that the reliability of the water within the NETMWD water right is a subject of differing interpretation. The water right is not a guarantee that 203,800 acre feet of water will actually be annually available from water located below elevation 228.5. The question does not affirmatively impose reliability of the volume but in most municipal supplies that topic is an essential part. Some analysis suggests that not all of the 203,800 acre feet possess 100% reliability.

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In a severe drought, not all of the water described in the NETMWD water right may be available.

B. Are there any considerations for existing water right holders (including contracts that may not be fully utilized), anticipated local needs over the term of a contract period, unexpected local need and retained local excess surplus supply for drought protection?

Answer: Yes, there are considerations in play for NETMWD. For water to be used for municipal or industrial purposes there is only one water right holder in Lake O' the Pines, NETMWD. There is uncertainty about drought severity and unanticipated local needs during the next 50 years. As part of the mission to assure an adequate supply for northeast Texas, NETMWD does intend to retain some control over water within its water right by not unconditionally placing all of the volume held by NETMWD in a water supply contract. Also, NETMWD is committed to assuring the health of the environment downstream of Lake O' the Pines. Some of the water within the water right of NETMWD is and will be assigned to fulfill that environmental flow purpose. Also, water for recreational purposes is also a consideration. Recreational pursuits at Lake O' the Pines have a positive economic impact on areas served by NETMWD and its customers. These considerations would likely take a priority over possible uses/sales in remote basins.

3. A detailed description /schedule for the steps that it would take for NETMWD to contract and sale any uncommitted Lake O' the Pines raw water to Region C, specifically to UTRWD.

Answer: Each negotiation involving NETMWD about possible water sales contract is distinct and that there is no standard form or process in response to a request for water.

It is worth noting that prior to signing a contract that would allow water to be transported beyond the basin of origin, NETMWD would evaluate whether the water is needed in the basin of origin. This step is primarily due to the present law and policy considerations found in Texas Water Code 11.085.

Further, NETMWD is not interested in selling any of its water right.

4. A detailed description/NETMWD's understanding of any conveyance mechanism required to transfer any uncommitted Lake O' the Pines raw water to Region C, specifically to UTRWD.

Answer: There is no conveyance mechanism in place to transfer raw water from Lake O' the Pines to Region C. There is no conveyance mechanism from Lake O' the Pines to Region C planned at this time.

If you have any questions regarding this information, please contact me at the executive office at the number listed below.

Sincerely,

Walt Sears

Walt Sears, Jr.
General Manager
Northeast Texas Municipal Water District

Cc: Larry Patterson, Upper Trinity Regional Water District

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

November 24, 2014

REPLY TO
ATTENTION OF

Regulatory Division

Jo. M. (Jody) Puckett, P.E.
Department Director
Dallas Water Utilities
1500 Marilla Street, Room 4A North
Dallas, TX 75201

Dear Ms. Puckett:

The U.S. Army Corps of Engineers, Fort Worth District Regulatory Division (USACE) is preparing a Draft Environmental Impact Statement (DEIS) for the proposed Lake Ralph Hall project located in Fannin County, Texas. The project proponent, Upper Trinity Regional Water District (UTRWD), submitted an application to the USACE for a Department of the Army permit under Section 404 of the Clean Water Act (CWA), to discharge dredged and fill material into waters of the United States (U.S.) for the purpose of constructing the proposed Lake Ralph Hall project.

UTRWD is legally obligated, as requested, to provide treated wholesale water to retail water providers within UTRWD's planning area, including Denton County and small portions of Collin, Grayson, Wise and Cooke counties to the extent that Denton County Customers' service areas extend outside the County. UTRWD presently obtains its supplies through contracts with various water rights holders, including a contract with Dallas Water Utilities (DWU). From information provided for the DEIS, UTRWD's contract with DWU provides UTRWD with up to 61,638 acre-feet/year and terminates in 2023. However, the Region C Planning Committee projects that the maximum firm supply available from DWU to UTRWD is 42,664 acre-feet/year in 2030. It is our understanding that the Region C Plan constrained UTRWD firm supply from DWU due to DWU supply limitations but assumed that DWU would eventually secure the additional supplies necessary to meet its obligations to UTRWD. To accurately define the need and purpose for the proposed Lake Ralph Hall project, as well as evaluate potential reasonable and practicable alternatives, identification and confirmation of information is needed. It is requested that DWU confirm:

1. Its intent to renew the contract with UTRWD;
2. The amount of water (or a range) UTRWD can expect from 2023 through 2030;
3. The amount of water (or a range) UTRWD can expect by 2040, 2050 and 2060;

If there are any contingencies or uncertainties about the upcoming renewal or the other periods identified, please enumerate and describe them.

If you have any questions concerning this matter or the preparation of the DEIS and information being gathered for it, please contact Mr. Chandler Peter at (817) 886-1736 or at chandler.j.peter@usace.army.mil .

Sincerely,

for Stephen L Brooks
Chief, Regulatory Division
Fort Worth District

Copies furnished:

Larry Patterson
Upper Trinity Regional Water District
900 N. Kealy
P.O. Drawer 305
Lewisville, TX 75067

Matt Barkley
Michael Baker Jr., Inc.
810 Hester's Crossing, Suite 163
Round Rock, TX 78681

CP

2003-336

dallas water utilities
city of dallas

January 28, 2015

Mr. Stephen Brooks
Chief, Regulatory Division
Department of the Army
Fort Worth District
Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

FEB 02 2015

CAP
ltr. 2015Jan30

Re: Dallas 2014 Long Range Water Supply Plan

Dear Mr. Brooks,

In response to your letter dated November 24, 2014, regarding the preparation of a Draft Environmental Impact Statement for the proposed Lake Ralph Hall Project, the following addresses the specific questions contained in your letter. Dallas has recently updated its Long Range Water Supply Plan which contains projections based on Dallas' existing contract with Upper Trinity Regional Water District (UTRWD) as well as assumptions with respect to any future water supply relationship Dallas may have with UTRWD.

1. ***Dallas' intent to renew the contract with Upper Trinity Regional Water District (UTRWD)***
   Dallas entered into an Untreated Water Purchase Contract with UTRWD on February 12, 1992. The contract has a 30 year term which expires on February 12, 2022. The contract does not contain a renewal clause. Dallas evaluates treated and untreated water requests from both existing customers and potential new customers as they are received. All treated and untreated water contracts with political subdivisions are subject to Dallas City Council approval.

2. ***The amount of water (or a range) UTRWD can expect from 2023 through 2030***
   Dallas has recently completed its 2014 Long Range Water Supply Plan (2014 LRWSP). In the development of the 2014 LRWSP Dallas has made the assumption that Untreated Water Purchase Contract with UTRWD is renewed in 2022 with a base amount of 10 MGD plus the demand of Argyle Water Supply Corporation, Corinth, Lake Cities Municipal Water Utilities Authority, Flower Mound, Highland Village, and Lewisville. The UTRWD's assumed demand on Dallas' system in 2020 is approximately 35 MGD and approximately 42 MGD in 2030.

3. ***The amount of water (or a range) UTRWD can expect by 2040, 2050 and 2060***
   As described in the response to Question 2 above the assumption in Dallas' recently completed 2014 LRWSP is the Untreated Water Purchase Contract with UTRWD is

Our Vision: To be an efficient provider of superior water and wastewater service and a leader in the wate

1500 Marilla, 4AN, Dallas, Texas 75201
Telephone: (214) 670-3146 • Fax: (214) 670-3154

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renewed in 2022. Additionally it is assumed that an additional 10 MGD contract could be negotiated subject to Dallas City Council approval in 2060. UTRWD's assumed demands on Dallas System are 44 MGD in 2040, 44 MGD in 2050, 54 MGD in 2060 and 54 MGD in 2070.

Please do not hesitate to contact Denis Qualls, Dallas Water Utilities, and Senior Program Manager of Planning at (214) 670-3843 or me.

Sincerely,

1/28/14

Jo M. (Jody) Puckett, P.E.
Director, Dallas Water Utilities

cc: Tom Taylor, UTRWD
Larry Patterson, UTRWD
Matt Barkly, Michael Baker Jr., Inc.

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

March 11, 2015

Regulatory Division

Mr. Kevin Ward
General Manager
Trinity River Authority of Texas
P.O. Box 60
Arlington, TX 76004

Dear Mr. Ward:

The United States Army Corps of Engineers, Fort Worth Regulatory Division (USACE) is preparing a Draft Environmental Impact Statement (DEIS) for the proposed Lake Ralph Hall project located in Fannin County, Texas. The project proponent, Upper Trinity Regional Water District (UTRWD), submitted an application to the USACE for a Department of the Army permit under Section 404 of the Clean Water Act (CWA), to discharge dredged and fill material into waters of the United States (U.S.) for the purpose of constructing the proposed Lake Ralph Hall project.

UTRWD is legally obligated, as requested, to provide treated wholesale water to retail water providers within UTRWD's planning area, including Denton County and small portions of Collin, Grayson, Wise and Cooke counties to the extent that Denton County Customers' service areas extend outside the County. UTRWD presently obtains its supplies by purchasing water from the Sulphur River Water District and Commerce out of Lake Chapman, and raw water from Denton and DWU and reuse. According to the 2011 Region C Water Plan, UTRWD's currently available supplies range between 33,158 and 63,463 acre□feet per year from 2010 to 2060 and they need to develop an additional 100,520 acre□feet per year by 2060. To meet part of the growing demands of its customers, UTRWD proposes to develop the Lake Ralph Hall reservoir and consequently, the 2011 Region C Plan identifies it as a recommended water management strategy for UTRWD.

Pursuant to the National Environmental Policy Act of 1969 (NEPA) and Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR 230), USACE is undertaking an independent evaluation and screening process of alternatives initially considered by UTRWD as well as others. One such alternative is Lake Livingston. In our effort to independently evaluate the Lake Livingston Alternative, we request the following information from TRA:

1. The amount of uncommitted raw water available from Lake Livingston to wholesale water providers in the State of Texas; and
2. A detailed description of the conveyance system and supplies that TRA currently uses to provide water to Region C wholesale water providers and the quantity of that water, if any, supplied from Lake Livingston.

If you have any questions concerning this matter or the preparation of the DEIS and information being gathered for it, please contact Mr. Chandler Peter at 817-886-1736 or at Chandler.J.Peter@usace.army.mil .

Sincerely,

for Stephen L Brooks
Chief, Regulatory Division
Fort Worth District

Copies furnished:

Larry Patterson
Upper Trinity Regional Water District
900 N. Kealy
P.O. Drawer 305
Lewisville, TX 75067

✓Matt Barkley
Michael Baker International
810 Hester's Crossing, Suite 163
Round Rock, TX 78681

Gcc

Trinity River Authority of Texas

General Office

July 6, 2015

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TRA/PEMD

Mr. Elston D. Eckhardt, P.E.
Chief, Civil Project Management
United States Army Corps of Engineers
819 Taylor Street
Fort Worth, TX 76102-0300

RE: Lake Livingston
Raw Water Supply
Upper Basin Raw Water Availability

Dear Elston:

I appreciated the opportunity to visit with you in Galveston concerning the United States Army Corps of Engineers' (USACE) inquiries to the Authority regarding Lake Livingston. The purpose of those inquiries appears related to the pending review of the Upper Trinity Regional Water District (UTRWD) Lake Ralph Hall project by the Fort Worth District Office. Included herewith is information that was previously provided to Stephen L. Brooks in your office in response to USACE's inquiries.

I write to emphasize the Authority's position regarding the possibility of upstream diversions of firm-yield water permitted in Lake Livingston, or sales of Authority reuse water as a practicable alternative to the construction of Lake Ralph Hall. In short, the Authority does not intend nor would it take steps to permit the sale of firm-yield Lake Livingston water in the upper Trinity River basin. Moreover, the Authority's reuse water entitlement associated with Lake Livingston is not sufficient to make a sale of that water to UTRWD a practicable alternative to the construction of Lake Ralph Hall.

Lake Livingston Firm Yield

The Authority owns and operates the Lake Livingston for its benefit and for the benefit of its project partner, the City of Houston, Texas. The Authority's total firm-yield permit entitlement in the Lake Livingston/Wallisville system is 403,200 acre-feet per year. The Authority's existing commitments (by contract and option agreement) from Lake Livingston total 162,261 acre-feet per year, leaving 240,939 acre-feet per year available for use in the permitted service area defined by the Authority's Lake Livingston permit (enclosed). That service area does not include the upper Trinity River basin, and the Authority would not take the steps necessary to permit an upper-basin diversion of firm-yield Lake Livingston water, which is needed for lower basin demands.

Much of the Authority's remaining 240,939 acre-feet per year of firm-yield water in Lake Livingston has been allocated as future supply by the Region H Regional Water Planning

Group's Regional Water Plan. The most current version of that plan is in the form of Region H's 2016 Initially Prepared Plan (2016 IPP), which was approved by that group on April 8, 2015. A copy of the IPP can be found at http://www.regionhwater.org/downloads/documents/IPP_20150420.pdf.

The 2016 IPP calls for sales to the City of Houston of no less than 150,000 acre-feet per year from Lake Livingston. Houston has, in fact, requested that the Authority commit the entire remaining available firm yield of Lake Livingston to the city's benefit. A copy of that request is enclosed herewith. Since receiving that request, Houston and the Authority have negotiated terms for the anticipated sale of at least 200,000 acre-feet per year to the city. A sale of that volume would leave only 49,939 acre-feet per year of firm yield, which the Authority anticipates reserving for use by existing and future customers in the lake's vicinity. Given existing and future commitments, there is no portion of Lake Livingston's firm yield available to provide a practicable alternative to the necessary construction of Lake Ralph Hall. Given lower basin demands, the use of Lake Livingston's firm yield as a source to meet upper basin needs is not contemplated by the Region H or Region C Water Plan. The Authority would oppose any action to modify either of those plans to permit upper basin use of Lake Livingston's firm yield.

Lake Livingston Reuse

In 2006, the Authority received a reuse permit from the Texas Commission on Environmental Quality (TCEQ). A copy of that permit is enclosed. The Authority's Lake Livingston permit presently empowers the Authority to use the bed and banks of the Trinity River to convey return flows from three upper basin wastewater treatment plants (WWTPs) downstream to Lake Livingston. Once return flows reach the lake, the Authority can divert up to 246,519 acre-feet per year of return flows for municipal and industrial use, those flows being discharged from three Authority WWTPs. That entitlement is limited, however, in several very important ways.

Most fundamentally, the Authority's reuse permit only authorizes the Authority to divert return flows it discharges. The total reuse permit entitlement reflects future, not present flows. 2014 daily average flows from the three associated WWTPs were 139 MGD, or 155,819 acre-feet per year. Of current flows, 30% are dedicated and required to reach Lake Livingston by the Authority's permit and a separate settlement agreement with the City of Houston, leaving 97 MGD or 108,737 acre-feet per year available for diversion. Of that amount, 7 MGD is dedicated to the Dallas County Utility and Reclamation District, 25 MGD to the City of Irving and 50 MGD to the North Texas Municipal Water District, leaving 14 MGD or approximately 15,000 acre-feet per year (after channel losses) of return flows available for future indirect reuse commitments.

Like the Region H Plan, the Authority has no desire and would not support an amendment to reallocate available return flows to UTRWD in the Region C Water Plan.

Lake Livingston is not a Practicable Alternative

My purpose in writing is to convey that water supply from Lake Livingston is not a practicable alternative to UTRWD's construction of Lake Ralph Hall. Lake Livingston's firm yield and the Authority's return flows are either currently committed by contract or allocated by the Region C and H Water Plans. Lake Ralph Hall is a critical priority for the future water supply in North Texas, and I respectfully request that your office make the required approvals to allow for its construction.

Sincerely,

J. KEVIN WARD
General Manager

JKW/cac

Enclosures

A-7: Lower Bois d’Arc Creek Reservoir Additional Yield Analysis of Potential Wetland Impacts

Michael Baker INTERNATIONAL

Lower Bois d'Arc Creek Reservoir Additional Yield
Analysis of Potential Wetland Impacts

Overview

The Texas Water Development Board (TWDB) conducted the *Reservoir Site Protection Study* in 2008 and in the study, for the Lower Bois d'Arc Creek Reservoir, several runs of the water availability model (WAM) were made to assess the firm yield of the reservoir at different pool elevations. The results of that assessment were used by the Upper Trinity Regional Water District (Applicant) to estimate the conditions required to achieve an additional 34,050 ac-ft/yr firm yield, the requirement for the Applicant's proposed Lake Ralph Hall (LRH) project. This memorandum documents potential impacts to wetlands that could be caused by increasing the firm yield of the proposed Lower Bois d'Arc Creek Reservoir by 34,050 ac-ft/yr. Increasing the firm yield would require raising the conservation pool 8.75 feet to approximately 543 feet msl (see Figure 1).

Impacted wetlands were categorized as no impact or permanent. Impacts to National Wetland Inventory (NWI) wetlands classified as lake or freshwater pond were considered no impact since they are open water and would remain open water after construction of the reservoir. Impacts to forested/shrub wetlands and emergent wetlands were considered permanent because the reservoir would inundate these areas thereby preventing the reestablishment of forested and emergent wetlands in the same location.

Method

Wetland information was obtained from U.S. Fish & Wildlife Service (USFWS) NWI Geographic Information System (GIS) shapefile digital data. To determine the areas of potentially impacted wetlands, the additional yield and original Lower Bois d'Arc Creek Reservoirs were created using the 543 ft and 534 ft elevation lines respectively, generated from the 2013 1/3 arc second National Elevation Dataset (NED). The best available and most recent data for this area was used to create the contour lines used for this analysis. The NED is a seamless raster product derived from U.S. Geological Survey (USGS) 10-meter Digital Elevation Models (DEMs). One ft contour intervals were generated using the 2013 NED and Spatial Analyst in ArcGIS. The resulting 543 ft and 534 ft contour lines were then used to create the reservoir polygons. The reservoir polygons were then overlain on the NWI wetlands. Any wetlands mapped within each of the reservoir polygons were considered to be impacted as indicated above based on the NWI classification.

Results

Table 1 lists the wetland types that were found within the Lower Bois d'Arc Creek Reservoir at 534 ft and 543 ft elevations and the difference between each reservoir. For the purpose of this analysis, impacts to the freshwater forested/shrub and emergent NWI wetland types were considered permanent. Impacts to lake or freshwater pond NWI wetland types were considered no impact (see Table 2).

Figure 1: Lower Bois d'Arc Creek Reservoir

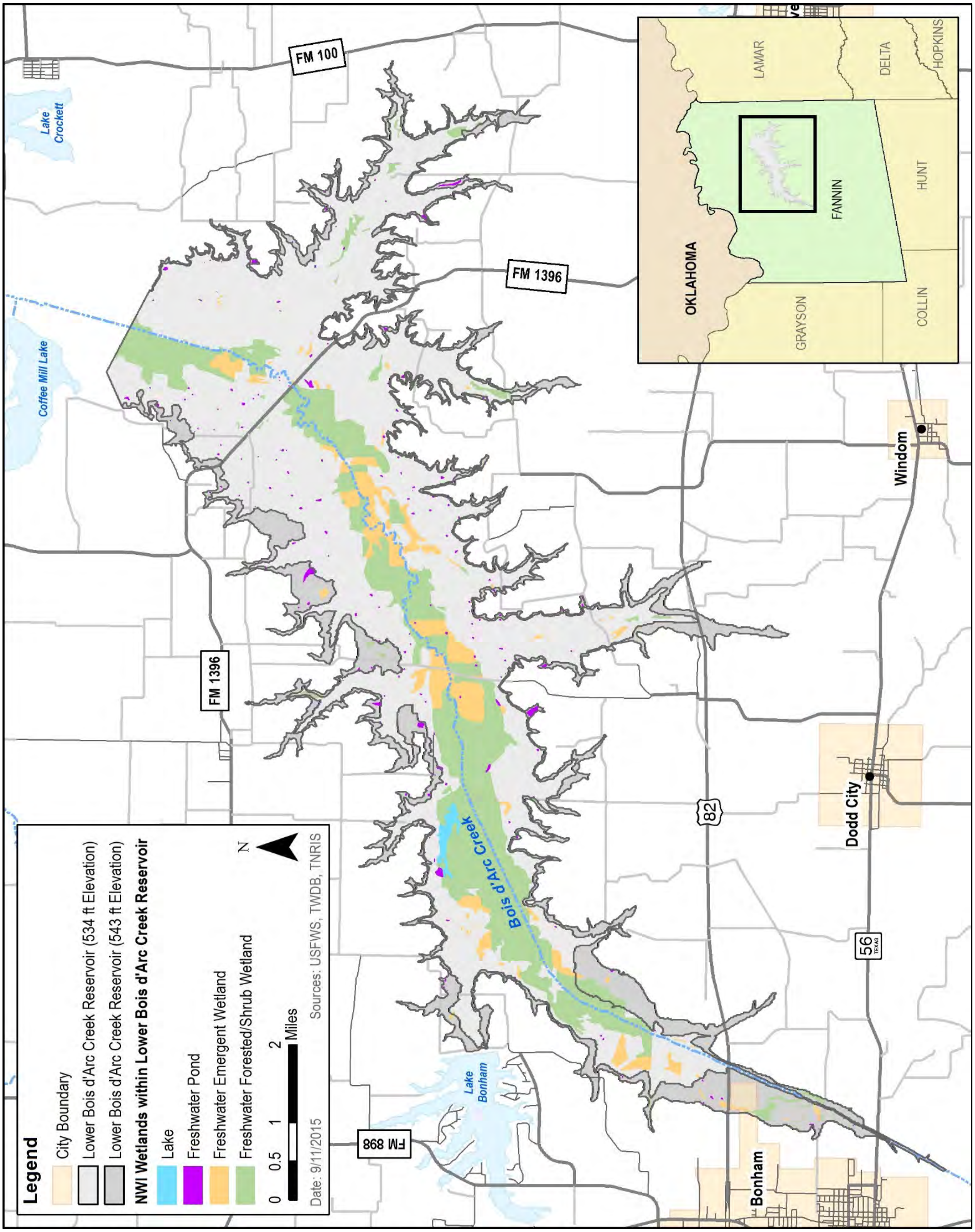

Table 1: Wetlands within the Lower Bois d'Arc Creek Reservoir at 534 ft and 543 ft Elevations Organized by NWI Wetland Type.

Wetland Type	543 Ft Elevation		534 Ft Elevation		Difference Between 543 ft and 534 ft Elevation	
	Acres	Areas	Acres	Areas	Acres	Areas
Lake	61.07	1	61.07	1	0.00	0
Freshwater Emergent Wetland	1,033.81	81	997.98	67	35.83	14
Freshwater Forested/Shrub Wetland	3,728.73	100	3,588.24	80	140.49	20
Freshwater Pond	119.76	244	65.52	160	54.23	84
Total	4,943.36	426	4,712.80	308	230.56	118

Table 2: Area of wetlands that could be directly[1] impacted by the construction of the Lower Bois d'Arc Creek Reservoir at 534 ft and 543 ft Elevations categorized as permanent.

Impact Type	543 Ft Elevation		534 Ft Elevation		Difference Between 543 ft and 534 ft Elevation	
	Acres	Areas	Acres	Areas	Acres	Areas
Permanent	4,762.54	181	4,586.21	147	176.32	34

Conclusion

Based on a review of NWI wetland acreage within the additional firm yield (543 ft elevation) and the original (534 ft elevation) Lower Bois d'Arc Creek Reservoirs, the additional firm yield contains approximately 176 acres of wetlands that would be permanently impacted if the conservation pool were raised to an elevation sufficient for meeting the Applicant's firm annual yield.

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[1] Impacts reported are direct impacts. Indirect and cumulative impacts to wetlands (e.g., hydrology changes, isolation, etc.) were not specifically evaluated but indirectly considered in this evaluation.

Appendix B

Geotechnical Data Report and Conceptual Design

Innovative approaches
Practical results
Outstanding service

GEOTECHNICAL DATA REPORT

Lake Ralph Hall Conceptual Design
(Upper Trinity Regional Water District)

Prepared for:

CH2M HILL, Inc.

June 2017

Prepared by:

FREESE AND NICHOLS, INC.
4055 International Plaza, Suite 200
Fort Worth, Texas 76109
817-735-7300

CHM16420

Innovative approaches
Practical results
Outstanding service

GEOTECHNICAL DATA REPORT

Lake Ralph Hall Conceptual Design
(Upper Trinity Regional Water District)

Prepared for:

CH2M HILL, Inc.

June 2017

STATE OF TEXAS
RUSSELL G. SPRINGER
106702
LICENSED
PROFESSIONAL ENGINEER
06-01-2017

FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F-2144

Prepared by:

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CHM16420

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APPENDICES

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

The Lake Ralph Hall project site is in the southeast corner of Fannin County approximately 4 miles northeast of Ladonia, Texas. The reservoir will be created by constructing an earthen dam along eastern end of the reservoir within the Sulphur River floodplain.

The earthen embankment will be approximately 13,000 feet long, constructed using cut material from within the floodplain, service spillway, emergency spillway, emergency spillway channel, and surrounding areas. The proposed top of the embankment is Elevation 565.0 feet, with varying upstream and downstream toe elevations along the alignment. The embankment will have a maximum height of approximately 65 feet.

The service spillway will be an uncontrolled overflow structure. The left and right gravity sections will be constructed of reinforced concrete. It will have vertical reinforced concrete abutments and a concrete labyrinth spillway section. The outlet channel, from the labyrinth weir to the stilling basin, will be constructed of reinforced concrete. The stilling basin will be lined with reinforced concrete and soil cement. The outlet channel, downstream of the stilling basin, will be lined with soil cement.

The emergency spillway will be excavated through the left abutment and will comprise a 1,500-foot wide spillway with an ogee crest and an unlined earthen channel. The downstream channel of the emergency spillway will curve to the south and outlet into the Sulphur River, downstream of the stilling basin.

Outlet works are expected to consist of a low-flow outlet structure and associated piping, located near the upstream toe of the dam. A separate pump station intake will also be considered, with the pump station located downstream from the dam.

1.2 AUTHORIZATION AND SCOPE

Freese and Nichols, Inc. (FNI) was contracted by CH2M HILL, Inc. (CH2M) to provide a conceptual design for the Lake Ralph Hall project. The conceptual design package includes a conceptual design level geotechnical site investigation to identify and characterize the soil and rock materials at the project site and to assess their engineering properties for use as foundational and embankment materials.

The geotechnical investigation included a field exploration and laboratory testing program, including classification testing, density determination, unconfined compressive strength and unconsolidated-undrained shear strength testing for use in developing strength parameters.

1.3 EXISTING DATA

In April 2005, Kleinfelder performed a preliminary subsurface exploration at the proposed dam site for Chiang, Patel & Yerby, Inc. (CP&Y). A report documenting the investigation, dated June 21, 2005, is attached in Appendix A-4.

The drilling investigation performed as part of this report included four (4) geotechnical borings drilled along the dam alignment with field electrical resistivity tests performed within the borings to assess the bedrock materials. Laboratory testing of the soil and rock materials in the report consisted primarily of classification testing and unconfined compressive strength testing.

2.0 FIELD EXPLORATION

2.1 BORING LOCATIONS

A total of 15 geotechnical borings, as noted in Table 3, were planned and drilled. This included five (5) dam embankment borings, five (5) borrow borings, three (3) emergency spillway borings, and two (2) borings for downstream drop structures. The boring locations were selected based on the dam configuration shown in the 2006 Water Right Application Drawings. A summary of the borings is provided in Table 1. The locations of the borings are presented on the Boring Location Map within Appendix A-1.

Table 1 – Schedule of Borings

Boring No.	Description	Date Drilled	Total Depth	Rock Coring
D-01	Dam Alignment	9/12/2016	100 feet	55 feet
D-02	Dam Alignment	9/13/2016	75 feet	55 feet
D-03	Dam Alignment	9/14/2016	60 feet	30 feet
D-04	Dam Alignment	9/14/2016	60 feet	25 feet
D-05	Dam Alignment	9/15/2016	75 feet	40 feet
ES-01	Emergency Spillway	9/16/2016	25 feet	N/A
ES-02	Emergency Spillway	9/16/2016	25 feet	N/A
ES-03	Emergency Spillway	9/16/2016	25 feet	N/A
DS-01	Drop Structure	9/16/2016	40 feet	5 feet
DS-02	Drop Structure	9/16/2016	40.1 feet	N/A
BA-01	Borrow Area	9/17/2016	25 feet	N/A
BA-02	Borrow Area	9/17/2016	25 feet	N/A
BA-03	Borrow Area	9/17/2016	25 feet	N/A
BA-04	Borrow Area	9/17/2016	25 feet	N/A
BA-05	Borrow Area	9/17/2016	25 feet	N/A

These borings were located in the field using a hand-held GPS device. The provided coordinates should be considered accurate only to the extent implied by the technique used in their determination.

2.2 DRILLING AND SAMPLING

Drilling and sampling was conducted using CME-55 and CME-75 truck-mounted drilling rigs provided and staffed by Texplor of Dallas, Inc. Continuous-flight augers and push sampling drilling techniques were used without drilling fluid for borings that were terminated in the overburden soils and or extended a few feet into the softer, upper part of the parent bedrock materials. For those borings that extended deeper into parent bedrock, hollow-stem augers were used in the overburden materials, and NX-core drilling methods with drilling fluid were used to core the bedrock. At the completion of drilling, sampling, and testing, each boring was backfilled using a cement-bentonite grout mixture pressure-tremied from the bottom of the hole to the ground surface.

Relatively undisturbed samples of cohesive soils were collected using the drilling rig to push a seamless, steel tube sampler into the soil (based upon ASTM D 1587). After a tube was recovered, the sample was extruded in the field, examined, and logged. During logging, an estimate of the sample consistency was obtained using a hand penetrometer. The penetrometer reading is recorded at a corresponding depth on the boring logs. Note that a reported value of “4.5+” indicates that the capacity of the penetrometer device was exceeded.

Select samples were collected by driving a split-spoon sampler during the Standard Penetration Test (SPT). This technique involves driving the spoon sampler a distance using a free-falling hammer (based upon ASTM D 1586). The logger records the number of blows required to drive the sampler over three successive 6-inch increments. The first 6 inches is the seating drive. The number of blows required to drive the sampler the last two 6-inch increments is the penetration in blows per foot. When resistance is high, the number of inches of penetration for 50 blows of the hammer is recorded. Materials recovered from the split-spoon sampler were placed in a plastic bag to reduce moisture loss and protect the sample.

Rock and rock-like materials were sampled in the dam alignment borings (D-##) and in one of the drop structure borings (DS-01) using coring, while the rock encountered in the remaining borings was evaluated in-place using the Texas Department of Transportation (TxDOT) Texas Cone Penetration (TCP) test. The TCP involves driving a steel cone into the material using a free-falling hammer (based upon Method TEX 132-E). During the test, the logger records either the number of blows producing 12 inches of penetration, or the total inches of penetration due to two successive increments of 50 blows (100 blows total).

Rock was cored in the noted borings using an NX-size, double tube core barrel with a carbide bit. The total length of the recovered sample was recorded as a percentage of the total run length. The total length of all the pieces greater than four inches in length was also recorded as a percentage of the total sample length, reported as the rock quality designation (RQD). Core breaks obviously caused by the drilling process were counted as a continuous piece. Breaks that were not easily distinguished as being a result of the drilling process were considered a natural break. Rock core samples were photographed during the logging process, and the photos are presented in Appendix A-1.

Logging of the borings was performed by Ronald Randall, P.G., Daniel Rohmer, P.G., and Zack Ready, all with Geoscience Consultants International, LLC. The depths at which the soil and rock samples were collected are indicated on the boring logs. The results of the various penetration tests, as well as the rock core recovery and RQD, are reported on the boring logs at the corresponding depth. After logging, moisture sensitive samples were sealed in a plastic bag, and the samples were then placed in a sample box for transport to Gorrondona & Associates, Inc. at their Fort Worth, Texas, laboratory.

2.3 BORING LOGS

A log of each boring is presented in Appendix A-1. A key to the symbols and terms used on the logs is also provided in Appendix A. The logs indicate material type, depth, and other details for each boring. Soil and rock descriptions presented on the boring logs resulted from a combination of field and laboratory test data and visual inspection. Stratigraphy lines correspond to the approximate boundary between strata, since the in-situ subsurface transition can be, and is often, gradual.

2.4 PACKER TESTS

Five (5) packer tests were performed within the dam alignment borings, with one test performed in each boring. The packer tests were performed to assess the transmissivity of the parent rock formation. The packer test results are summarized in Table 3.

Table 2 – Packer Test Summary

Boring No.	Date	Packer Test Depth	Depth to Tip of Packer	Result
D-01	9/12/2016	50 – 100 feet	50 feet	No Take
D-02	9/13/2016	25 – 75 feet	25 feet	No Take
D-03	9/14/2016	35 – 60 feet	35 feet	No Take
D-04	9/14/2016	35 – 60 feet	35 feet	No Take
D-05	9/15/2016	40 – 75 feet	40 feet	No Take

Results of the packer tests were all “no take”. The details of each packer test are contained on the report forms in Appendix A-1.

3.0 LABORATORY TESTING

Laboratory testing was performed by either Gorrondona & Associates, Inc. (Gorrondona) in their Fort Worth, Texas, laboratory or by TRI Environmental, Inc. (TRI) in their Austin, Texas, laboratory. The samples selected for unconfined-unconsolidated triaxial shear testing were sent to TRI was primarily performed on both composite samples and individual samples obtained in the borings. Test results are presented in Appendix A-3. The results of the tests are also reported on each boring log and/or laboratory test reports, as appropriate.

Testing was performed to allow for material classification (according to the Unified Soil Classification System, ASTM D 2487) and to evaluate various engineering properties of the materials. The laboratory testing program included the following:

- Atterberg Limits, ASTM D4318, "Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils."
- Crumb Dispersion, ASTM D6572, "Standard Test Methods for Determining Dispersive Characteristics of Clayey Soils by the Crumb Test."
- Dry Density Determinations, ASTM D7263, "Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens."
- Moisture Content Tests, ASTM D2216, "Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass."
- Percent Passing a Number 200 Sieve, ASTM D1140, "Standard Test Methods for Amount of Material in Soils Finer than the No. 200 (75-µm) Sieve."
- Unconfined Compressive Strength of Soil, ASTM D2166, "Standard Test Method for Unconfined Compressive Strength of Cohesive Soil." This test was performed on undisturbed samples.
- Unconfined Compressive Strength of Rock, ASTM D7102, "Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures."
- Unconsolidated-Undrained Triaxial Shear Strength, ASTM D2850, "Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils." This test was performed on remolded and undisturbed samples.

4.0 GEOLOGIC AND SUBSURFACE CONDITIONS

4.1 SITE DESCRIPTION

The Lake Ralph Hall project site is in the southeast corner of Fannin County approximately 4 miles northeast of Ladonia, Texas, as depicted on the Boring Location Plan in Appendix A-1. The project site is in an undeveloped agricultural field situated across a mature stream valley of the North Sulphur River Basin. The North Sulphur River trends west to east with gently rolling grade breaks bounding the northern and southern banks.

4.2 PHYSIOGRAPHIC SETTING

The project site is located near the northern edge of the Blackland Prairies, the subprovince of the Gulf Coastal Plains physiographic province of North Central Texas. This region is the innermost subprovince of the Gulf Coastal Plains and comprises mostly chalks and marls that weather to deep, black, fertile clay soils. The regional landscapes are characterized by gentle, undulating surfaces, most of which are cleared of most natural vegetation and cultivated for crops and/or livestock.

4.3 GEOLOGIC FORMATIONS

The Bureau of Economic Geology's 1992 Geologic Map of Texas indicates that the project area is primarily underlain by the Cretaceous-age Taylor Group, particularly the Ozan Formation. Younger alluvial sediments of Quarternary age line and fill the scour zone within the Ozan made by the original North Sulphur River. These alluvial sediments primarily comprise clayey and silty soils with varying amounts of sand and gravel and are primarily found in the floodplain valley which extends about 4,000 feet to either side of the incised river channel.

The Ozan Formation underlies the alluvial deposits within the floodplain and is overlain by clay residuum, derived from the underlying Ozan, outside of the floodplain. The Ozan Formation is the lowest member of the Taylor Group and forms most of the "primary" bedrock beneath the study area. The Ozan consists of up to 425 feet of bluish-gray, calcareous clays (marl) and mudstones with occasional thin, sandy layers. Unweathered Ozan is indurated, rock-like material. The Ozan weathers into light gray shale and light yellow-brown shaly clay. Figure 3 in Appendix A-2 shows the boring locations as they relate to the mapped geologic formations.

4.4 GENERALIZED STRATIGRAPHY

The subsurface stratigraphy encountered in the borings varies widely and is largely dependent on location and landform type and position. The two primary landform types at the project site comprise either floodplain deposits resulting from the North Sulphur River or weathered overburden materials (residuum) on the terraces above the floodplain. Based on geologic maps and the NRCS Soil Survey for Fannin County, the floodplain deposits are primarily located adjacent to the existing North Sulphur River channel, extending about ½ to ¾ miles to the north and south of the incised channel. Figure 4 in Appendix A-2 shows the boring locations as they related to the mapped soil units from the NRCS Soil Survey.

Both the alluvial deposits and residuum encountered in the borings consisted primarily of moderately to highly plastic, lean and fat clay soils, with occasional layers of varying sand contents, though no distinct sand or gravel layers were observed in the borings. The overburden soils varied in thickness based on their relative distance from the floodplain but typically consisted of about 30 to 40 feet of alluvium underlain by a few feet of weathered clay soils in the floodplain. In the terrace locations, the alluvium was typically about 15 to 20 feet thick, and the underlying weathered clay was 10 to 25 feet thick. Beneath the weathered clay soils was moderately to unweathered marl bedrock. The marl bedrock was encountered in the borings at depths ranging from 20 to 38 feet below the ground surface.

A subsurface diagram along the dam alignment is included as Figure 2 in Appendix A-2. The subsurface diagram includes the subsurface stratigraphy as indicated in the borings and includes both the borings from the most recent investigation and from Kleinfelder's 2005 investigation.

4.5 GROUNDWATER

Observations were made during drilling for the occurrence of seepage and/or the collection of groundwater. The borings were drilled using a combination of techniques, with some of the borings using drilling fluid during rock coring. Observations for seepage and groundwater were made prior to the introduction of the drilling fluid, when applicable. When drilling fluid was not used, observations were also made at the end of drilling. Packer tests were performed within the dam alignment borings, with one test performed in each boring. The remaining borings were backfilled with pressure-injected grout after completion; therefore, delayed seepage observations could not be made, with the exception of the packer borings.

A summary of the seepage and groundwater observations during Phase 1, is provided in Table 3. Refer to the boring logs in Appendix A-1 for specific observations made during the field exploration. Note that these observations are only indicative of conditions at the time and place indicated. A groundwater study has not been performed. Long-term observations would be necessary to evaluate groundwater levels and fluctuations.

Table 3 – Summary of Seepage and Groundwater Observations

Boring No.	Comments
EMBANKMENT BORINGS	
D-01	No seepage observed.
D-02	No seepage observed.
D-03	No seepage observed.
D-04	No seepage observed.
D-05	No seepage observed.
ES-01	No seepage observed.
ES-02	No seepage observed.
ES-03	No seepage observed.
DS-01	No seepage observed.
DS-02	No seepage observed.
BA-01	No seepage observed.
BA-02	No seepage observed.
BA-03	No seepage observed.
BA-04	No seepage observed.
BA-05	No seepage observed.

5.0 SUMMARY OF LABORATORY TEST RESULTS

5.1 CLASSIFICATION AND MOISTURE CONTENT

The soils encountered by the borings within the project area are primarily alluvial deposits and residuum from the weathered parent bedrock materials. The alluvial and weathered soils primarily consisted of highly plastic clays, with some moderately plastic clay layers. The clay soils were underlain by parent bedrock materials comprising marl, in which the upper part of the bedrock formation was soft enough to be sampled using standard soil samplers.

Classification and moisture content testing comprised a bulk of the laboratory testing performed and included some hydrometer testing. Unconfined compressive strength testing was performed on discrete samples. In-situ SPT and TCP blow count values were limited since tube sampling was effective for the mostly clay soils, and bedrock materials were primarily cored; therefore, they are not included in the summary below. Where unconfined testing or in-situ testing was not performed, the soil stiffness and density described on the boring logs was based on field classification methods.

Some of the samples were combined to form composite samples, particularly in the borrow and emergency spillway areas where excavated soil strata are likely to be mixed and stockpiled. A summary of the laboratory test result ranges is summarized, based on material classification, in Table 4 below. The results are also included on the boring logs.

Table 4 – Summary of Classification and Unconfined Test Results

Classification	Liquid Limit [percent]	Plasticity Index [percent]	Minus P200$^{(1)}$ [percent]	Water Content [percent]	Dry Density [pcf]	Unconfined Compressive Strength [tsf]	Unconfined Compressive Strain at Failure
CH (Alluvium)	50 – 82	25 – 57	78 – 100	14 – 27	96 – 114	1.1 – 3.3 (1)	2.5 – 15.9
CH (Ozan)	61 – 77	34 – 53	54 – 98	13 – 30	97 – 121	1.3 – 4.3 (2)	2.2 – 6.9
CL	36 – 46	16 – 26	85	16 – 22	101 – 105	--	--
MARL	50 - 65	27 – 37	67 – 97	17 – 21	106 – 116	8.3 – 15.2	1.8 – 2.4

Notes: (1) Does not include outlier value of 9.2 tsf from test performed in Boring D-01 at 14 feet.
(2) Does not include outlier value of 19.1 tsf from test performed in Boring D-02 at 20 feet.

5.2 CRUMB TESTING

Laboratory crumb dispersion testing was performed by Gorrondona and TRI on selected soil samples obtained in the borings. The crumb dispersion testing was performed in general accordance with ASTM

D6572–06. A 2-minute, 1-hour, and 6-hour crumb test reading was performed. A summary of the crumb dispersion test results is provided in Table 5. The detailed crumb dispersion test results are included as part of Appendix A-3.

Table 5 – Summary of Crumb Test Results

Boring No.	Depth	USCS	Dispersive Classification
BA-01	1.5 – 4	CH	4
BA-01	4 – 5	CH	1
BA-01	7 – 10	CH	4
BA-01	14 – 20	CH	2
BA-02	1 - 7	CH	1
BA-02	7 – 10	CH	1
BA-03	0 – 4	CH	1
BA-03	4 – 20	CH	1
BA-03	4 – 20	CH	1
BA-03	4 – 20	CH	1
BA-04	0 – 15	CH	1
BA-04	0 – 15	CH	1
BA-05-1	0 – 7	MH	1
BA-05-1	0 – 7	MH	1
BA-05-2	0 – 14	CH	1
BA-05-2	0 – 14	CH	2
BA-05	14 – 20	CL	1
ES-01	0 – 3	CH	1
ES-01	3 – 9	CH	1
ES-01	10 – 20	CH	1
ES-02	1 – 4	CH	1
ES-02	4 – 7	CH	1
ES-02	7 – 10	CH	1
ES-02	13 – 15	CL	1
ES-03	3 – 6	CH	1
ES-03	6 – 10	CH	1
ES-03	14 – 20	CH	1

The overall crumb dispersion test results indicate the tested samples were nondispersive (Grade 1), with a few results up to highly dispersive (Grade 4). Out of 27 soil samples tested, 2 resulted in a Crumb Grade

4 indicating the sample was dispersive. A dispersive soil may sometimes give a nondispersive reaction in the crumb test; however, a dispersive reaction in the crumb test is an indication that the soil is probably dispersive.

5.3 SHEAR STRENGTH TESTING

Unconsolidated-undrained shear strength testing was performed on intact and remolded samples obtained from the borings. The remolded specimens were obtained from the combined samples from the emergency spillway and borrow area borings. The shear strength testing was performed by TRI in general accordance with ASTM D2850. The results of the shear strength tests are provided in Table 6. The detailed test results are included as part of Appendix A-3.

Table 6 – Summary of Unconsolidated-Undrained Shear Strength Test Results

Boring No.	Sample Type	Depth	Dry Density [pcf]	Moisture Content [percent]	USCS	Minor Principal Stress (1) [psf]	Undrained Shear Strength [psf]	Strain at Failure (1)
D-02	Intact	9 – 10	103	23	CH	9.4	2.1	15.0
D-03	Intact	7 – 8	100	24	CH	10.1	2.4	15.0
D-03	Intact	23 – 25	100	23	CH	12.2	3.1	14.4
D-04	Intact	6 – 7	96	26	CH	10.1	2.4	13.1
D-04	Intact	18 – 20	102	23	CH	11.5	2.1	15.0
D-05	Intact	29 – 30	97	27	CH	12.2	2.3	10.6
BA-03	Remolded	4 – 20	92	30	CH	1.4 – 2.9 – 4.3	0.9	14.2 – 11.8 – 11.7
BA-04	Remolded	0 – 15	92	29	CH	2.9 – 4.3 – 5.8	0.7	14.9 – 15.0 – 14.7
BA-05-1	Remolded	0 – 7	93	30	MH (2)	5.8 – 7.2 – 8.6	1.3	15.0 – 15.0 – 15.0
BA-05-2	Remolded	7 – 14	96	27	CH	5.8 – 7.2 – 8.6	0.8	14.7 – 15.0 – 15.0

Notes: (1) Remolded samples were tested at three different confining pressures.
(2) Based on typical soil types encountered at the site, this classification result may be due to lab error.

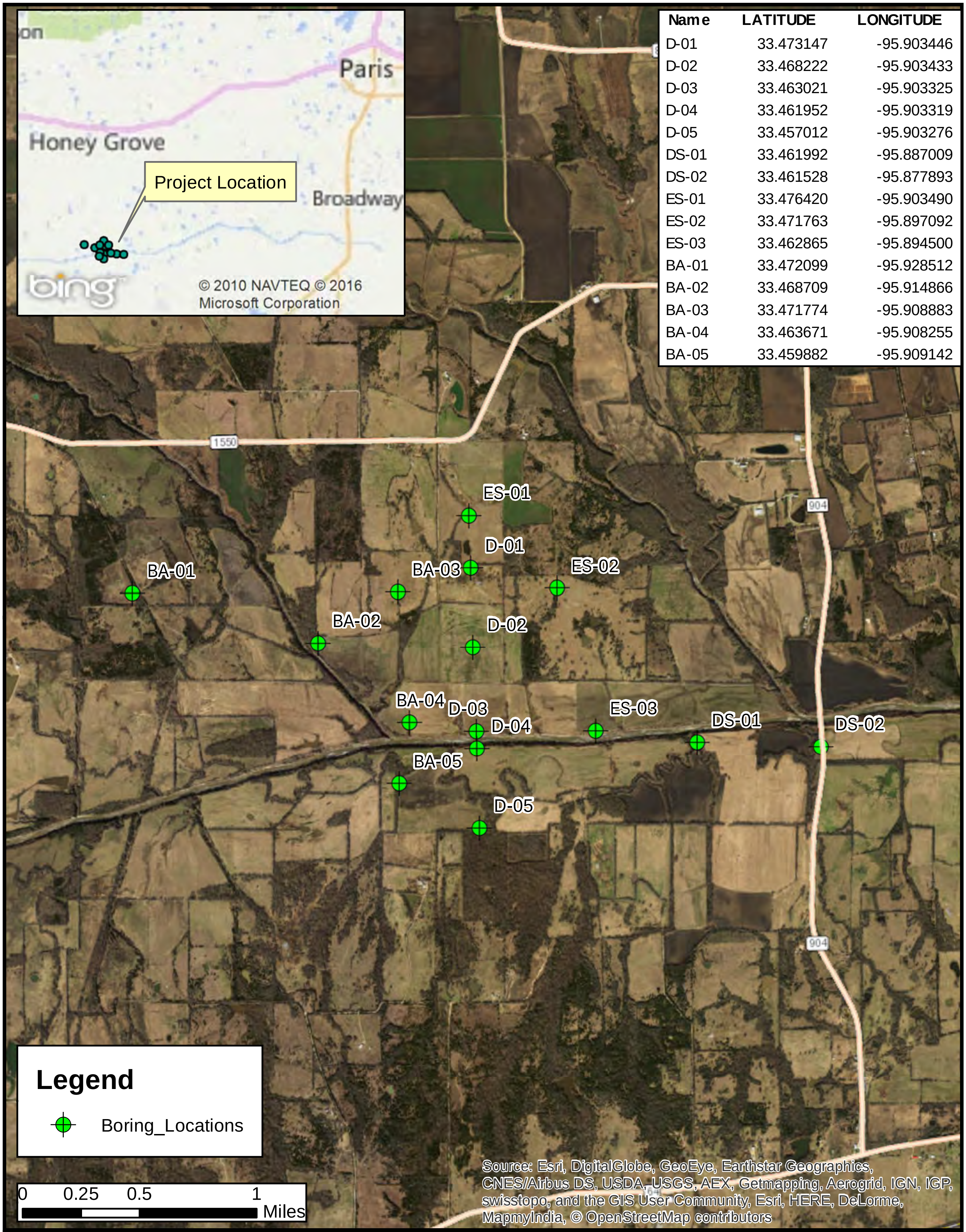
6.0 LIMITATIONS

This report was prepared specifically for use by Freese and Nichols, Inc.; CH2M HILL, Inc.; and the Upper Trinity Regional Water District (UTRWD) for the Lake Ralph Hall project and shall not be used for other projects or purposes. The intent of this Geotechnical Data Report is to present the data obtained during the field exploration and laboratory testing programs and does not contain conclusions or recommendations based on the data collected. Freese and Nichols, Inc. makes no other representation, guarantee or warranty, express or implied, regarding the services, communication (oral or written), report, opinion, or instrument of service provided.

This report, and any future addenda or reports regarding this site, specific to this project, may be made available to bidders to supply them with the data contained in this report regarding probable subsurface conditions and laboratory test results at the location and time noted; however, additive conclusions or recommendations made from the information presented by others are their responsibility. Paragraphs, statements, test results, boring logs, figures, etc., should not be taken out of context, nor utilized without a knowledge and awareness of their intent within the purpose of this report.

APPENDIX A-1

FIELD EXPLORATION DATA



Name	LATITUDE	LONGITUDE
D-01	33.473147	-95.903446
D-02	33.468222	-95.903433
D-03	33.463021	-95.903325
D-04	33.461952	-95.903319
D-05	33.457012	-95.903276
DS-01	33.461992	-95.887009
DS-02	33.461528	-95.877893
ES-01	33.476420	-95.903490
ES-02	33.471763	-95.897092
ES-03	33.462865	-95.894500
BA-01	33.472099	-95.928512
BA-02	33.468709	-95.914866
BA-03	33.471774	-95.908883
BA-04	33.463671	-95.908255
BA-05	33.459882	-95.909142

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors

FREESE AND NICHOLS

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N
W E
S

UTRWD Lake Ralph Hall

Boring Location Map

FN JOB NO CHM16420
FILE 16420 BLM.mxd
DATE 8/11/2016
SCALE 1:3,000
DESIGNED Tony Bosecker
DRAFTED MPT

1
FIGURE

BORING LOG LEGEND AND NOMENCLATURE

Abbreviations

U – Undisturbed Sample (tube)
A – Auger Sample
CS – Continuous Sample
C – Rock Core
SPT – Standard Penetration Test
TCP – Texas Cone Penetration
CFA – Continuous Flight Auger
HSA – Hollow Stem Auger
NT – Not Testable
NP – Non Plastic
ATD – At Time of Drilling
AD – After Drilling

General Terms

Term	Description
Blow Counts	Results from either the Standard Penetration Test (SPT) or the Texas Cone Penetration (TCP) test.
Recovery	Length of sample or core recovered divided by the total length pushed, driven, or cored (expressed as a %)
Rock Quality Designation (RQD)	Cumulative length of unfractured pieces of core material more than 4 inches in length divided by the total length of material cored (expressed as a percentage)

Consistency of Cohesive Soil

Description	Comp. Strength, tsf	SPT Blows	TCP Blows	Criteria
Very Soft	< 0.25	0 – 2	0 – 8	Sample sags under its own weight and is easily deformed
Soft	≥ 0.25 – < 0.5	> 2 – 4	> 8 – 20	Easily pinched between fingers and remolded with light finger pressure
Medium Stiff	≥ 0.5 – < 1.0	> 4 – 8	N/A for TxDOT	Imprinted easily with fingers and remolded with firm finger pressure
Stiff	≥ 1.0 – < 2.0	> 8 – 15	>20 – 40	Imprinted with strong finger pressure or indented easily with fingernail
Very Stiff	≥ 2.0 – < 4.0	> 15 – 30	> 40 to 80	Light imprint from finger or light indent with fingernail
Hard	≥ 4.0	> 30	>80	Difficult to indent with fingernail

Apparent Density of Cohesionless Soil

Description	SPT Blow Count	Texas Cone Blow Count
Very Loose	0 – 4	0 – 8
Loose	> 4 – 10	> 8 – 20
Medium Dense	> 10 – 30	> 20 to 80
Dense	> 30 – 50	80 to ≥ 5”
Very Dense	> 50	0” to < 5”

Soil Structure

Description	Criteria
Stratified	Alternating layers of varying material/color with layers ≥ 1/4-inch thick
Laminated	Alternating layers of varying material/color with layers < 1/4-inch thick
Fissured	Breaks along definite planes with little resistance
Slickensided	Fracture planes appear polished or glossy; shows movement direction
Blocky	Cohesive soil that can be broken into small, angular lumps
Lensed	Inclusion of small pockets of soil that is different from dominate type
Homogenous	Same color and appearance throughout

Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water

Textural Adjectives

Textural Item	Description
Pit	Pinhole sized openings
Vug	Small openings up to 4 inches in size
Cavity	Opening larger than 4 inches
Honeycomb	Numerous and grouped pits and vugs
Vesicle	Small openings in volcanic rocks

BORING LOG LEGEND AND NOMENCLATURE

Rock Hardness Descriptors

Rock Material Hardness	Uniaxial Comp. Strength, MPa	Field Identification Tests
Very Soft	0.6—1.25	Scratched with fingernail. Slight indention produced by light blow of point of geologic prick. Requires power tools for excavation. Peels with pocket knife.
Soft	1.25—5.0	Hand-held specimen crumbles under firm blows with point of geologic pick.
Moderately Soft	5.0—12.5	Shallow indentations (1 to 3 mm) produced by light blows with point of geologic pick. Peels with pocket knife with difficulty.
Moderately Hard	12.5—50.0	Cannot be scraped or peeled with pocket knife. Intact hand-held specimen breaks with single blow of geologic hammer. Can be distinctly scratched with 20d common steel nail.
Hard	50.0—100.0	Intact hand-held specimen requires more than one hammer blow to break it. Can be faintly scratched with 20d common steel nail.
Very Hard	100.0—250.0	Intact specimen breaks only be repeated, heavy blows with geologic hammer. Cannot be scratched with 20d common steel nail.
Extremely Hard	> 250.0	Intact specimen can only be chipped, not broken, by repeated, heavy blows of geologic hammer.

Degree of Rock Weathering

Description	Criteria
Unweathered	No evidence of chemical or mechanical alteration
Slightly Weathered	Slight discoloration of surface or discontinuities; < 10% volume altered
Weathered	Discoloring evident; 10 to 50% of volume altered
Highly Weathered	Entire mass discolored; alteration through majority of rock
Decomposed	Rock reduced to soil consistency with some rock-like texture

Rock Bedding Structure

Description	Criteria
Laminated	< 3/8 inch
Very Thinly Bedded	3/8—1 inch
Thinly Bedded	1 inch—4 inches
Moderately Bedded	4 inches—1 foot
Thickly Bedded	1 foot—3 feet
Very Thickly Bedded	3– 10 feet
Massive	> 10 feet

Soil Column Graphic Symbols*

Graphic	Represented Soil Types	Graphic	Represented Soil Types
▨	Fat Clay, Fat Clay with sand, Sandy Fat Clay	▩	Well-Graded Sand or Poorly-Graded Sand; little to no fines
▨	Lean Clay, Lean Clay with sand, Sandy Lean Clay, Silty Clay	▨	Clayey Gravel, Gravel-Sand-Clay Mixtures
▥	Inorganic Silt and Organic Silt	○	Silty Gravel, Gravel-Sand-Silt Mixtures
▨	Clayey Sand, Clay-Sand Mixtures	●	Well-Graded Gravel or Poorly-Graded Gravel; little to no fines
▥	Silty Sands, Sand-Silt Mixtures	⊠	Fill with Significant Debris or Deleterious Material

Rock Column Graphic Symbols*

Graphic	Represented Rock Types	Graphic	Represented Rock Types
▦	Limestone, Shaly/Marly Limestone, Limestone with Shale	▤	Marl, Marl with Limestone, Marl with Shale
▤	Shale, Shale with Limestone	░	Sandstone, Shaly Sandstone, Sandstone with Shale
▨	Mudstone	▩	Generic Bedrock Symbol

* Combined graphics may be used for dual classifications. Not all graphics represented. Refer to lithology description for soil classification or rock type.

LOG OF BORING NO. BA-01

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/17/2016
Phase No.: ****
Logged By: RR
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/17/2016
Rig Type: CME 55
Hammer Type: Automatic
Drill Method: CFA & DRY
Latitude: 33.472099
Longitude: -95.928512
Elevation: 552.9 ft.

DEPTH, ft	SAMPLE TYPE	SAMPLE BLOW COUNTS	SAMPLE HAND PENETROMETER (P) / TORVANE (T), tsf	SAMPLE RECOVERY, %	SAMPLE RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.5+ (P)	50		▨	SANDY LEAN CLAY (CL), brown, very stiff, slightly moist, silty									
	U-2		4.5+ (P)	58		▨	FAT CLAY (CH), grayish brown, hard, moist (Ozan Formation) 1.5/551.4									
	U-3		4.5+ (P)	67		▨		13	121							
	U-4		4.5+ (P)	75		▨										
5	U-5		4.5+ (P)	92		▨	FAT CLAY (CH), mottled gray, orange and light brown, hard, moist, few iron oxide deposits (Ozan Formation) 4/548.9									548
	U-6		4.5+ (P)	83		▨										
	U-7		4.5+ (P)	75		▨		19								
	U-8		4.5+ (P)	83		▨										
	U-9		4.5+ (P)	83		▨										
10	U-10		4.5+ (P)	92		▨										543
15	U-11		4.5+ (P)	83		▨										538
						▨	-with numerous calcareous deposits from 18 to 22 feet									
20	U-12		4.5+ (P)	42		▨										533
						▨	FAT CLAY (CH), dark gray, gray and light brown, very hard, moist, shaly, slightly fissile, weathered (Ozan Formation) 23/529.9									
25	U-13		4.5+ (P)	100		▨										528
							Total boring depth 25.0 ft.									

Water Observations:
Dry At Time Of Drilling

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

LOG OF BORING NO. BA-02

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/17/2016
Phase No.: ****
Logged By: RR
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/17/2016
Rig Type: CME 55
Hammer Type: Automatic
Drill Method: CFA & DRY
Latitude: 33.468709
Longitude: -95.914866
Elevation: 509.9 ft.

DEPTH, ft	SAMPLE TYPE	SAMPLE BLOW COUNTS	SAMPLE HAND PENE-TROMETER (P) / TORVANE (T), tsf	SAMPLE RECOVERY, %	SAMPLE RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.5+ (P)	50		▨	SANDY LEAN CLAY (CL), light brown, hard, slightly moist, silty									
	U-2		4.5+ (P)	50		▨	1/508.9 FAT CLAY (CH), grayish brown, hard, moist (Alluvium)									
	U-3		4.5+ (P)	75		▨										
	U-4		4.5+ (P)	67		▨										
	U-5		4.5+ (P)	58		▨	-few calcareous deposits below 4 feet	20	108							
5						▨										505
	U-6		4.5+ (P)	83		▨										
	U-7		4.5+ (P)	58		▨										
	U-8		4.5+ (P)	100		▨										
	U-9		4.5+ (P)	83		▨	-some orange color below 8 feet									
	U-10		4.5+ (P)	83		▨										
10						▨										500
	U-11		4.5+ (P)	100		▨										
15						▨										495
						▨	18/491.9 FAT CLAY (CH), mottled gray, orange and light brown, hard, moist, numerous calcareous nodules (Alluvium)									
	U-12		4.5+ (P)	83		▨		26		87	71	28	43			
20						▨										490
						▨	22/487.9 FAT CLAY (CH), dark gray, hard, moist, shaly, slightly fissile, weathered (Ozan Formation)									
	U-13		4.5+ (P)	92		▨										
25							Total boring depth 25.0 ft.									485

Water Observations:
Dry At Time Of Drilling

Remarks:

FREESE AND NICHOLS

LOG OF BORING NO. BA-03

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/17/2016
Logged By: RR
Rig Type: CME 55
Latitude: 33.471774

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.908883

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/17/2016
Drill Method: CFA & DRY
Elevation: 543.7 ft.

	SAMPLE															
DEPTH, ft	**TYPE**	**BLOW COUNTS**	**HAND PENE-TROMETER (P) / TORVANE (T), tsf**	**RECOVERY, %**	**RQD, %**	**SYMBOL**	**MATERIAL DESCRIPTION**	**WATER CONTENT, %**	**UNIT DRY WEIGHT, pcf**	**% PASSING NO. 200 SIEVE**	**LIQUID LIMIT**	**PLASTIC LIMIT**	**PLASTICITY INDEX**	**UNC. COMPRESSIVE STRENGTH, tsf**	**STRAIN AT FAILURE, %**	**ELEVATION, ft**
	U-1		4.5+ (P)	50		▨	FAT CLAY (CH), grayish brown, hard, moist (Ozan Formation)									
	U-2		4.5+ (P)	42		▨		14								
	U-3		4.5+ (P)	58		▨										
	U-4		4.5+ (P)	50		▨										
5	U-5		4.5+ (P)	67		▨	4/539.7 FAT CLAY (CH), mottled gray, orange and light brown, hard, moist (Ozan Formation)									539
	U-6		4.5+ (P)	100		▨		19	107							
	U-7		4.5+ (P)	75		▨	-trace calcareous deposits and iron oxide deposits below 6 feet									
	U-8		4.5+ (P)	100		▨										
	U-9		4.5+ (P)	100		▨										
10	U-10		4.5+ (P)	75		▨										534
15	U-11		4.5+ (P)	100		▨										529
						▨	-with calcareous deposits below 18 feet									
20	U-12		4.5+ (P)	83		▨										524
						▨	22/521.7 FAT CLAY (CH), dark gray, hard, moist, with calcareous deposits, iron oxide stains, shaly, slightly fissile, weathered (Ozan Formation)									
25	U-13		4.5+ (P)	100		▨										519
							Total boring depth 25.0 ft.									

Water Observations:
Dry At Time Of Drilling

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

FREESE AND NICHOLS

LOG OF BORING NO. BA-04

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/17/2016
Logged By: RR
Rig Type: CME 55
Latitude: 33.463671

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.908255

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/17/2016
Drill Method: CFA & DRY
Elevation: 505.1 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.5+ (P)	50		▨	FAT CLAY (CH), grayish brown, hard to stiff, moist (Alluvium)									
	U-2		4.5+ (P)	58		▨										
	U-3		2.5 (P)	67		▨										
	U-4		2.5 (P)	83		▨										
	U-5		2.0 (P)	92		▨										
5						▨										500
	U-6		2.0 (P)	83		▨	-trace iron oxide deposits below 5 feet									
	U-7		1.5 (P)	92		▨	-stiff to very stiff below 6 feet									
	U-8		2.0 (P)	92		▨										
	U-9		1.75 (P)	100		▨		22	103							
	U-10		2.25 (P)	100		▨										
10						▨										495
	U-11		3.5 (P)	100		▨	-with calcareous deposits below 14 feet									
15						▨										490
						▨	FAT CLAY (CH), mottled brown, orange and gray, hard, moist, with few calcareous deposits (Ozan Formation) 18/487.1									
	U-12		3.5 (P)	100		▨										
20						▨										485
	U-13		4.0 (P)	100		▨										
25							Total boring depth 25.0 ft.									480

Water Observations:
Dry At Time Of Drilling

Remarks:

LOG OF BORING NO. BA-05

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/17/2016
Phase No.: ****
Logged By: RR
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/17/2016
Rig Type: CME 55
Hammer Type: Automatic
Drill Method: CFA & DRY
Latitude: 33.459882
Longitude: -95.909142
Elevation: 503.4 ft.

DEPTH, ft	SAMPLE					SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	TYPE	BLOW COUNTS	HAND PENETROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %											
	U-1		4.5+ (P)	42		▨	FAT CLAY (CH), dark gray, hard, moist (Alluvium)									
	U-2		4.5+ (P)	58		▨										
	U-3		4.5+ (P)	42		▨										
	U-4		4.5+ (P)	50		▨										
5	U-5		4.5+ (P)	58		▨										498
	U-6		3.25 (P)	67		▨	-gray, very stiff to hard below 5 feet	20	101							
	U-7		4.0 (P)	75		▨										
	U-8		4.5 (P)	92		▨	FAT CLAY (CH), mottled gray, orange and brown, very stiff, few calcareous deposits, iron oxide deposits (Alluvium) 7/496.4									
	U-9		3.25 (P)	92		▨		18	109							
10	U-10		3.5 (P)	83		▨										493
15	U-11		1.25 (P)	92		▨	LEAN CLAY (CL), mottled gray, orange and light brown, medium stiff, moist, few iron oxide deposits, some silt (Alluvium) 13/490.4	22	105							488
20	U-12		1.25 (P)	92		▨										483
25	U-13		1.25 (P)	83		▨										478
							Total boring depth 25.0 ft.									

Water Observations:
Dry At Time Of Drilling

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

FREESE AND NICHOLS

LOG OF BORING NO. D-01

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/12/2016
Phase No.: ****
Logged By: D. Rohmer
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/12/2016
Rig Type: CME 75
Hammer Type: Automatic
Drill Method: HSA & NX Core
Latitude: 33.473147
Longitude: -95.903446
Elevation: 553.5 ft.

DEPTH, ft	SAMPLE					SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %											
	U-1		4.5+ (P)	58		▨	FAT CLAY (CH), brown, hard, dry, roots present (Alluvium) -brown to red-brown below 1 foot -roots present within upper 4 feet									
	U-2		4.5+ (P)	75		▨										
	U-3		4.5+ (P)	79		▨		17	108	98	73	24	49			
	U-4		4.5+ (P)	75		▨										
	U-5		4.25 (P)	83		▨	-dark gray below 4 feet									
5						▨										549
	U-6		3.75 (P)	100		▨										
	U-7		3.25 (P)	100		▨				96	61	21	40			
	U-8		4.5+ (P)	79		▨	-red-brown to light gray below 7.5 feet									
	U-9		4.5+ (P)	77		▨										
	U-10		4.5+ (P)	75		▨										
10						▨										544
						▨	-brown below 12 feet									
	U-11		4.5+ (P)	77		▨		15	114	95	52	17	35	9.2	2.9	
15						▨										539
	U-12		4.5+ (P)	69		▨	FAT CLAY, dark gray, hard, calcareous (Ozan Formation) 19.2/534.3									
20						▨										534
						▨				98	67	21	46			
	U-13		4.25 (P)	81		▨										
25						▨										529
	U-14		4.5+ (P)	72		▨										

Water Observations:

Remarks:

FREESE AND NICHOLS

LOG OF BORING NO. D-01

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/12/2016
Logged By: D. Rohmer
Rig Type: CME 75
Latitude: 33.473147

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.903446

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/12/2016
Drill Method: HSA & NX Core
Elevation: 553.5 ft.

DEPTH, ft	SAMPLE TYPE	SAMPLE BLOW COUNTS	SAMPLE HAND PENETROMETER (P) / TORVANE (T), tsf	SAMPLE RECOVERY, %	SAMPLE RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
							FAT CLAY, dark gray, hard, calcareous (Ozan Formation) *(continued)* -pale brown to medium gray below 30 feet									
										96	70	27	43			
	U-15		4.5+ (P)	72												
35																519
								19	108							
	U-16		4.5+ (P)	61			-slightly fissile to moderately fissile below 39 feet									
40																514
							-moderately fissile below 44 feet									
	U-17		4.5+ (P)	67												
45							45/508.5 MARL, dark gray, very soft to soft, calcareous, occasionally fissile, with bivalve fossils (Ozan Formation) -with low angle fracture at 45.7 feet									509
	C-18			98	97		-with brownish yellow to medium gray weathered zone at 47.7, 48.1 and 49 feet -with low angle fracture at 48.3 feet -with horizontal fracture at 49 feet	21	106	97	65	28	37	8.3	2.4	
50																504
							-with low angle fracture at 50.5 feet									
	C-19			96	96											
							-with low angle fracture at 54.1 feet									
55																499
	C-20			100	100		-with low angle fracture at 57.6 feet -with low angle fracture at 58.3 feet									

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

LOG OF BORING NO. D-01

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/12/2016
Logged By: D. Rohmer
Rig Type: CME 75
Latitude: 33.473147

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.903446

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/12/2016
Drill Method: HSA & NX Core
Elevation: 553.5 ft.

DEPTH, ft	SAMPLE TYPE	SAMPLE BLOW COUNTS	SAMPLE HAND PENE-TROMETER (P) / TORVANE (T), tsf	SAMPLE RECOVERY, %	SAMPLE RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
							MARL, dark gray, very soft to soft, calcareous, occasionally fissile, with bivalve fossils (Ozan Formation) *(continued)*									
	C-21			98	98											
65																489
	C-22			100	100		-with low angle fracture at 67.5 feet									
70																484
	C-23			97	97		-with horizontal fracture, iron staining at 72.1 feet									
75																479
							-with low angle fracture at 75.7 feet									
	C-24			99	99											
80																474
	C-25			71	71											
85																469
	C-26			100	100											

Water Observations:

Remarks:

LOG OF BORING NO. D-01

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/12/2016
Logged By: D. Rohmer
Rig Type: CME 75
Latitude: 33.473147
Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.903446
Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/12/2016
Drill Method: HSA & NX Core
Elevation: 553.5 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	C-27			95	95	▨	MARL, dark gray, very soft to soft, calcareous, occasionally fissile, with bivalve fossils (Ozan Formation) *(continued)* -with bivalve fossil at 94.1 feet									
95	C-28			54	51	▨	-with bivalve fossil at 96 feet -with low angle fracture at 97.7 feet									459
100							Total boring depth 100.0 ft.									454
105																449
110																444
115																439

Water Observations:

Remarks:

FREESE AND NICHOLS

LOG OF BORING NO. D-02

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/13/2016
Logged By: D. Rohmer
Rig Type: CME 75
Latitude: 33.468222

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.903433

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/13/2016
Drill Method: HSA & NX Core
Elevation: 508.2 ft.

DEPTH, ft	SAMPLE TYPE	SAMPLE BLOW COUNTS	SAMPLE HAND PENE-TROMETER (P) / TORVANE (T), tsf	SAMPLE RECOVERY, %	SAMPLE RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		3.0 (P)	83		▨	FAT CLAY (CH), yellow-brown, very stiff, moist (Alluvium) -medium gray, very stiff to hard, dry to moist, with calcareous deposits below 0.5 feet									
	U-2		4.5+ (P)	83												
	U-3		4.5+ (P)	67				14	114							
	U-4		4.5+ (P)	79												
	U-5		4.5+ (P)	92												
5	U-6		2.75 (P)	92												503
	U-7		2.5 (P)	83				20	106	88	64	19	45	3	7.7	
	U-8		2.5 (P)	88			-light gray to red-brown, very stiff, moist below 7 feet									
	U-9		2.0 (P)	88												
	U-10		1.5 (P)	92			-stiff below 9.5 feet	23	103	92	54	29	25			
10																498
						▨	13/495.2 FAT CLAY (CH), medium gray to brown, hard, dry, moderately fissile, with occasional bivalve fossils (Ozan Formation)									
	U-11		4.5+ (P)	58						97	74	25	49			
15																493
							-very dark gray and very fissile, highlighted with marl below 18 feet									
	U-12		4.5+ (P)	63												
20						▤	20/488.2 MARL, dark gray, soft, calcareous, occasionally fissile, with occasional bivalve fossils (Ozan Formation)									488
	C-13			100	100			18	112	54	61	27	34	19.1	2.2	
25																483
	C-14			100	100											

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

LOG OF BORING NO. D-02

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/13/2016
Phase No.: ****
Logged By: D. Rohmer
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/13/2016
Rig Type: CME 75
Hammer Type: Automatic
Drill Method: HSA & NX Core
Latitude: 33.468222
Longitude: -95.903433
Elevation: 508.2 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENETROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
							MARL, dark gray, soft, calcareous, occasionally fissile, with occasional bivalve fossils (Ozan Formation) *(continued)*									
	C-15			100	100											
35																473
							-with low angle fracture at 36.1 feet									
	C-16			100	100		-with bivalve fossil at 37 feet	20	107	70	60	29	31			
							-with trilobite fossil at 37.9 feet									
40																468
	C-17			92	92											
45																463
	C-18			92	92											
50																458
							-gray, coarse, 7-inch sandstone seam at 50 feet									
	C-19			100	100											
55																453
	C-20			100	100											

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

LOG OF BORING NO. D-02

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/13/2016
Logged By: D. Rohmer
Rig Type: CME 75
Latitude: 33.468222

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.903433

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/13/2016
Drill Method: HSA & NX Core
Elevation: 508.2 ft.

DEPTH, ft	SAMPLE					SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	TYPE	BLOW COUNTS	HAND PENETROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %											
							MARL, dark gray, soft, calcareous, occasionally fissile, with occasional bivalve fossils (Ozan Formation) *(continued)*									
	C-21			100	100											
65																443
	C-22			98	98											
70																438
	C-23			91	91											
75							Total boring depth 75.0 ft.									433
80																428
85																423

Water Observations:

Remarks:

LOG OF BORING NO. D-03

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/14/2016
Phase No.: ****
Logged By: D. Rohmer
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/14/2016
Rig Type: CME 75
Hammer Type: Automatic
Drill Method: HSA & NX Core
Latitude: 33.463021
Longitude: -95.903325
Elevation: 501.9 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.5+ (P)	50			FAT CLAY, very dark gray, hard, moist (Alluvium)									
	U-2		4.5+ (P)	75												
	U-3		4.5+ (P)	75												
	U-4		2.75 (P)	75			-medium gray, very stiff to stiff below 4 feet									
5	U-5		2.0 (P)	75												497
	U-6		1.75 (P)	75												
	U-7		1.75 (P)	75				24	100	93	56	29	27			
	U-8		2.25 (P)	79			-grayish-brown, very stiff, with calcareous nodules below 8 feet									
	U-9		2.75 (P)	71												
10																492
	U-10		3.0 (P)	92												
15																487
20	U-11		2.75 (P)	52				23	105	96	77	20	57	2.8	15.6	482
							-red-brown to gray with trace coarse-grained sand below 22.5 feet									
	U-12		2.0 (P)	60				23	100	91	56	23	33			
25																477
							28/473.9 FAT CLAY with SAND (CH), yellow-brown to medium gray, hard, dry, moderately fissile (Ozan Formation)									
	U-13		4.5+ (P)	88				20	107	85	72	24	48	4.3	4.3	
30							30/471.9									472

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

FREESE AND NICHOLS

LOG OF BORING NO. D-03

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/14/2016
Phase No.: ****
Logged By: D. Rohmer
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/14/2016
Rig Type: CME 75
Hammer Type: Automatic
Drill Method: HSA & NX Core
Latitude: 33.463021
Longitude: -95.903325
Elevation: 501.9 ft.

DEPTH, ft	SAMPLE					SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	TYPE	BLOW COUNTS	HAND PENETROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %											
	C-14			96	92		MARL, dark gray, very soft to soft, calcareous, occasionally fissile (Ozan Formation) *(continued)* -yellow-brown to gray from 30.2 to 34 feet -low angle fractures from 32.3 to 32.4 feet	18		73	58	24	34			
35																467
	C-15			90	90											
40																462
	C-16			100	100											
							-fissile below 43.8 feet									
45																457
	C-17			100	100											
50																452
	C-18			94	94			18	114					15.2	1.9	
55																447
	C-19			97	97											
60							Total boring depth 60.0 ft.									442

Water Observations:

Remarks:

LOG OF BORING NO. D-04

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/14/2016
Logged By: D. Rohmer
Rig Type: CME 75
Latitude: 33.461952

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.903319

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/14/2016
Drill Method: HSA & NX Core
Elevation: 501.1 ft.

DEPTH, ft	SAMPLE TYPE	SAMPLE BLOW COUNTS	SAMPLE HAND PENE-TROMETER (P) / TORVANE (T), tsf	SAMPLE RECOVERY, %	SAMPLE RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.5+ (P)	96		▨	FAT CLAY (CH), dark brown, hard, moist (Alluvium)									
	U-2		4.5+ (P)	75			-dark gray, hard to very stiff, with calcareous nodules below 1 foot									
	U-3		3.5 (P)	71				22	97							
	U-4		2.75 (P)	75												
	U-5		2.25 (P)	71												
5																496
	U-6		2.0 (P)	83												
	U-7		2.0 (P)	75				26	96	100	66	31	35			
	U-8		2.5 (P)	83			-brown to dark gray, very stiff below 7 feet									
	U-9		2.75 (P)	83												
	U-10		3.25 (P)	96				24	103	98	70	23	47			
10																491
							-yellow-brown to gray, stiff below 12 feet									
	U-11		1.5 (P)	58				23	104					1.8	5.3	
15																486
	U-12		1.25 (P)	56				23	102	96	54	24	30			
20																481
	U-13		1.5 (P)	56				22	106					2.1	15.2	
25																476
						▨	27/474.1 FAT CLAY with GRAVEL (CH), yellow-brown to gray, very stiff, fine-grained gravel (Alluvium)									
	U-14		3.0 (P)	58				24	103	78	55	19	36	1.1	2.5	
30																471

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

FREESE AND NICHOLS

LOG OF BORING NO. D-04

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/14/2016
Phase No.: ****
Logged By: D. Rohmer
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/14/2016
Rig Type: CME 75
Hammer Type: Automatic
Drill Method: HSA & NX Core
Latitude: 33.461952
Longitude: -95.903319
Elevation: 501.1 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
						▨	FAT CLAY with GRAVEL (CH), yellow-brown to gray, very stiff, fine-grained gravel (Alluvium) *(continued)*									
	U-15		4.5+ (P)	83		▨	34/467.1 FAT CLAY (CH), dark gray, hard, dry moderately fissile (Ozan Formation)									
35							35/466.1 MARL, dark gray, very soft to soft, calcareous, occassional fissile, with bivalve fossils (Ozan Formation) -yellow-brown, weathered at 35.1, 35.4, 36.3, 36.5, 36.9, and 37.7 feet									466
	C-16			91	91											
40																461
	C-17			90	90			18	114	90	60	26	34	11.3	1.8	
							-low angle fracture at 43.6 feet									
45																456
							-low angle fracture at 46 feet									
	C-18			98	98											
50																451
	C-19			98	98											
55																446
	C-20			100	100											
60							Total boring depth 60.0 ft.									441

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

LOG OF BORING NO. D-05

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/15/2016
Phase No.: ****
Logged By: D. Rohmer
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/15/2016
Rig Type: CME 75
Hammer Type: Automatic
Drill Method: HSA & NX Core
Latitude: 33.457012
Longitude: -95.903276
Elevation: 503.0 ft.

DEPTH, ft	SAMPLE TYPE	SAMPLE BLOW COUNTS	SAMPLE HAND PENE-TROMETER (P) / TORVANE (T), tsf	SAMPLE RECOVERY, %	SAMPLE RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.25 (P)	83		▨	LEAN CLAY with SAND (CL), brown, hard, moist, fine-grained sand (Alluvium)									
	U-2		4.5+ (P)	58												
	U-3		4.5+ (P)	54												
	U-4		3.75 (P)	63						85	36	20	16			
	U-5		4.5+ (P)	58			-very stiff below 4.5 feet									
5	U-6		2.0 (P)	42												498
	SPT-7	3-2-3 (5)					-medium stiff below 6.5 feet									
	SPT-8	3-5-7 (12)					-stiff below 8.5 feet	22								
10																493
	SPT-9	5-5-6 (11)														
15						▨	FAT CLAY (CH), gray, stiff, moist (Alluvium) 15/488.0									488
							-dark brown, very stiff, dry to moist below 18 feet									
	U-10		3.75 (P)	92				19	112	94	58	19	39	3.3	15.9	
20																483
							-gray to red-brown below 23 feet									
	U-11		2.5 (P)	83				21	108					2.9	14.9	
25																478
	U-12		2.25 (P)	96				27	97	89	50	25	25			

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

FREESE AND NICHOLS

LOG OF BORING NO. D-05

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/15/2016
Logged By: D. Rohmer
Rig Type: CME 75
Latitude: 33.457012

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.903276

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/15/2016
Drill Method: HSA & NX Core
Elevation: 503.0 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENETROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
						▨	FAT CLAY (CH), gray, stiff, moist (Alluvium) *(continued)*									
						▨	33/470.0 FAT CLAY (CH), medium gray, hard, calcareous, moderately fissile (Ozan Formation)									
	U-13		4.5+ (P)	58		▨										
35						▤	35/468.0 MARL, medium to dark gray, very soft to soft, calcareous, occassionally fissile, with bivalve fossils (Ozan Formation)									468
	C-14			100	100	▤		17	116	67	50	23	27	13.6	2.4	
40						▤										463
	C-15			100	100	▤										
45						▤										458
	C-16			100	100	▤		17	116							
50						▤										453
	C-17			88	88	▤										
55						▤										448
	C-18			94	94	▤										

Water Observations:

Remarks:

FREESE AND NICHOLS

LOG OF BORING NO. D-05

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/15/2016
Logged By: D. Rohmer
Rig Type: CME 75
Latitude: 33.457012

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.903276

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/15/2016
Drill Method: HSA & NX Core
Elevation: 503.0 ft.

DEPTH, ft	SAMPLE					SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	TYPE	BLOW COUNTS	HAND PENETROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %											
						▨	MARL, medium to dark gray, very soft to soft, calcareous, occassionally fissile, with bivalve fossils (Ozan Formation) *(continued)*									
	C-19			95	95	▨										
65						▨										438
	C-20			100	100	▨										
70						▨										433
	C-21			97	97	▨										
75							Total boring depth 75.0 ft.									428
80																423
85																418

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

LOG OF BORING NO. DS-01

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/16/2016
Logged By: ZR
Rig Type: CME 75
Latitude: 33.461992

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.887009

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/16/2016
Drill Method: HSA & NX Core
Elevation: 495.8 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.5+ (P)	67		▨	FAT CLAY (CH), brown, hard, dry, with trace sand, with calcareous particles (Alluvium)									
	U-2		4.5+ (P)	42		▨										
	U-3		4.5+ (P)	29		▨										
	U-4		4.5+ (P)	58		▨	-dark brown below 3 feet									
	U-5		4.5+ (P)	58		▨										
5	U-6		3.5 (P)	83		▨	-brown, very stiff, with trace calcareous nodules below 5 feet									491
	U-7		2.75 (P)	75		▨		26	101	90	82	28	54	2.6	15.7	
	U-8		2.5 (P)	79		▨										
	U-9		3.0 (P)	67		▨	-with trace calcareous nodules and particles below 8 feet									
	U-10		2.5 (P)	83		▨										
10						▨										486
	U-11		3.5 (P)	50		▨	-mottled with brown and gray below 13 feet	26	100							
15						▨										481
	U-12		3.5 (P)	67		▨	-with trace fine-grained sand at 18 feet									
20						▨										476
	U-13		1.75 (P)	67		▨	-light brown and light gray, stiff, with trace fine-grained sand and trace calcareous particles below 23 feet	24	102	91	56	22	34	1.6	15.4	
25						▨										471
	U-14		2.0 (P)	63		▨	-with trace gravel at 28 feet									

Water Observations:
None At Time Of Drilling

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

LOG OF BORING NO. DS-01

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/16/2016
Logged By: ZR
Rig Type: CME 75
Latitude: 33.461992
Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.887009
Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/16/2016
Drill Method: HSA & NX Core
Elevation: 495.8 ft.

DEPTH, ft	SAMPLE					SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %											
						▨	FAT CLAY (CH), brown, hard, dry, with trace sand, with calcareous particles (Alluvium) *(continued)*									
35	U-15		4.5+ (P)	38		▤	MARL, dark gray, very soft to soft, fissile, calcareous, with occasional vertical iron stains, with occasional fossils (Ozan Formation) 33/462.8 -with horizontal fractures from 35.5 to 35.6 feet									461
	C-16			93	82	▤	-with multiple planar fractures below 37.5 feet	20	112					13.8	2.3	
40							Total boring depth 40.0 ft.									456
45																451
50																446
55																441

Water Observations:
None At Time Of Drilling

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

FREESE AND NICHOLS

LOG OF BORING NO. DS-02

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/16/2016
Phase No.: ****
Logged By: ZR
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/16/2016
Rig Type: CME 75
Hammer Type: Automatic
Drill Method: CFA & DRY
Latitude: 33.461490
Longitude: -95.877970
Elevation: 493.4 ft.

DEPTH, ft	SAMPLE					SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %											
	U-1		4.25 (P)	50		▨	FAT CLAY (CH), dark brown, hard, dry, with trace fine-grained sand									
	U-2		4.5+ (P)	50		▨										
	U-3		2.0 (P)	63		▨	-dark brown, stiff below 2 feet	17		93	51	20	31			
	U-4		1.5 (P)	67		▨										
	U-5		2.0 (P)	67		▨										
5	U-6		1.75 (P)	71		▨	-dark brown and brown below 5 feet									488
	U-7		2.0 (P)	58		▨										
	U-8		2.75 (P)	79		▨	-brown, very stiff, with trace calcareous nodules and trace fine-grained sand below 7 feet									
	U-9		2.75 (P)	79		▨										
	U-10		3.0 (P)	83		▨										
10						▨										483
						▨	-yellow-brown below 13 feet									
	U-11		3.0 (P)	83		▨		27	111	95	80	27	53	2.1	3.3	
15						▨										478
	U-12		3.5 (P)	71		▨										
20						▨										473
	U-13		2.25 (P)	63		▨	-mottled with yellow-brown and gray, stiff, with silt below 23 feet									
25						▨										468
	U-14		1.75 (P)	54		▨										

Water Observations:

Remarks:

LOG OF BORING NO. DS-02

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/16/2016
Logged By: ZR
Rig Type: CME 75
Latitude: 33.461490

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.877970

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/16/2016
Drill Method: CFA & DRY
Elevation: 493.4 ft.

DEPTH, ft	SAMPLE: TYPE	SAMPLE: BLOW COUNTS	SAMPLE: HAND PENE-TROMETER (P) / TORVANE (T), tsf	SAMPLE: RECOVERY, %	SAMPLE: RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
						▨	FAT CLAY (CH), dark brown, hard, dry, with trace fine-grained sand *(continued)*									
35	U-15		4.5+ (P)	54		▨	33/460.4 FAT CLAY (CH), yellow-brown and gray, hard, dry, fissile, with trace calcareous nodules and particles (Ozan Formation)	29	97	89	77	24	53	1.3	6.9	458
	U-16		4.5+ (P)	29		▱	38/455.4 MARL, gray, very soft to soft, calcareous, fissile (Ozan Formation)									
40	TCP	50/0.50" 50/0.25"					Total boring depth 40.1 ft.									453
45																448
50																443
55																438

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

FREESE AND NICHOLS

LOG OF BORING NO. ES-01

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/16/2016
Logged By: ZR
Rig Type: CME 75
Latitude: 33.476420

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.903490

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/16/2016
Drill Method: CFA & DRY
Elevation: 540.3 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENETROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.5+ (P)	42		▨	FAT CLAY with SAND (CH), light brown, hard, dry, trace calcareous particles, fine-grained sand (Alluvium)									
	U-2		4.5+ (P)	50		▨										
	U-3		4.5+ (P)	63		▨	-with calcareous parting and iron staining at 2 feet 3/537.3	16								
	U-4		4.5+ (P)	67		▨	FAT CLAY (CH), light brown and light gray, hard, dry, fissile, with trace sand, with calcareous partings and nodules (Ozan Formation)									
	U-5		4.5+ (P)	63		▨										
5	U-6		4.5+ (P)	92		▨		30	98							535
	U-7		4.5+ (P)	100		▨	-with calcareous partings from 6 to 9 feet									
	U-8		4.5+ (P)	96		▨										
	U-9		4.5+ (P)	92		▨										
	U-10		4.5+ (P)	88		▨	-brown and light gray below 9 feet									
10						▨										530
	U-11		4.5+ (P)	75		▨		22								
15						▨										525
	U-12		4.5+ (P)	67		▨										
20						▨										520
	U-13		4.5+ (P)	67		▨	-with dark gray fissile seams and gypsum partings below 23 feet									
25							Total boring depth 25.0 ft.									515

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

LOG OF BORING NO. ES-02

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Date Drilling Started: 9/16/2016
Logged By: D. Rohmer
Rig Type: CME 75
Latitude: 33.471763

Drilling Co.: Texplor of Dallas, Inc.
Hammer Type: Automatic
Longitude: -95.897092

Project No.: CHM16420
Phase No.: ****
Date Drilling Completed: 9/16/2016
Drill Method: CFA & DRY
Elevation: 545.2 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.5+ (P)	29		▨	LEAN CLAY with SAND (CL), light brown, hard, with occasional iron stains (Alluvium)									
	U-2		4.5+ (P)	75		▨	1/544.2 FAT CLAY (CH), brown, hard, dry, with trace fine-grained sand and occasional iron stains (Alluvium)									
	U-3		4.5+ (P)	71												
	U-4		4.5+ (P)	71			-yellow-brown and light gray below 3 feet									
	U-5		4.5+ (P)	75												
5	U-6		4.5+ (P)	100			-with trace calcareous particles at 5 feet									540
	U-7		4.5+ (P)	50												
	U-8		4.5+ (P)	79				19								
	U-9		4.5+ (P)	58												
	U-10		4.5+ (P)	71												
10																535
						▨	13/532.2 LEAN CLAY with SAND (CL), yellow-brown and light gray, dry, hard (Alluvium)									
	U-11		4.0 (P)	63				16	101	85	46	20	26			
15																530
						▨	18/527.2 FAT CLAY (CH), yellow-brown and gray, hard, dry, with trace calcareous nodules, fissile (Ozan Formation)									
	U-12		4.25 (P)	67												
20																525
	U-13		4.5+ (P)	71												
25							Total boring depth 25.0 ft.									520

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

LOG OF BORING NO. ES-03

Project Description: Lake Ralph Hall Conceptual Design Study
Project Location: Fannin County, Ladonia, Texas
Project No.: CHM16420
Date Drilling Started: 9/16/2016
Phase No.: ****
Logged By: ZR
Drilling Co.: Texplor of Dallas, Inc.
Date Drilling Completed: 9/16/2016
Rig Type: CME 75
Hammer Type: Automatic
Drill Method: CFA & DRY
Latitude: 33.462865
Longitude: -95.894500
Elevation: 498.2 ft.

DEPTH, ft	SAMPLE TYPE	BLOW COUNTS	HAND PENE-TROMETER (P) / TORVANE (T), tsf	RECOVERY, %	RQD, %	SYMBOL	MATERIAL DESCRIPTION	WATER CONTENT, %	UNIT DRY WEIGHT, pcf	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	UNC. COMPRESSIVE STRENGTH, tsf	STRAIN AT FAILURE, %	ELEVATION, ft
	U-1		4.5+ (P)	42		▨	FAT CLAY (CH), dark brown, hard, dry, with trace calcareous particles (Alluvium)									
	U-2		4.5+ (P)	42												
	U-3		4.25 (P)	58												
	U-4		2.25 (P)	58			-very stiff below 3 feet									
	U-5		2.0 (P)	58			-dark brown with brown-yellow and brown below 4 feet									
5	U-6		3.0 (P)	67			-with calcareous nodules below 5 feet									493
	U-7		3.0 (P)	58												
	U-8		2.75 (P)	67												
	U-9		2.75 (P)	67												
	U-10		3.0 (P)	71												
10																488
	U-11		3.0 (P)	58			-yellow-brown and gray, with trace sand below 13 feet									
15																483
	U-12		3.25 (P)	50				26								
20																478
	U-13		2.75 (P)	54		▨	LEAN CLAY with SAND (CL), yellow-brown and light gray, very stiff, fine-grained sand (Alluvium) 23/475.2									
25							Total boring depth 25.0 ft.									473

Water Observations:

Remarks:

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual. These logs are subject to the limitations, conclusions, and recommendations in the associated report.

BOREHOLE PERMEABILITY CALCULATION USING PACKER TESTING

FREESE AND NICHOLS

Project Name: Lake Ralph Hall

Location: Fannin County, Texas

Test Date: 9/12/2016

Tested By: D. Rohmer

Project No.: CHM16420

Borehole No.: D-01

Test Interval: 50 to 100 feet bgs

Hole Diameter	3.12	inches
Depth to Tip of Packer	50.0	feet
Height of Gauge Above Ground	3.5	feet
Groundwater Depth	Dry	feet bgs
Nitrogen Pressure	85	psi

Calculated Gauge Pressure

Overburden Soil Thickness	45	feet	(To)
Consolidated Material Thickness	5	feet	(Tcm)
Height of Water Column	53.0	feet	(Hwc)

Effective Pressure = (To * 0.75) + (Tcm) - (Hwc * 0.433) = **15.8** psi

Pressure Coefficient* = ________ (Cp) based on borehole diameter and test length

---

Start Time	0:00:00		**End Time**	0:10:00	
Gauge Pressure	16.0	psi	Gauge pressure	16.0	psi
Water Meter Reading	52.8	gal	Water Meter Reading	52.8	gal

Test No.	Start Time	End Time	Flow (Q) (gpm)	Pressure (psi)		Permeability (ft/sec)	Permeability (cm/sec)
				Gauge	Effective		
1	0:00	0:10	0.000	28.0	15.8	0.0E+00	0.0E+00

Comments and Conclusions

* Pressure coefficient obtained from U.S. DOT Earth Manual - Water Resources Tech Pub 1985, DES. E-18

BOREHOLE PERMEABILITY CALCULATION USING PACKER TESTING

Project Name: Lake Ralph Hall
Location: Fannin County, Texas
Test Date: 9/13/2016
Tested By: D. Rohmer

Project No.: CHM16420
Borehole No.: D-02
Test Interval: 25 to 75 feet bgs

Hole Diameter 3.25 inches
Depth to Tip of Packer 25.0 feet
Height of Gauge Above Ground 3.2 feet
Groundwater Depth Dry feet bgs
Nitrogen Pressure 100 psi

Calculated Gauge Pressure

Overburden Soil Thickness 20 feet (To)
Consolidated Material Thickness 5 feet (Tcm)
Height of Water Column 20.2 feet (Hwc)

Effective Pressure = (To * 0.75) + (Tcm) - (Hwc * 0.433) = **11.3** psi

Pressure Coefficient* = ______ (Cp) based on borehole diameter and test length

---

Start Time 0:00:00
Gauge Pressure 11.0 psi
Water Meter Reading 52.3 gal

End Time 0:10:00
Gauge pressure 11.0 psi
Water Meter Reading 52.3 gal

Test No.	Start Time	End Time	Flow (Q) (gpm)	Pressure (psi)		Permeability (ft/sec)	Permeability (cm/sec)
				Gauge	Effective		
1	0:00	0:10	0.000	28.0	11.3	0.0E+00	0.0E+00

Comments and Conclusions

* Pressure coefficient obtained from U.S. DOT Earth Manual - Water Resources Tech Pub 1985, DES. E-18

BOREHOLE PERMEABILITY CALCULATION USING PACKER TESTING

FREESE AND NICHOLS

Project Name: Lake Ralph Hall

Location: Fannin County, Texas

Test Date: 9/14/2016

Tested By: D. Rohmer

Project No.: CHM16420

Borehole No.: D-03

Test Interval: 35 to 60 feet bgs

Hole Diameter 3.25 inches

Depth to Tip of Packer 35.0 feet

Height of Gauge Above Ground 3.5 feet

Groundwater Depth Dry feet bgs

Nitrogen Pressure 100 psi

Calculated Gauge Pressure

Overburden Soil Thickness 30 feet (To)

Consolidated Material Thickness 5 feet (Tcm)

Height of Water Column 33.5 feet (Hwc)

Effective Pressure = (To * 0.75) + (Tcm) - (Hwc * 0.433) = **13.0** psi

Pressure Coefficient* = ______ (Cp) based on borehole diameter and test length

---

Start Time 0:00:00

Gauge Pressure 13.0 psi

Water Meter Reading 52.6 gal

End Time 0:10:00

Gauge pressure 13.0 psi

Water Meter Reading 52.6 gal

Test No.	Start Time	End Time	Flow (Q) (gpm)	Pressure (psi)		Permeability (ft/sec)	Permeability (cm/sec)
				Gauge	Effective		
1	0:00	0:10	0.000	28.0	13.0	0.0E+00	0.0E+00

Comments and Conclusions

* Pressure coefficient obtained from U.S. DOT Earth Manual - Water Resources Tech Pub 1985, DES. E-18

BOREHOLE PERMEABILITY CALCULATION USING PACKER TESTING

FREESE AND NICHOLS

Project Name: Lake Ralph Hall
Location: Fannin County, Texas
Test Date: 9/14/2016
Tested By: D. Rohmer

Project No.: CHM16420
Borehole No.: D-04
Test Interval: 40 to 60 feet bgs

Hole Diameter 3.25 inches
Depth to Tip of Packer 40.0 feet
Height of Gauge Above Ground 4.5 feet
Groundwater Depth Dry feet bgs
Nitrogen Pressure 100 psi

Calculated Gauge Pressure

Overburden Soil Thickness 35 feet (To)
Consolidated Material Thickness 5 feet (Tcm)
Height of Water Column 39.5 feet (Hwc)

Effective Pressure = (To * 0.75) + (Tcm) - (Hwc * 0.433) = **14.1** psi

Pressure Coefficient* = ______ (Cp) based on borehole diameter and test length

---

Start Time 0:00:00
Gauge Pressure 14.0 psi
Water Meter Reading 53.1 gal

End Time 0:10:00
Gauge pressure 14.0 psi
Water Meter Reading 53.1 gal

Test No.	Start Time	End Time	Flow (Q) (gpm)	Pressure (psi) Gauge	Pressure (psi) Effective	Permeability (ft/sec)	Permeability (cm/sec)
1	0:00	0:10	0.000	28.0	14.1	0.0E+00	0.0E+00

Comments and Conclusions

---

* Pressure coefficient obtained from U.S. DOT Earth Manual - Water Resources Tech Pub 1985, DES. E-18

BOREHOLE PERMEABILITY CALCULATION USING PACKER TESTING

FREESE AND NICHOLS

Project Name: Lake Ralph Hall

Location: Fannin County, Texas

Test Date: 9/15/2016

Tested By: D. Rohmer

Project No.: CHM16420

Borehole No.: D-05

Test Interval: 45 to 75 feet bgs

Hole Diameter	3.25	inches
Depth to Tip of Packer	40.0	feet
Height of Gauge Above Ground	6.0	feet
Groundwater Depth	Dry	feet bgs
Nitrogen Pressure	85	psi

Calculated Gauge Pressure

Overburden Soil Thickness	35	feet	(To)
Consolidated Material Thickness	5	feet	(Tcm)
Height of Water Column	46.0	feet	(Hwc)

Effective Pressure = (To * 0.75) + (Tcm) - (Hwc * 0.433) = **11.3** psi

Pressure Coefficient* = ______ (Cp) based on borehole diameter and test length

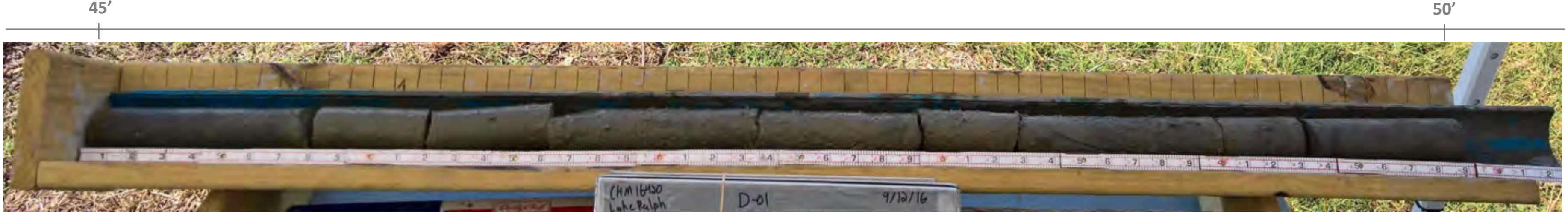
---

Start Time	0:00:00		**End Time**	0:10:00	
Gauge Pressure	11.0	psi	Gauge pressure	11.0	psi
Water Meter Reading	53.6	gal	Water Meter Reading	53.6	gal

Test No.	Start Time	End Time	Flow (Q) (gpm)	Pressure (psi)		Permeability (ft/sec)	Permeability (cm/sec)
				Gauge	Effective		
1	0:00	0:10	0.000	28.0	11.3	0.0E+00	0.0E+00

Comments and Conclusions

* Pressure coefficient obtained from U.S. DOT Earth Manual - Water Resources Tech Pub 1985, DES. E-18



FNI PROJECT:	CHM16420
FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

FREESE AND NICHOLS

4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

UTRWD Lake Ralph Hall

SAMPLE PHOTOGRAPHS

BORING D-01

PLATE
D-01-1

FNI PROJECT:	CHM16420
FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

FREESE AND NICHOLS

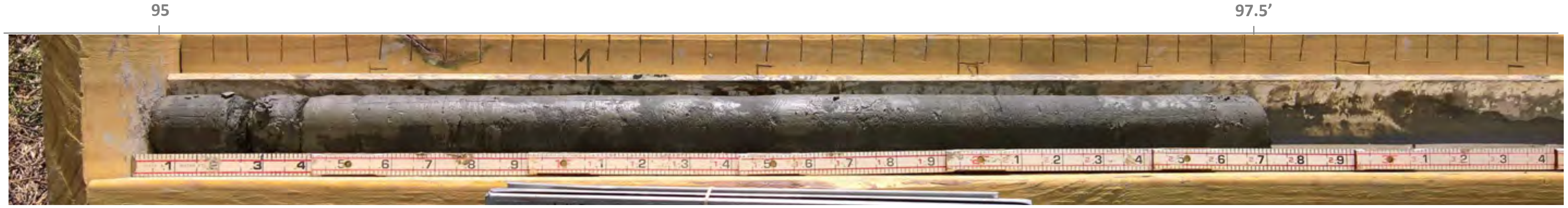
4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

UTRWD Lake Ralph Hall

SAMPLE PHOTOGRAPHS

BORING D-01

PLATE
D-01-2



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FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

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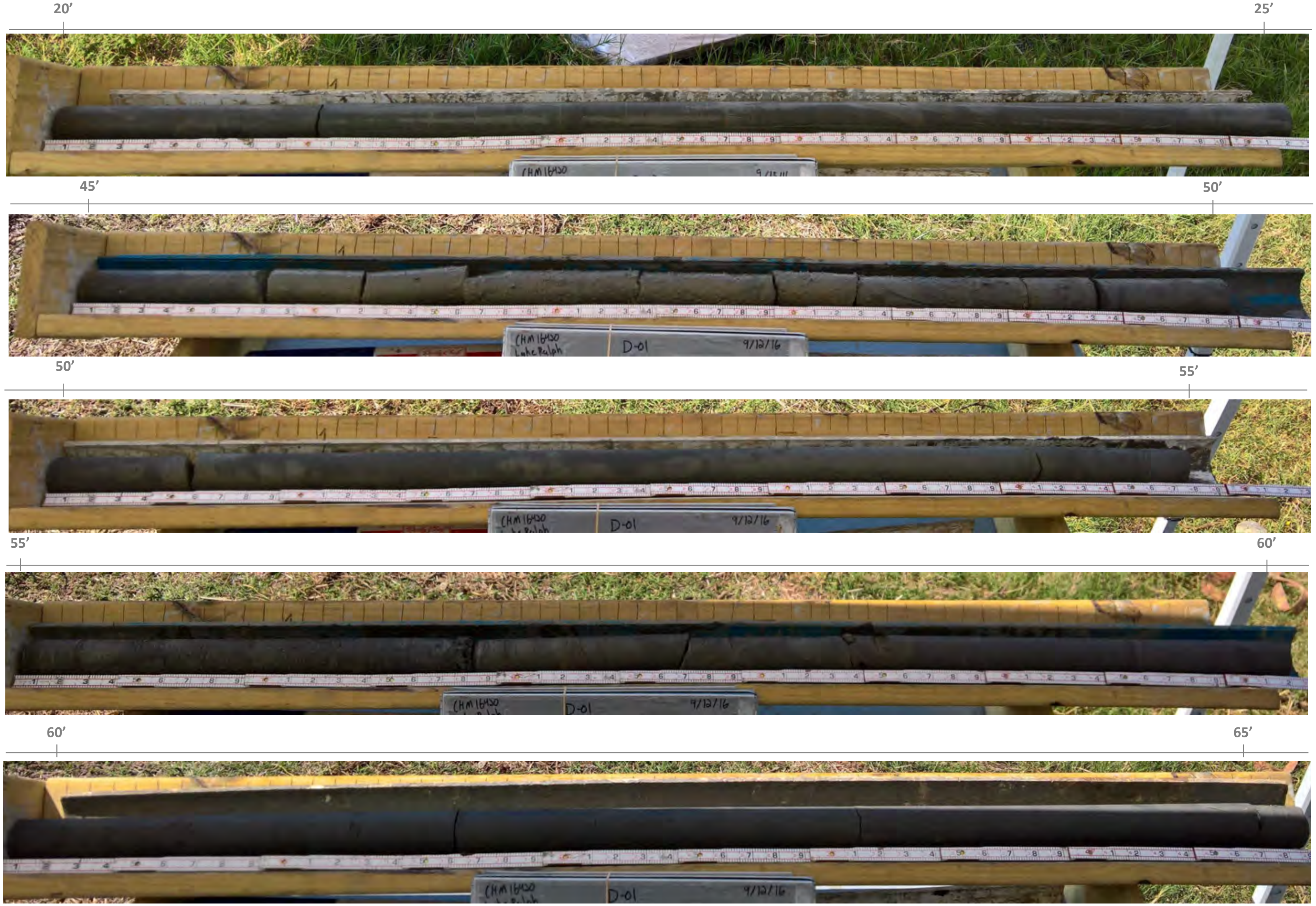
FORT WORTH, TX 76109

UTRWD Lake Ralph Hall

SAMPLE PHOTOGRAPHS

BORING D-01

PLATE
D-01-3



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FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

FREESE AND NICHOLS

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FORT WORTH, TX 76109

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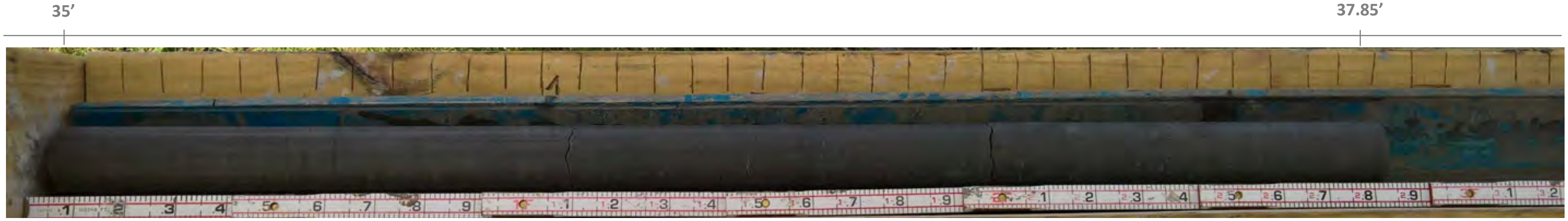
SAMPLE PHOTOGRAPHS

BORING D-02

PLATE
D-02-1



37.85—Ammonite Fossil

FNI PROJECT:	CHM16420
FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

FREESE AND NICHOLS

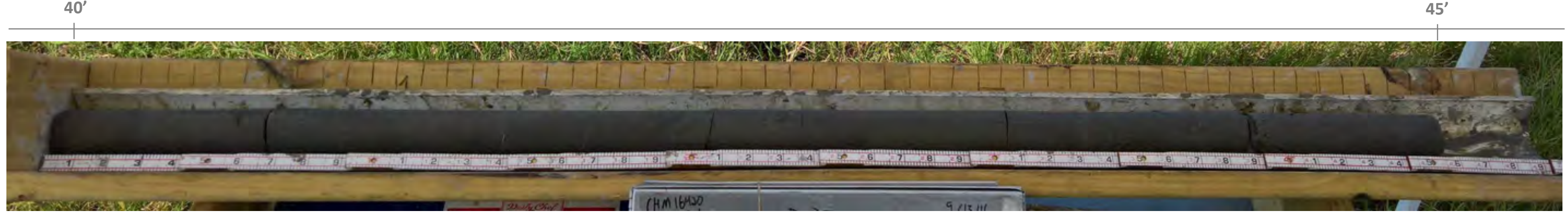
4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

UTRWD Lake Ralph Hall

SAMPLE PHOTOGRAPHS

BORING D-02

PLATE
D-02-2



FNI PROJECT: CHM16420

FILE: T:\STUDY\GEO\Rock Core Photos

DATE: December 2016

PREPARED: MK

FREESE AND NICHOLS

4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

UTRWD Lake Ralph Hall

SAMPLE PHOTOGRAPHS

BORING D-02

PLATE
D-02-3

FNI PROJECT:	CHM16420
FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

FREESE AND NICHOLS
4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

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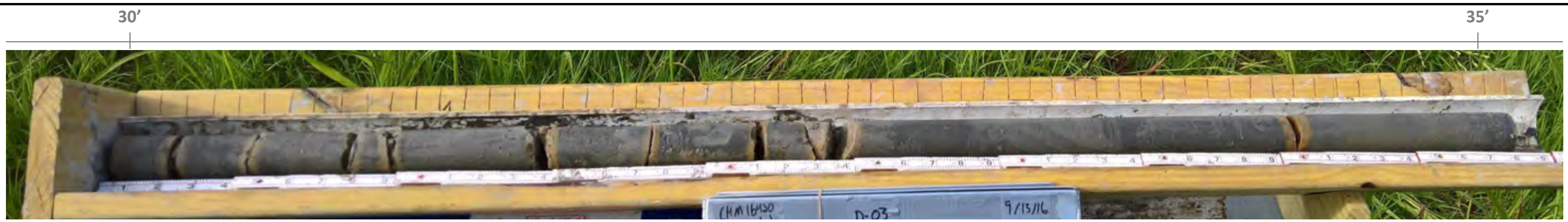
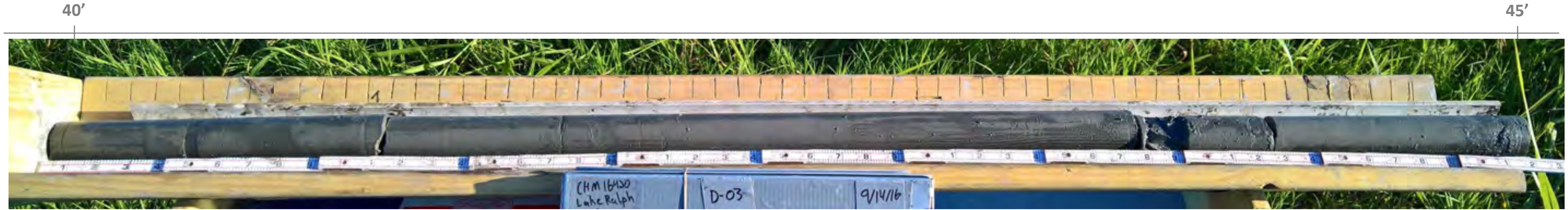
SAMPLE PHOTOGRAPHS

BORING D-02

PLATE
D-02-4





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FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

FREESE AND NICHOLS
4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

UTRWD Lake Ralph Hall

SAMPLE PHOTOGRAPHS
BORING D-03

PLATE
D-03-1

FNI PROJECT: CHM16420

FILE: T:\STUDY\GEO\Rock Core Photos

DATE: December 2016

PREPARED: MK

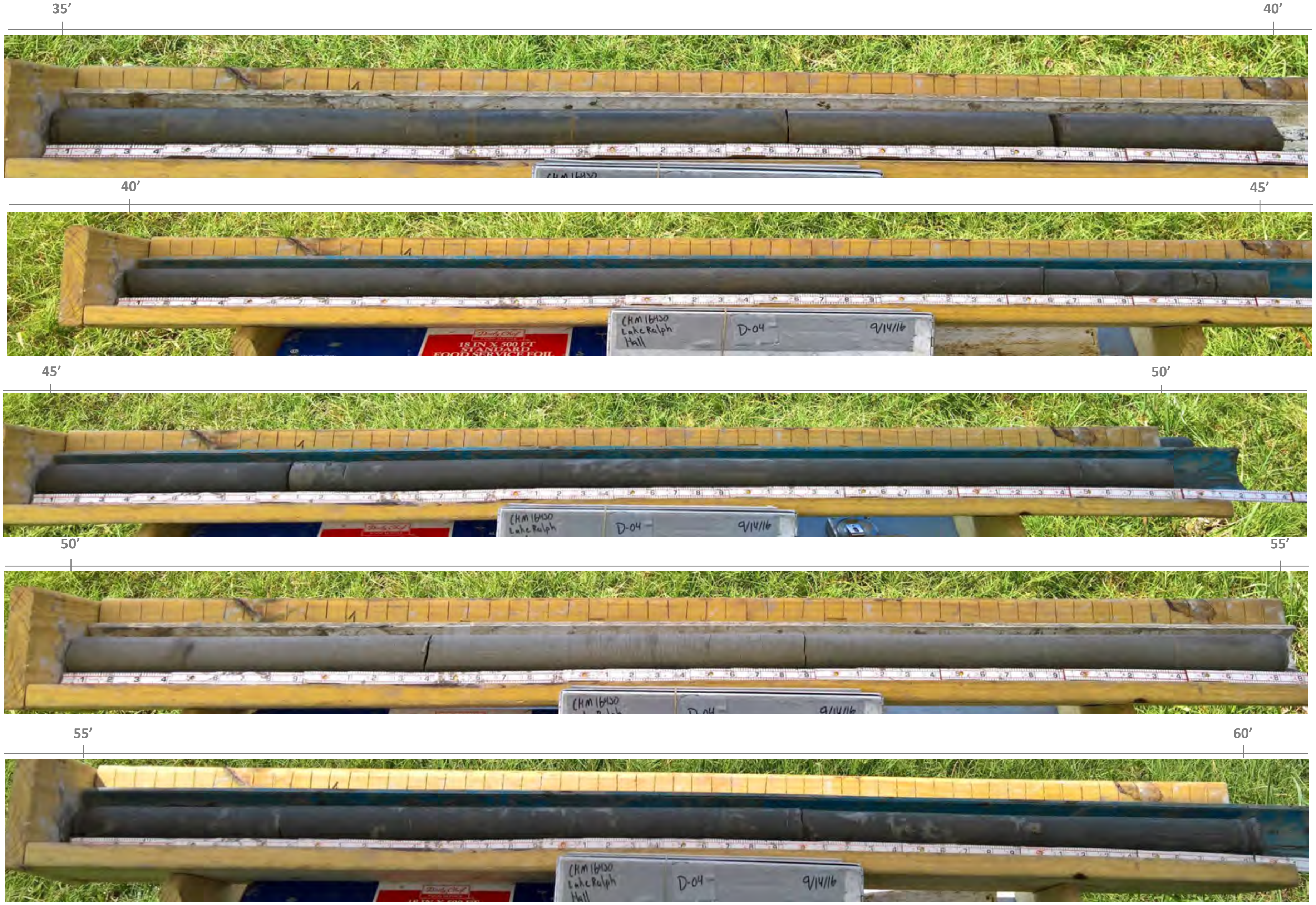
4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

UTRWD Lake Ralph Hall

SAMPLE PHOTOGRAPHS

BORING D-03

PLATE
D-03-2



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FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

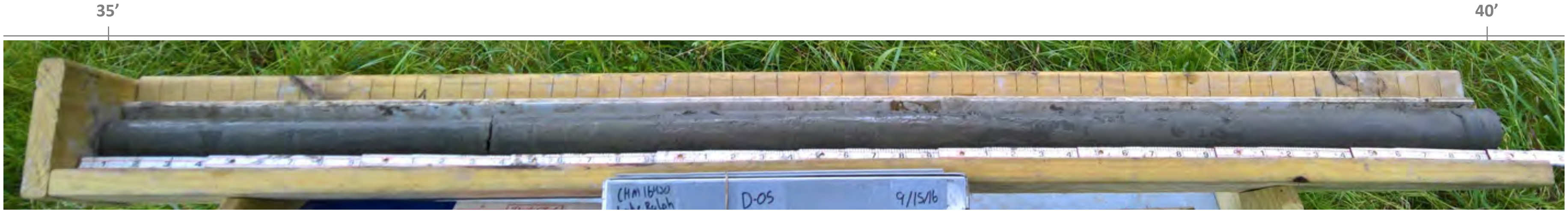
FREESE AND NICHOLS
4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

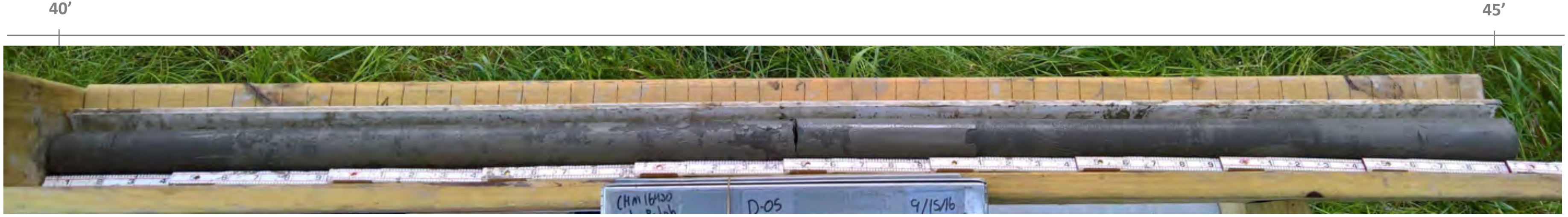
UTRWD Lake Ralph Hall

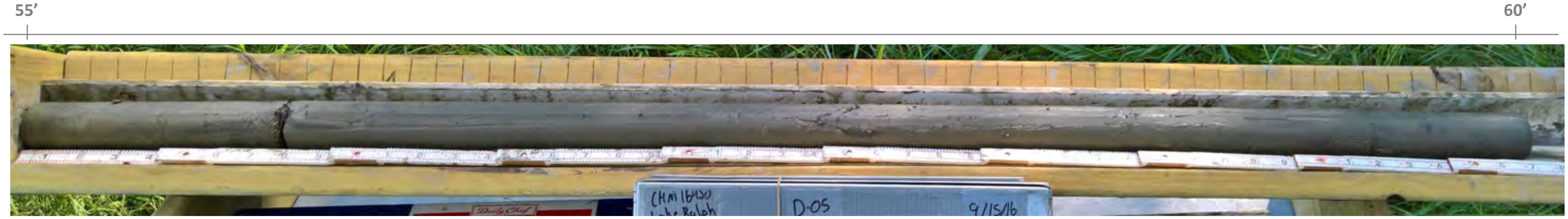
SAMPLE PHOTOGRAPHS

BORING D-04

PLATE
D-04-1







FNI PROJECT:	CHM16420
FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

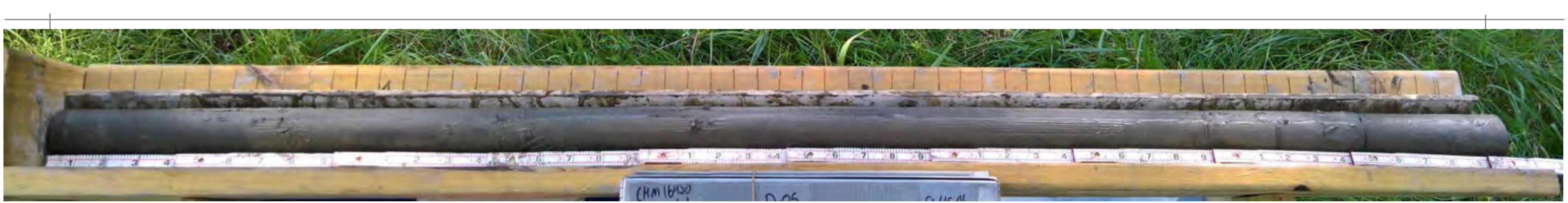
FREESE AND NICHOLS
4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

UTRWD Lake Ralph Hall

SAMPLE PHOTOGRAPHS

BORING D-05

PLATE
D-05-1



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FILE:	T:\STUDY\GEO\Rock Core Photos
DATE:	December 2016
PREPARED:	MK

FREESE AND NICHOLS

4055 INTERNATIONAL PLAZA, STE 200
FORT WORTH, TX 76109

UTRWD Lake Ralph Hall

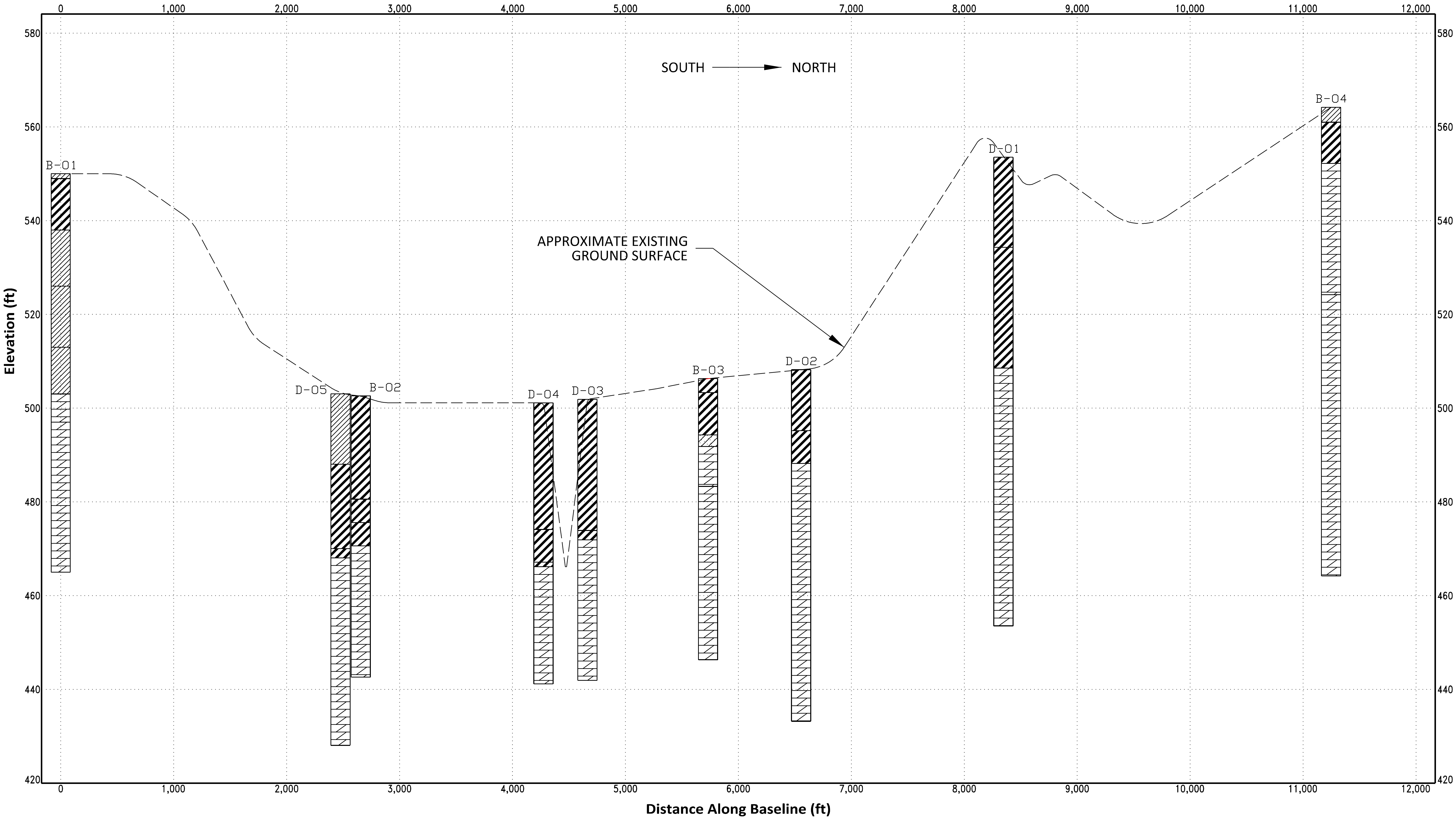
SAMPLE PHOTOGRAPHS

BORING D-05

PLATE
D-05-2

APPENDIX A-2

SOIL AND ROCK STRATIGRAPHY FIGURES



Legend

- ▨ USCS Low Plasticity Clay
- ▨ USCS High Plasticity Clay
- ▨ USCS Clayey Sand
- ▤ Marl

UTRWD Lake Ralph Hall

SUBSURFACE DIAGRAM

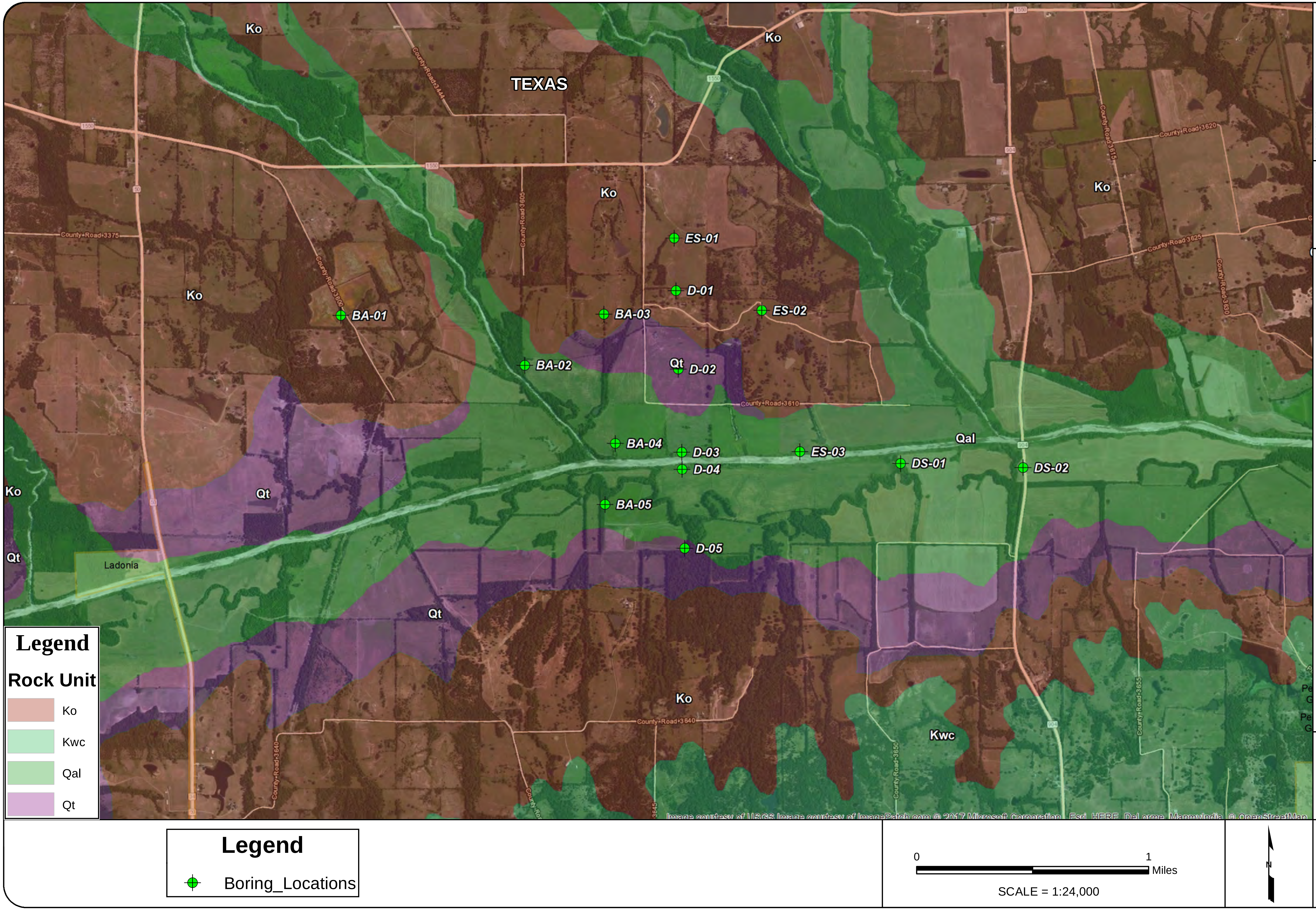
FNI JOB NO CHM16420

DATE 05/26/2017

FILE Fence Log.dgn

DRAFTED RGS

FIGURE 2



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FN PROJECT NO.	CHM16420
DATE CREATED	June 2017
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) 4202 Texas North Central
FILE NAME	CHM16420-Geol.mxd
PREPARED BY	MPT

UTRWD

Lake Ralph Hall

Boring Location/Geologic Map

FREESE AND NICHOLS, INC.
10814 JOLLYVILLE ROAD
BUILDING 4, SUITE 100
AUSTIN, TX 78759
PHONE: 512.617.3100

FIGURE

3

Updated: Monday, May 24, 2010

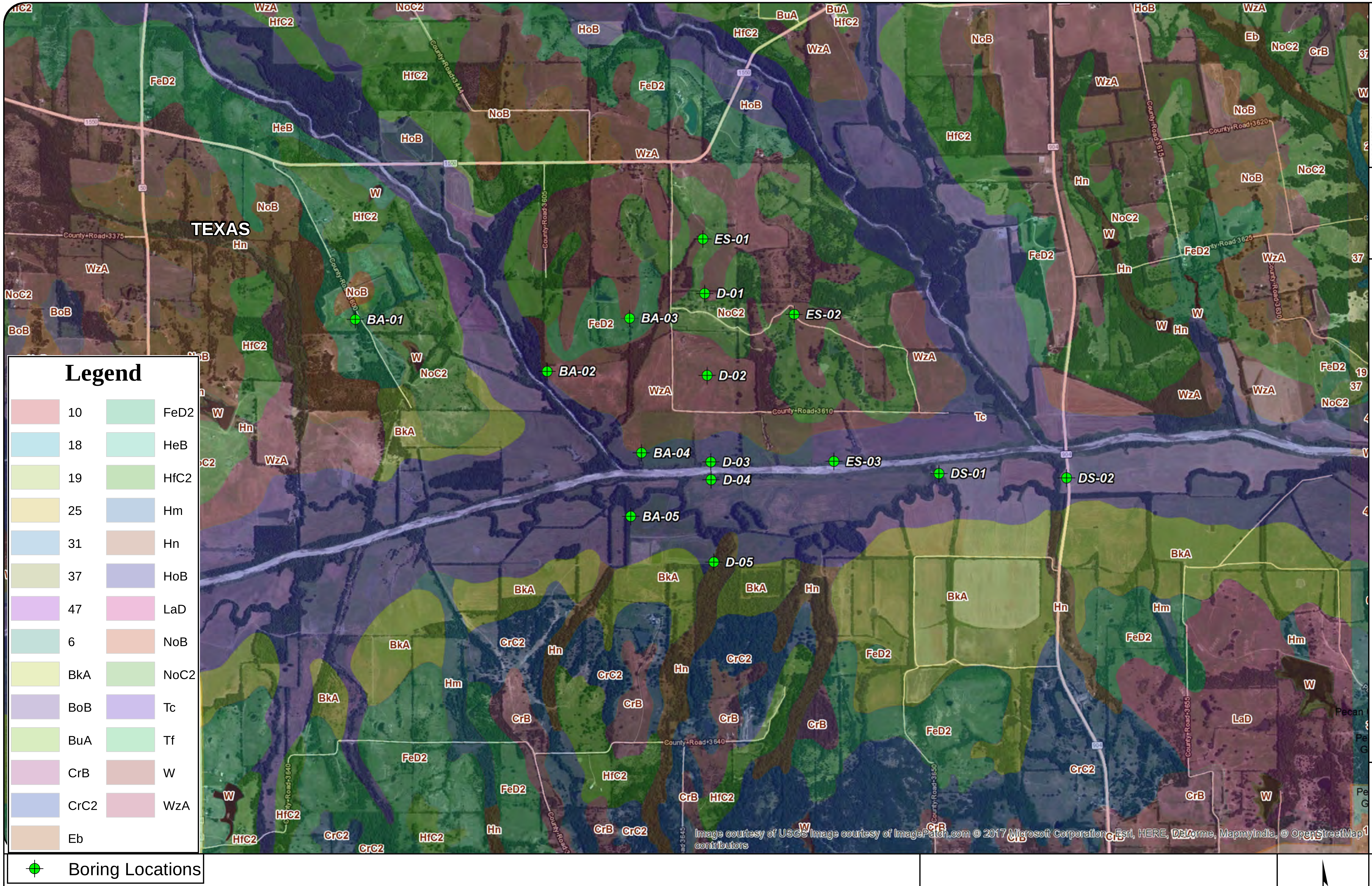


Image courtesy of USGS Image courtesy of ImagePatch.com © 2017 Microsoft Corporation Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors

0 — 1 Miles

SCALE = 1:24,000

N

FN PROJECT NO.	CHM16420
DATE CREATED	June 2017
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) 4202 Texas North Central
FILE NAME	CHM16420-Soils.mxd
PREPARED BY	MPT

UTRWD

Lake Ralph Hall

Boring Location/NRCS Soil Unit Map

FREESE AND NICHOLS, INC.
10814 JOLLYVILLE ROAD
BUILDING 4, SUITE 100
AUSTIN, TX 78759
PHONE: 512.617.3100

FIGURE

4

Updated: Monday, May 24, 2010

NRCS SOIL UNIT MAP DESCRIPTIONS

County	Map Unit Symbol	Map Unit Soil Name
Lamar and Delta	10	Crockett loam, 1 to 3 percent slopes
Lamar and Delta	18	Elbon silty clay loam, 0 to 1 percent slopes, frequently flooded
Lamar and Delta	19	Ferris clay, 5 to 12 percent slopes, eroded
Lamar and Delta	25	Heiden-Ferris complex, 3 to 5 percent slopes
Lamar and Delta	31	Lamar clay loam, 5 to 8 percent slopes
Lamar and Delta	37	Normangee clay loam, 2 to 5 percent slopes, eroded
Lamar and Delta	47	Trinity clay, 0 to 1 percent slopes, occasionally flooded
Lamar and Delta	6	Benklin silt loam, 0 to 1 percent slopes
Fannin	BkA	Benklin silt loam, 0 to 1 percent slopes
Fannin	BoB	Bonham silt loam, 1 to 3 percent slopes
Fannin	BuA	Burleson clay, 0 to 1 percent slopes
Fannin	CrB	Crockett loam, 1 to 3 percent slopes
Fannin	CrC2	Crockett loam, 2 to 5 percent slopes, eroded
Fannin	Eb	Elbon silty clay loam, frequently flooded
Fannin	FeD2	Ferris clay, 5 to 12 percent slopes, eroded
Fannin	HeB	Heiden clay, 1 to 3 percent slopes
Fannin	HfC2	Heiden-Ferris complex, 2 to 6 percent slopes, eroded
Fannin	Hm	Hopco silt loam, occasionally flooded
Fannin	Hn	Hopco silt loam, frequently flooded
Fannin	HoB	Houston Black clay, 1 to 3 percent slopes
Fannin	LaD	Lamar clay loam, 5 to 8 percent slopes
Fannin	NoB	Normangee clay loam, 1 to 3 percent slopes
Fannin	NoC2	Normangee clay loam, 2 to 5 percent slopes, eroded
Fannin	Tc	Tinn clay, 0 to 1 percent slopes, occasionally flooded
Fannin	Tf	Tinn clay, 0 to 1 percent slopes, frequently flooded
Fannin	W	Water
Fannin	WzA	Wilson silt loam, 0 to 1 percent slopes

APPENDIX A-3

LABORATORY TEST DATA

FREESE AND NICHOLS, INC.
4055 INTERNATIONAL PLAZA, SUITE 200
FORT WORTH, TX 76109-4895
(817) 735-7300

GEOTECHNICAL LABORATORY TEST SUMMARY

PROJECT NAME: Lake Ralph Hall Conceptual Design Study
PROJECT NO.: CHM16420

Borehole	Depth	USCS	Water Content [%]	Dry Density [pcf]	Percent Passing No. 200 Sieve	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compressive Strength [tsf]	Strain at Failure [percent]	
BA-01	2	CH	13	121							
BA-01	6	CH	19								
BA-02	4	CH	20	108							
BA-02	19	CH	26		87	71	28	43			
BA-03	1	CH	14								
BA-03	5	CH	19	107							
BA-04	9	CH	22	103							
BA-05	5	CH	20	101							
BA-05	8	CH	18	109							
BA-05	14	CL	22	105							
D-01	2	CH	17	108	98	73	24	49			
D-01	6	CH			96	61	21	40			
D-01	14	CH	15	114	95	52	17	35	9.2	2.9	
D-01	23	CH			98	67	21	46			
D-01	33	CH			96	70	27	43			
D-01	38	CH	19	108							
D-01	45	MARL	21	106	97	65	28	37	8.3	2.4	
D-02	2	CH	14	114							
D-02	6	CH	20	106	88	64	19	45	3	7.7	
D-02	9	CH	23	103	92	54	29	25			
D-02	13	CH			97	74	25	49			
D-02	20	CH	18	112	54	61	27	34	19.1	2.2	
D-02	35	MARL	20	107	70	60	29	31			

FREESE AND NICHOLS, INC.
4055 INTERNATIONAL PLAZA, SUITE 200
FORT WORTH, TX 76109-4895
(817) 735-7300

GEOTECHNICAL LABORATORY TEST SUMMARY

PROJECT NAME: Lake Ralph Hall Conceptual Design Study
PROJECT NO.: CHM16420

Borehole	Depth	USCS	Water Content [%]	Dry Density [pcf]	Percent Passing No. 200 Sieve	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compressive Strength [tsf]	Strain at Failure [percent]	
D-03	7	CH	24	100	93	56	29	27			
D-03	19	CH	23	105	96	77	20	57	2.8	15.6	
D-03	23	CH	23	100	91	56	23	33			
D-03	29	CH	20	107	85	72	24	48	4.3	4.3	
D-03	34	MARL	18		73	58	24	34			
D-03	50	MARL	18	114					15.2	1.9	
D-04	2	CH	22	97							
D-04	6	CH	26	96	100	66	31	35			
D-04	9	CH	24	103	98	70	23	47			
D-04	13	CH	23	104					1.8	5.3	
D-04	18	CH	23	102	96	54	24	30			
D-04	23	CH	22	106					2.1	15.2	
D-04	28	CH	24	103	78	55	19	36	1.1	2.5	
D-04	40	MARL	18	114	90	60	26	34	11.3	1.8	
D-05	3	CL			85	36	20	16			
D-05	8	CL	22								
D-05	19	CH	19	112	94	58	19	39	3.3	15.9	
D-05	24	CH	21	108					2.9	14.9	
D-05	29	CH	27	97	89	50	25	25	--	--	
D-05	35	MARL	17	116	67	50	23	27	13.6	2.4	
D-05	45	MARL	17	116							
DS-01	6	CH	26	101	90	82	28	54	2.6	15.7	
DS-01	13	CH	26	100							
DS-01	23	CH	24	102	91	56	22	34	1.6	15.4	
DS-01	35	MARL	20	112					13.8	2.3	
DS-02	2	CH	17		93	51	20	31			
DS-02	13	CH	27	111	95	80	27	53	2.1	3.3	
DS-02	33	CH	29	97	89	77	24	53	1.3	6.9	

FREESE AND NICHOLS

FREESE AND NICHOLS, INC.
4055 INTERNATIONAL PLAZA, SUITE 200
FORT WORTH, TX 76109-4895
(817) 735-7300

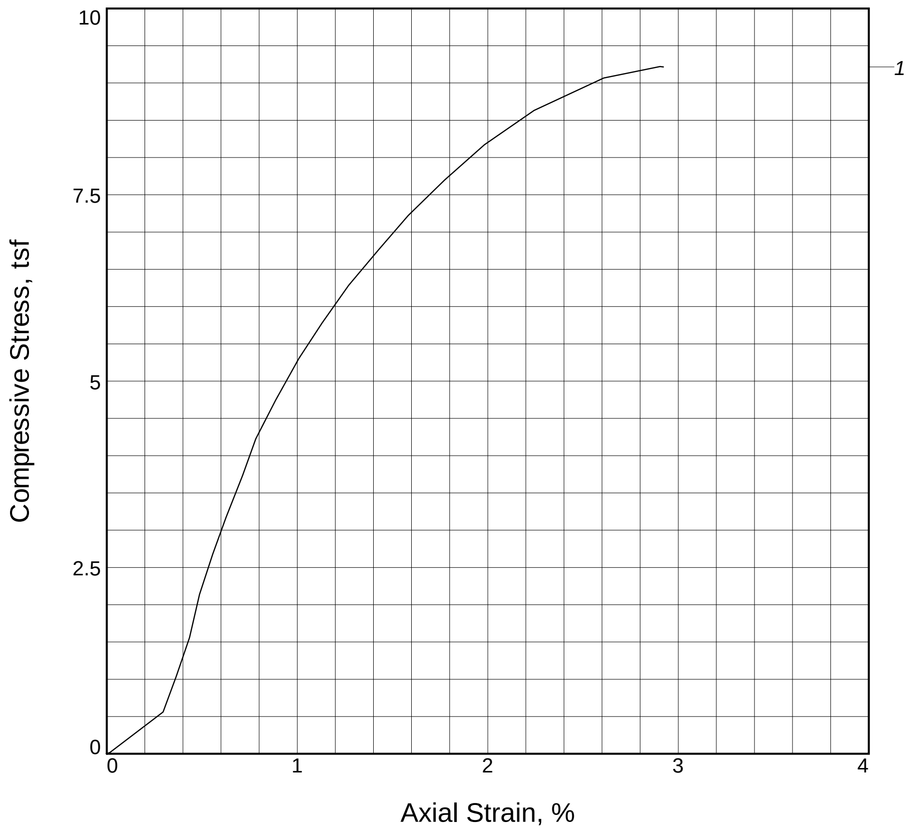
GEOTECHNICAL LABORATORY TEST SUMMARY

PROJECT NAME: Lake Ralph Hall Conceptual Design Study
PROJECT NO.: CHM16420

Borehole	Depth	USCS	Water Content [%]	Dry Density [pcf]	Percent Passing No. 200 Sieve	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compressive Strength [tsf]	Strain at Failure [percent]	
ES-01	2	CH	16								
ES-01	5	CH	30	98							
ES-01	13	CH	22								
ES-02	7	CL	19								
ES-02	13	CL	16	101	85	46	20	26			
ES-03	18	CH	26								

FREESE AND NICHOLS

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	9.220			
Undrained shear strength, tsf	4.610			
Failure strain, %	2.9			
Strain rate, %/min.	1.00			
Water content, %	15.0			
Wet density, pcf	130.9			
Dry density, pcf	113.8			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.77			
Specimen height, in.	5.75			
Height/diameter ratio	2.08			

Description:

LL = 52 | **PL =** 17 | **PI =** 35 | **Assumed GS=** | **Type:** Shelby Tube

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:
Shear Plane Failure

Figure _______

Client: Freese and Nichols, Inc.

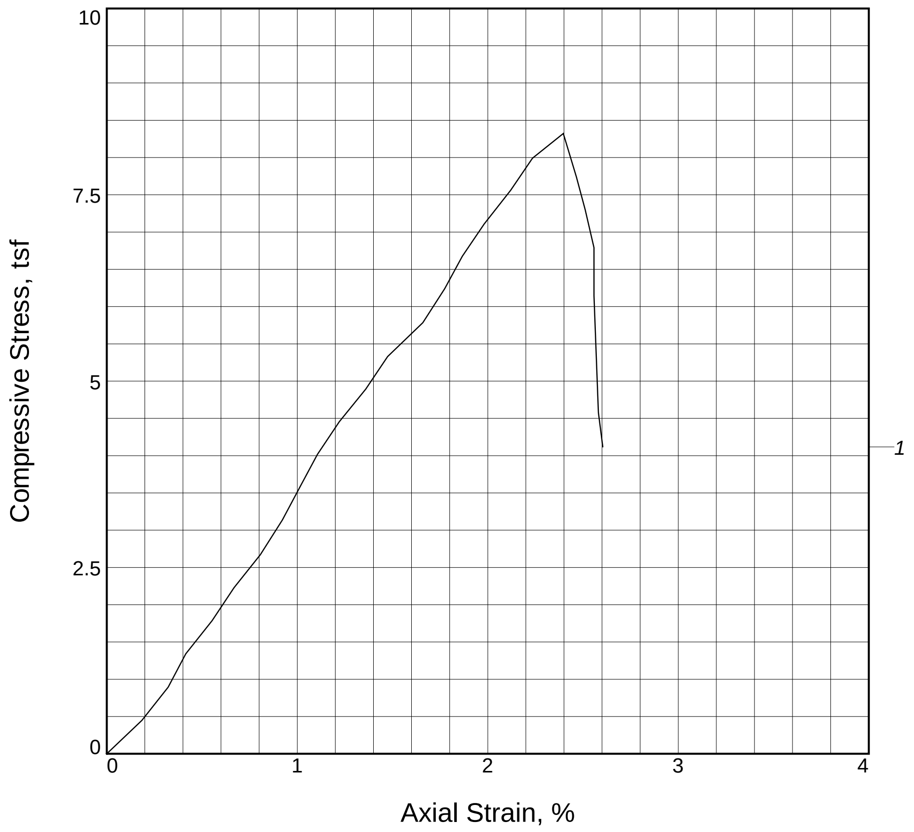
Project: UTRWD Lake Ralph Hall

Location: D-01
Sample Number: U11 **Depth:** (14.0-15.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	8.323			
Undrained shear strength, tsf	4.162			
Failure strain, %	2.4			
Strain rate, %/min.	0.50			
Water content, %	20.5			
Wet density, pcf	128.2			
Dry density, pcf	106.4			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	1.97			
Specimen height, in.	4.34			
Height/diameter ratio	2.20			

Description:

LL = 65

PL = 28

PI = 37

GS=

Type: Rock Core

Project No.: CHM16420

Date Sampled: 10/13/16

Remarks:

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

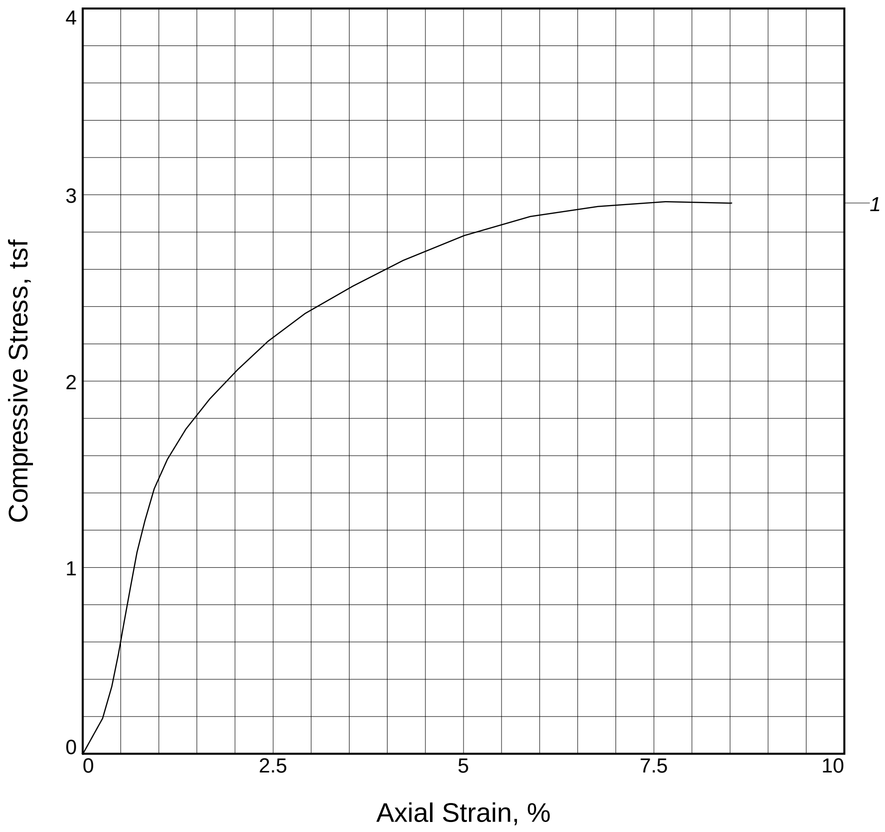
Location: D-01

Sample Number: C18 **Depth:** (45.0-46.2) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Jack **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	2.963			
Undrained shear strength, tsf	1.481			
Failure strain, %	7.7			
Strain rate, %/min.	1.00			
Water content, %	20.4			
Wet density, pcf	127.7			
Dry density, pcf	106.1			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.76			
Specimen height, in.	5.75			
Height/diameter ratio	2.08			

Description:

LL = 64	**PL =** 19	**PI =** 45	**GS=**	**Type:** Shelby Tube

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:
Shear Plane Failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

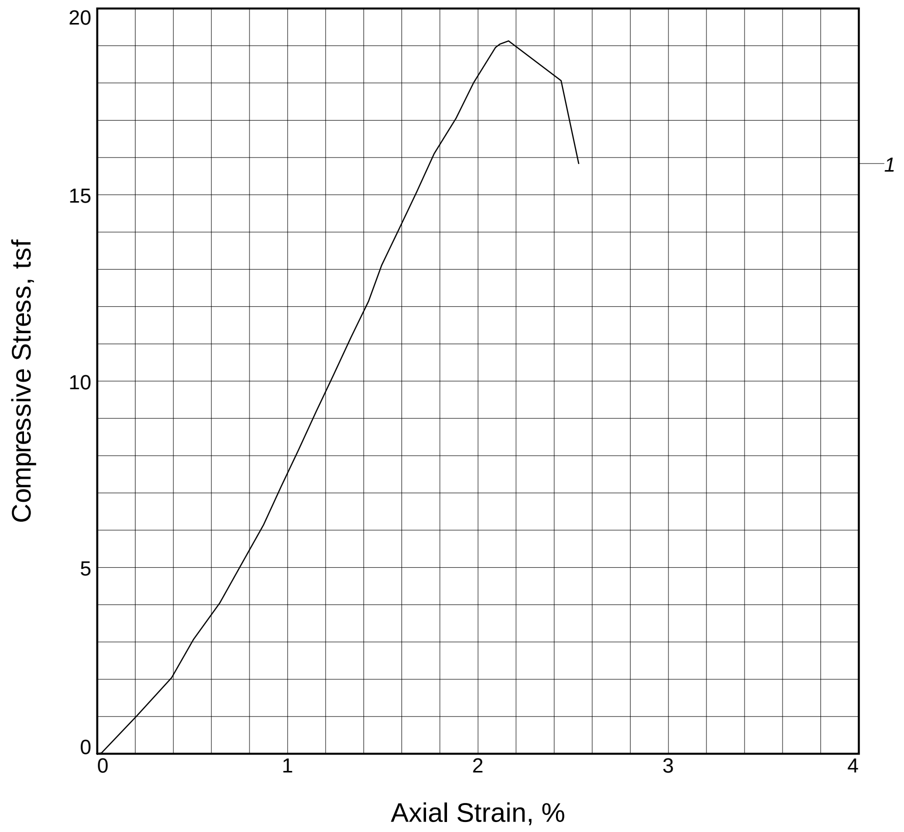
Location: D-02

Sample Number: U6 **Depth:** (6.0-7.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	19.130			
Undrained shear strength, tsf	9.565			
Failure strain, %	2.2			
Strain rate, %/min.	0.50			
Water content, %	18.1			
Wet density, pcf	132.3			
Dry density, pcf	112.0			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	1.95			
Specimen height, in.	4.35			
Height/diameter ratio	2.23			

Description:

LL = 61	**PL =** 27	**PI =** 34	**GS=**	**Type:** Rock Core

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

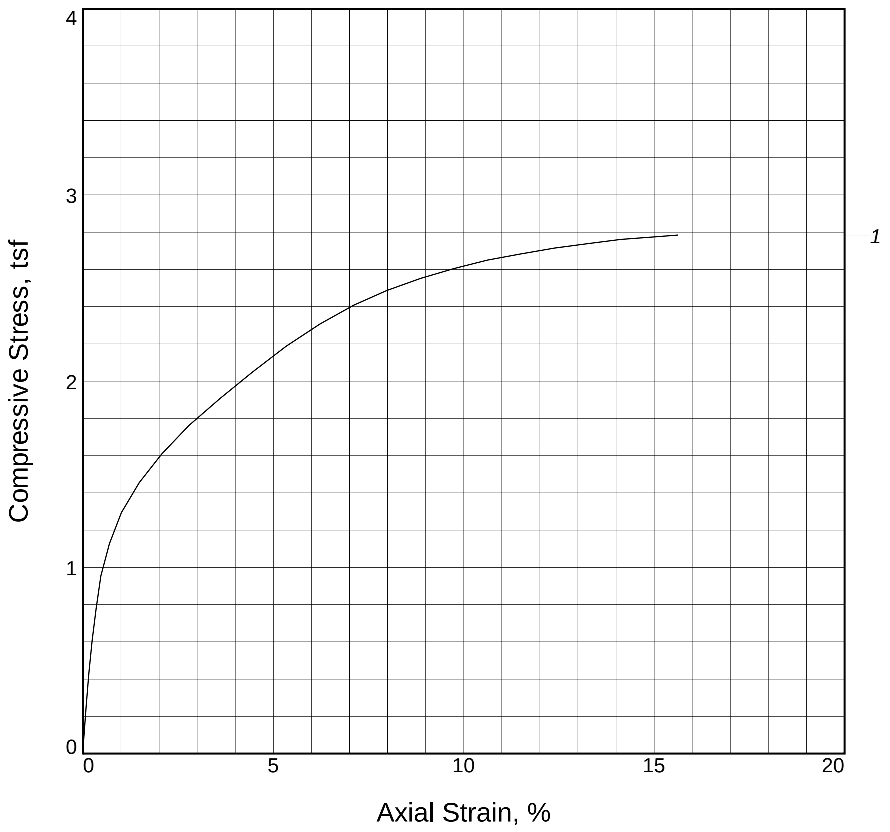
Location: D-02

Sample Number: C1 **Depth:** (20.0-21.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	2.785			
Undrained shear strength, tsf	1.392			
Failure strain, %	15.6			
Strain rate, %/min.	1.00			
Water content, %	23.4			
Wet density, pcf	128.9			
Dry density, pcf	104.5			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.73			
Specimen height, in.	5.75			
Height/diameter ratio	2.11			

Description:

LL = 77	**PL =** 20	**PI =** 57	**GS=**	**Type:** Shelby tube

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:
Bulge Failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

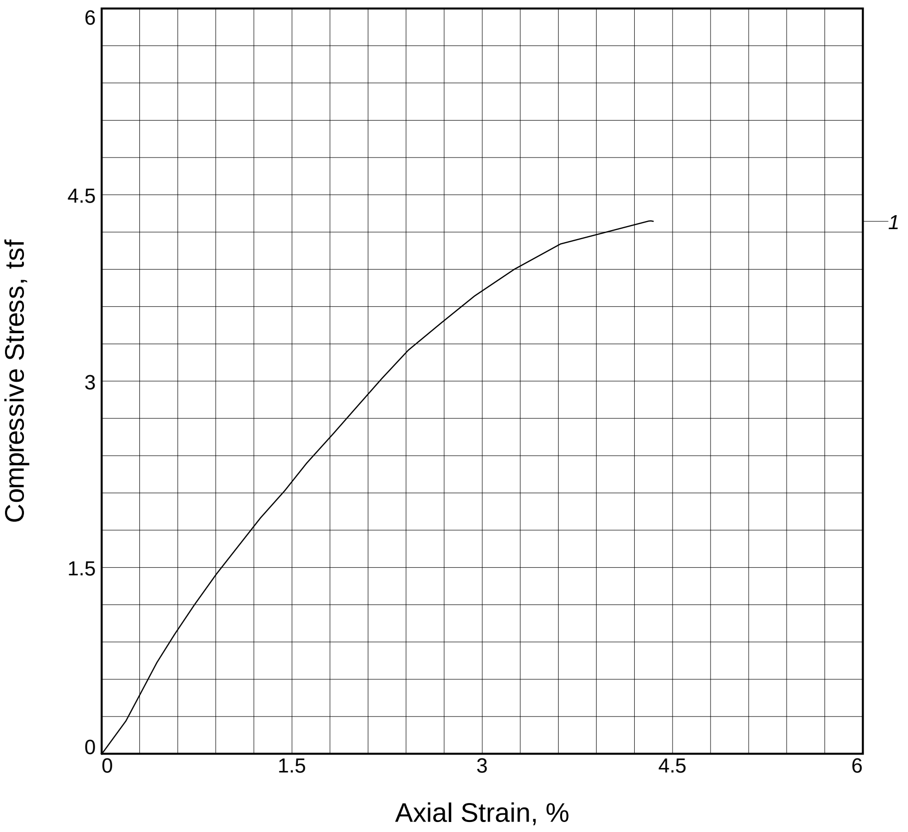
Location: D-03

Sample Number: U11 **Depth:** (19.0-20.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	4.290			
Undrained shear strength, tsf	2.145			
Failure strain, %	4.3			
Strain rate, %/min.	1.00			
Water content, %	20.3			
Wet density, pcf	128.6			
Dry density, pcf	106.9			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.77			
Specimen height, in.	5.75			
Height/diameter ratio	2.08			

Description:

LL = 72	**PL =** 24	**PI =** 48	**GS=**	**Type:** Shelby tube

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:
Shear Plane Failure

Figure _______

Client: Freese and Nichols, Inc.

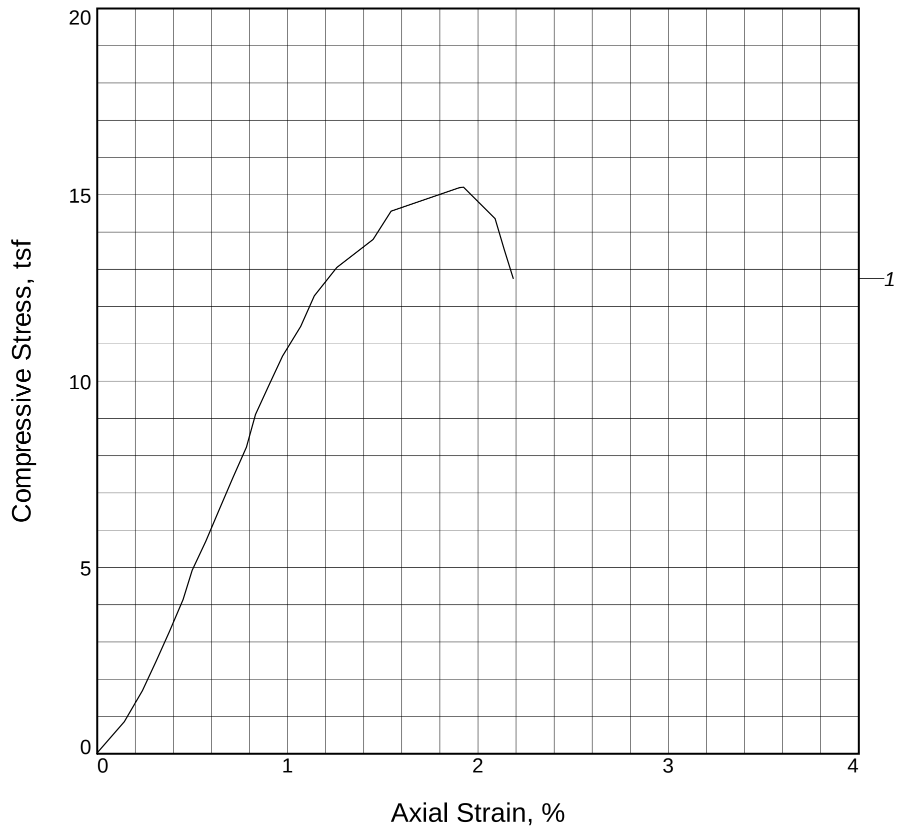
Project: UTRWD Lake Ralph Hall

Location: D-03
Depth: (29.0-31.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	15.207			
Undrained shear strength, tsf	7.603			
Failure strain, %	1.9			
Strain rate, %/min.	0.50			
Water content, %	18.2			
Wet density, pcf	134.3			
Dry density, pcf	113.6			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	1.93			
Specimen height, in.	4.21			
Height/diameter ratio	2.18			

Description:

LL =	**PL =**	**PI =**	**GS=**	**Type:** Rock Core

Project No.: CHM16420
Date Sampled: 10/13/16
Remarks:

Figure _______

Client: Freese and Nichols, Inc.

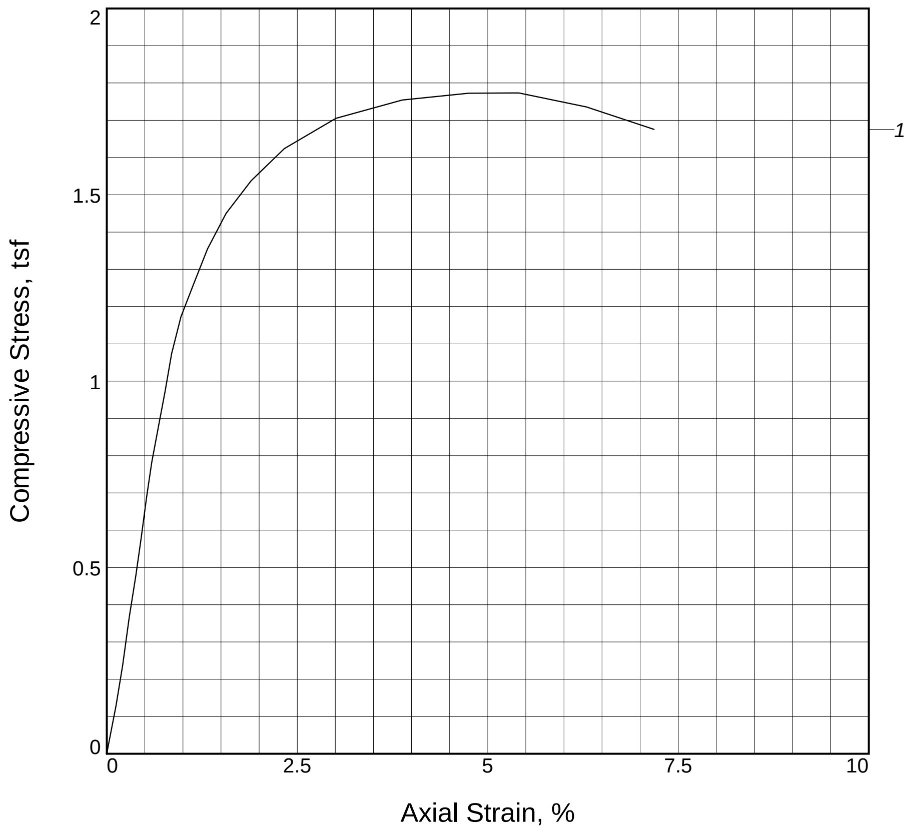
Project: UTRWD Lake Ralph Hall

Location: D-03
Sample Number: C5 **Depth:** (50.0-51.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Jack **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	1.773			
Undrained shear strength, tsf	0.887			
Failure strain, %	5.3			
Strain rate, %/min.	1.00			
Water content, %	22.7			
Wet density, pcf	127.1			
Dry density, pcf	103.5			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.72			
Specimen height, in.	5.75			
Height/diameter ratio	2.11			

Description:

LL =	**PL =**	**PI =**	**GS=**	**Type:** Shelby tube

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:
Shear Plane Failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

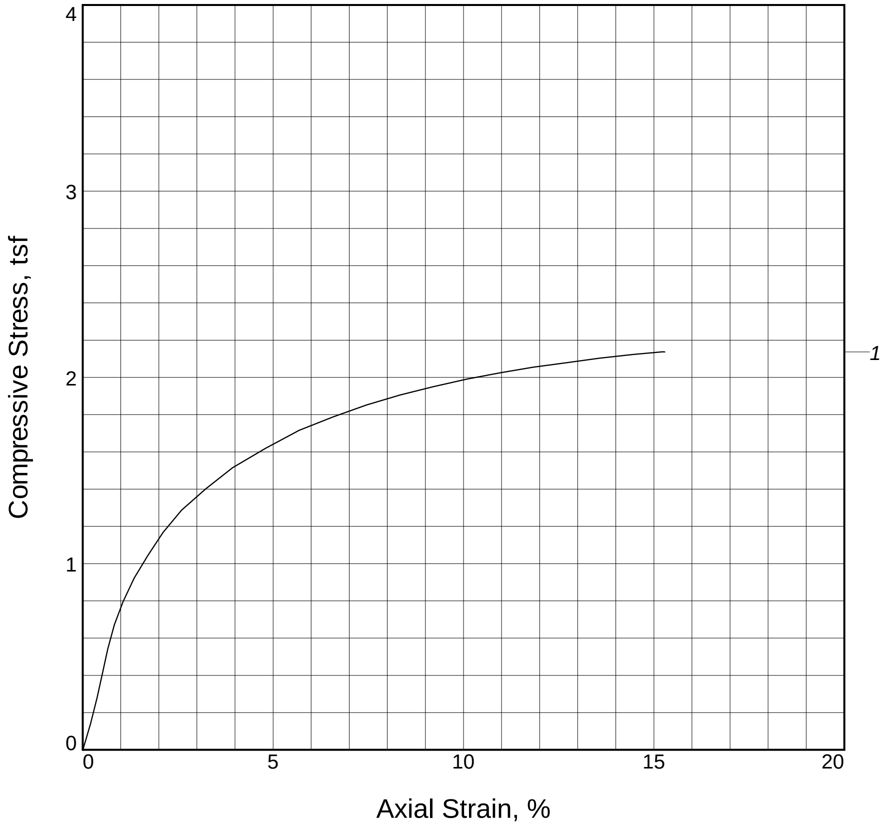
Location: D-04

Sample Number: U11 **Depth:** (13.0-15.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	2.137			
Undrained shear strength, tsf	1.069			
Failure strain, %	15.2			
Strain rate, %/min.	1.00			
Water content, %	22.1			
Wet density, pcf	129.8			
Dry density, pcf	106.3			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.73			
Specimen height, in.	5.77			
Height/diameter ratio	2.11			

Description:

LL =	**PL =**	**PI =**	**GS=**	**Type:** Shelby tube

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:
Bulge failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

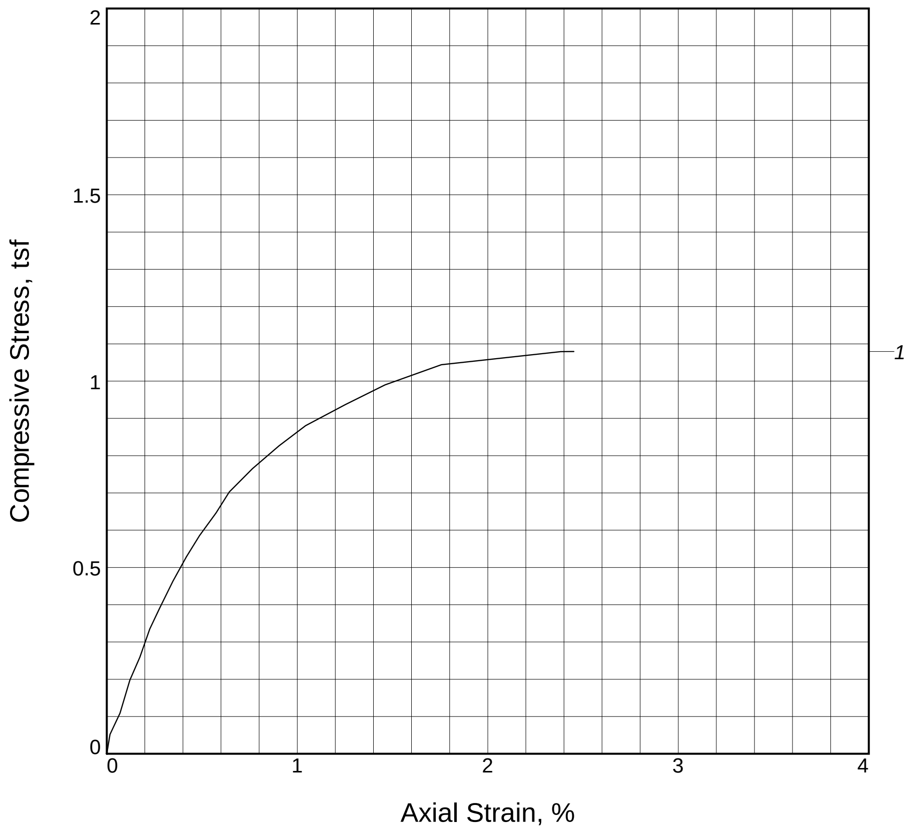
Location: D-04

Sample Number: U13 **Depth:** (23.0-25.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	1.080			
Undrained shear strength, tsf	0.540			
Failure strain, %	2.5			
Strain rate, %/min.	1.00			
Water content, %	24.2			
Wet density, pcf	127.6			
Dry density, pcf	102.7			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.78			
Specimen height, in.	5.75			
Height/diameter ratio	2.07			

Description:

LL = 55	**PL =** 19	**PI =** 36	**GS=**	**Type:** Shelby Tube

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:
Shear Plane Failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

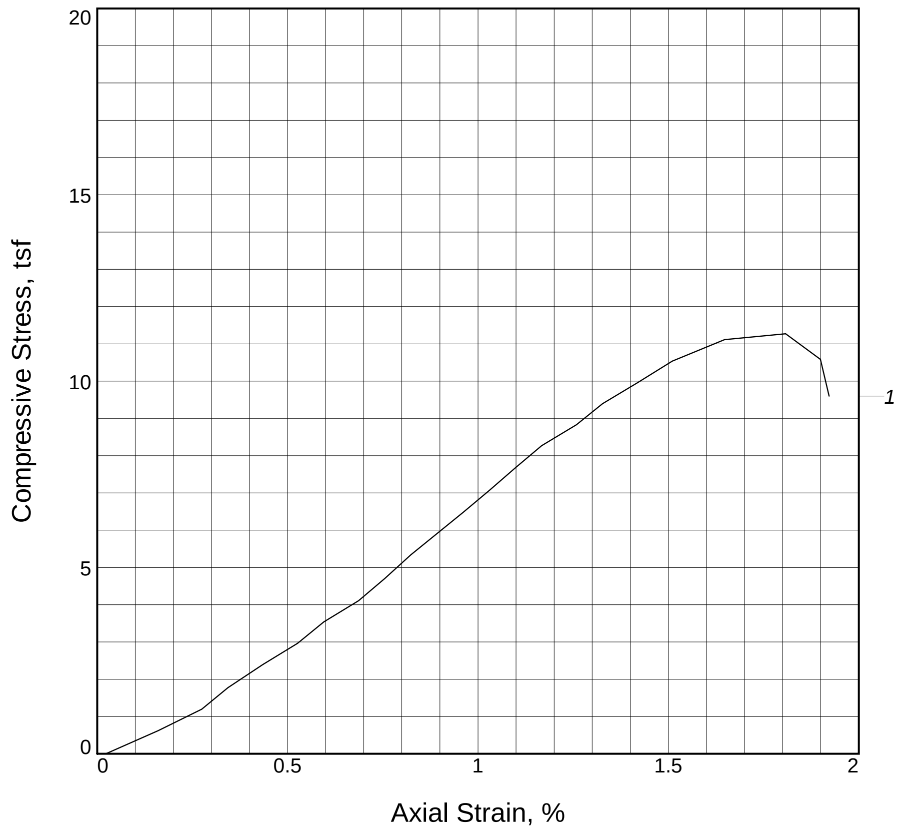
Location: D-04

Sample Number: U14 **Depth:** (28.0-30.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	11.271			
Undrained shear strength, tsf	5.636			
Failure strain, %	1.8			
Strain rate, %/min.	0.50			
Water content, %	17.6			
Wet density, pcf	133.8			
Dry density, pcf	113.8			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.03			
Specimen height, in.	4.37			
Height/diameter ratio	2.15			

Description:

LL = 60 | **PL =** 26 | **PI =** 34 | **GS=** | **Type:** Rock Core

Project No.: CHM16420
Date Sampled: 10/13/16
Remarks:

Figure _______

Client: Freese and Nichols, Inc.

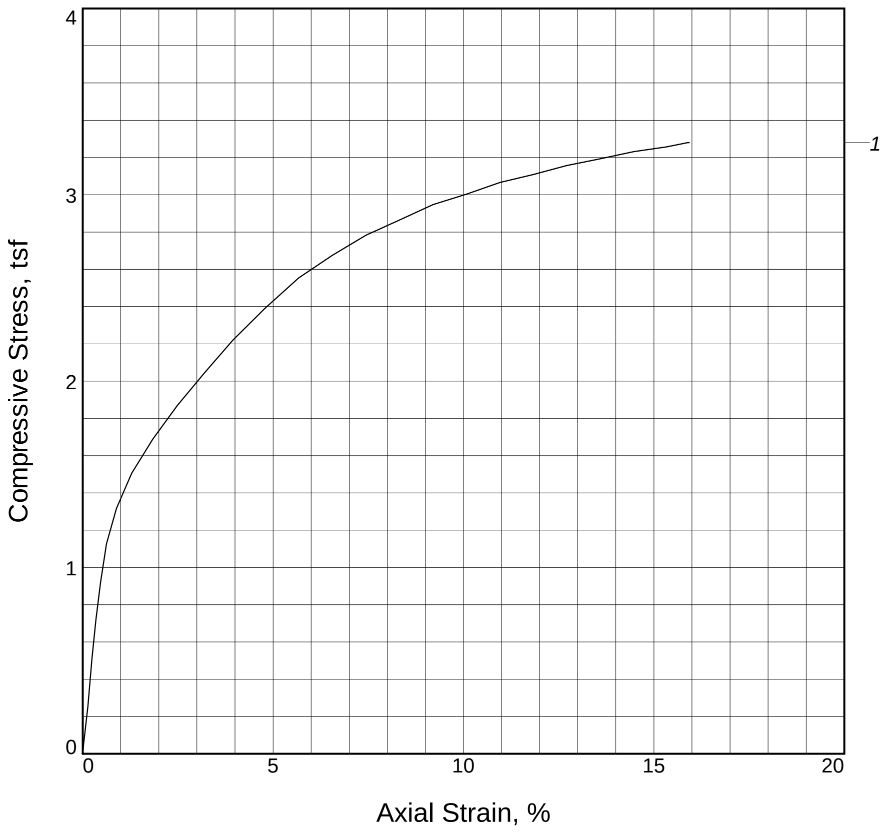
Project: UTRWD Lake Ralph Hall

Location: D-04
Sample Number: C2 **Depth:** (40.0-41.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Jack **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	3.280			
Undrained shear strength, tsf	1.640			
Failure strain, %	15.9			
Strain rate, %/min.	1.00			
Water content, %	18.8			
Wet density, pcf	132.6			
Dry density, pcf	111.6			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.75			
Specimen height, in.	5.75			
Height/diameter ratio	2.09			

Description:

LL = 58	**PL =** 19	**PI =** 39	**GS=**	**Type:** Shelby tube

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:
Bulge Failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

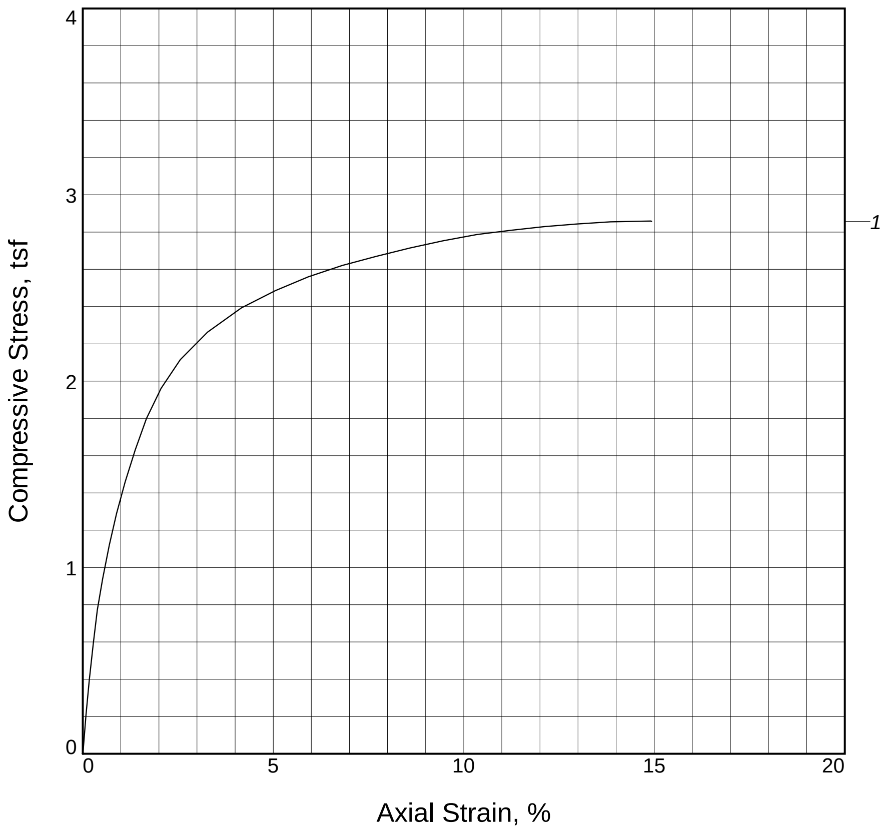
Location: D-05

Sample Number: U7 **Depth:** (19.0-20.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	2.859			
Undrained shear strength, tsf	1.429			
Failure strain, %	14.9			
Strain rate, %/min.	1.00			
Water content, %	21.1			
Wet density, pcf	130.3			
Dry density, pcf	107.6			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.76			
Specimen height, in.	5.74			
Height/diameter ratio	2.08			

Description:

LL =	**PL =**	**PI =**	**GS=**	**Type:** Shelby Tube

Project No.: CHM16420

Date Sampled: 10/11/16

Remarks:
Bulge Failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

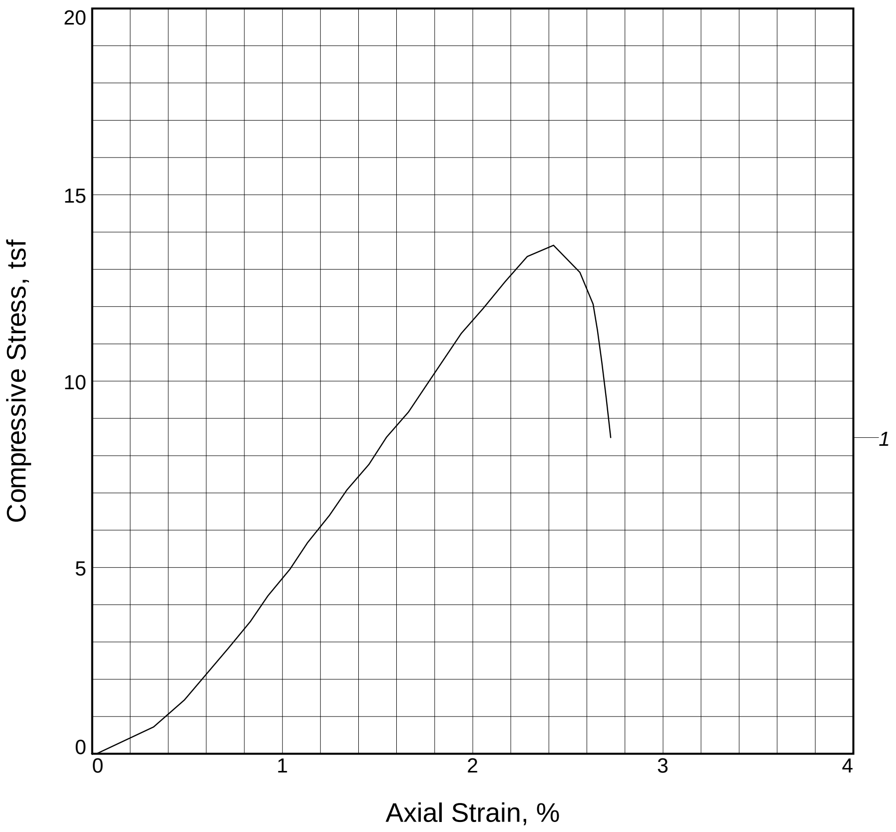
Location: D-05

Sample Number: U8 **Depth:** (24.0-25.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Lupe **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	13.644			
Undrained shear strength, tsf	6.822			
Failure strain, %	2.4			
Strain rate, %/min.	0.50			
Water content, %	17.0			
Wet density, pcf	136.1			
Dry density, pcf	116.3			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	1.98			
Specimen height, in.	4.33			
Height/diameter ratio	2.19			

Description:

LL = 50	**PL =** 23	**PI =** 27	**GS=**	**Type:** Rock Core

Project No.: CHM16420
Date Sampled: 10/13/16
Remarks:

Figure _______

Client: Freese and Nichols, Inc.

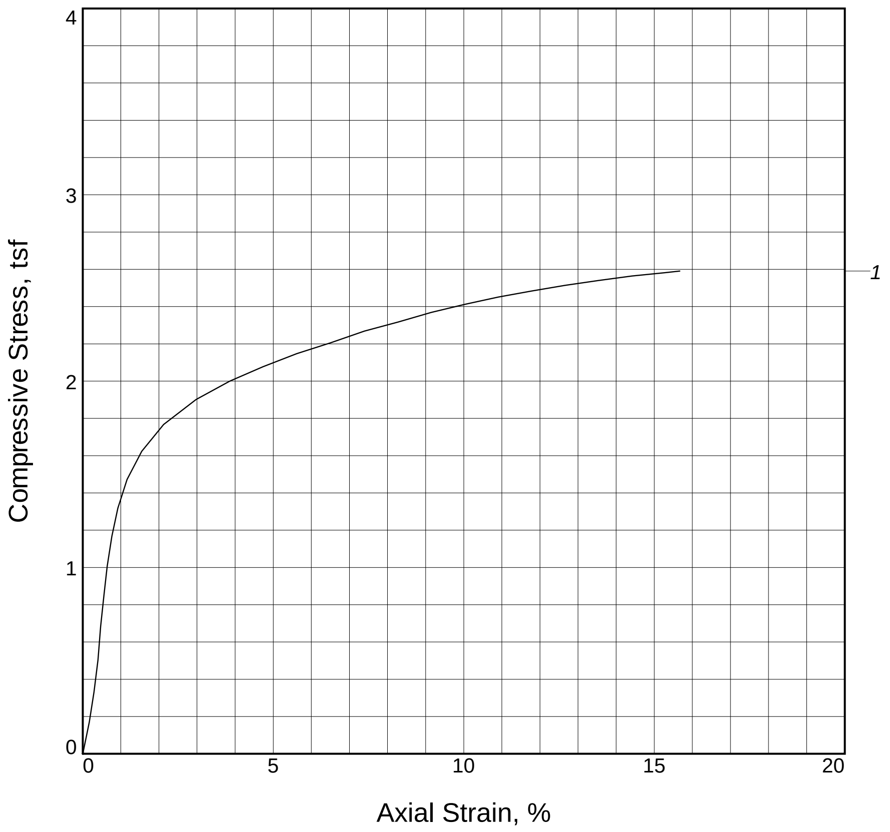
Project: UTRWD Lake Ralph Hall

Location: D-05
Sample Number: C1 **Depth:** (35.0-36.3) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Jack **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	2.591			
Undrained shear strength, tsf	1.295			
Failure strain, %	15.7			
Strain rate, %/min.	1.00			
Water content, %	26.1			
Wet density, pcf	127.1			
Dry density, pcf	100.7			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.78			
Specimen height, in.	5.75			
Height/diameter ratio	2.07			

Description:

LL = 83	**PL =** 28	**PI =** 55	**GS=**	**Type:** Shelby Tube

Project No.: CHM16420

Date Sampled: 10/13/16

Remarks:
Bulge Failure

Figure _______

Client: Freese and Nichols, Inc.

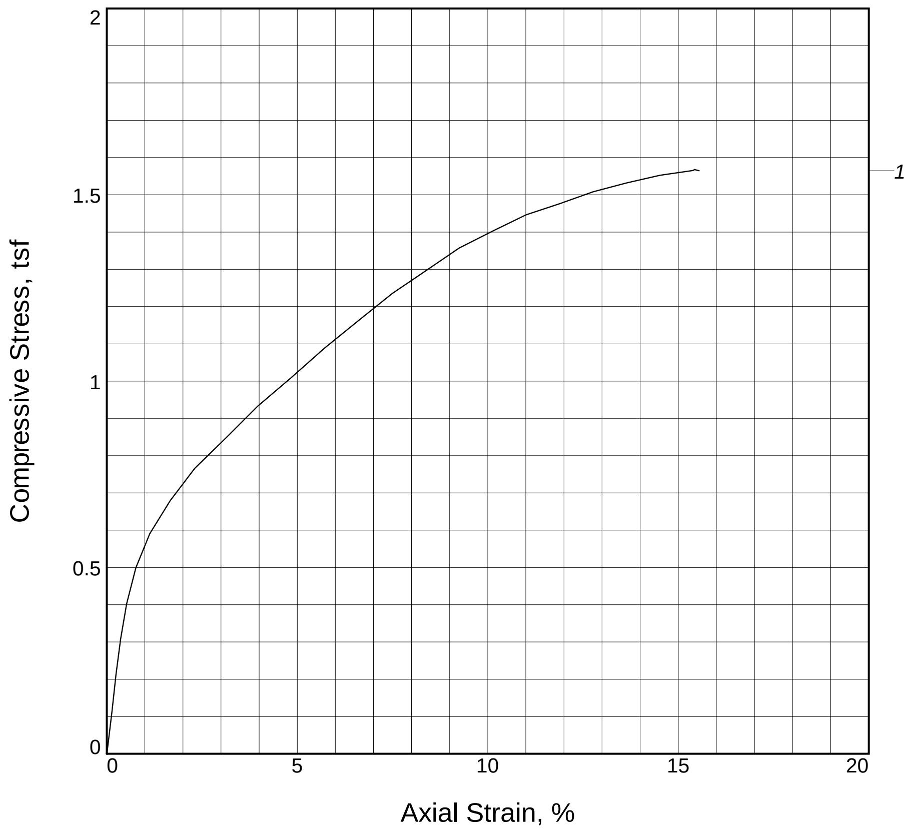
Project: UTRWD Lake Ralph Hall

Location: DS-01
Sample Number: U7 **Depth:** (6.0-7.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Jack **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	1.568			
Undrained shear strength, tsf	0.784			
Failure strain, %	15.4			
Strain rate, %/min.	1.00			
Water content, %	24.0			
Wet density, pcf	126.0			
Dry density, pcf	101.6			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.79			
Specimen height, in.	5.75			
Height/diameter ratio	2.06			

Description:

LL = 56	**PL =** 22	**PI =** 34	**GS=**	**Type:** Shelby Tube

Project No.: CHM16420

Date Sampled: 10/13/16

Remarks:
Bulge Failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

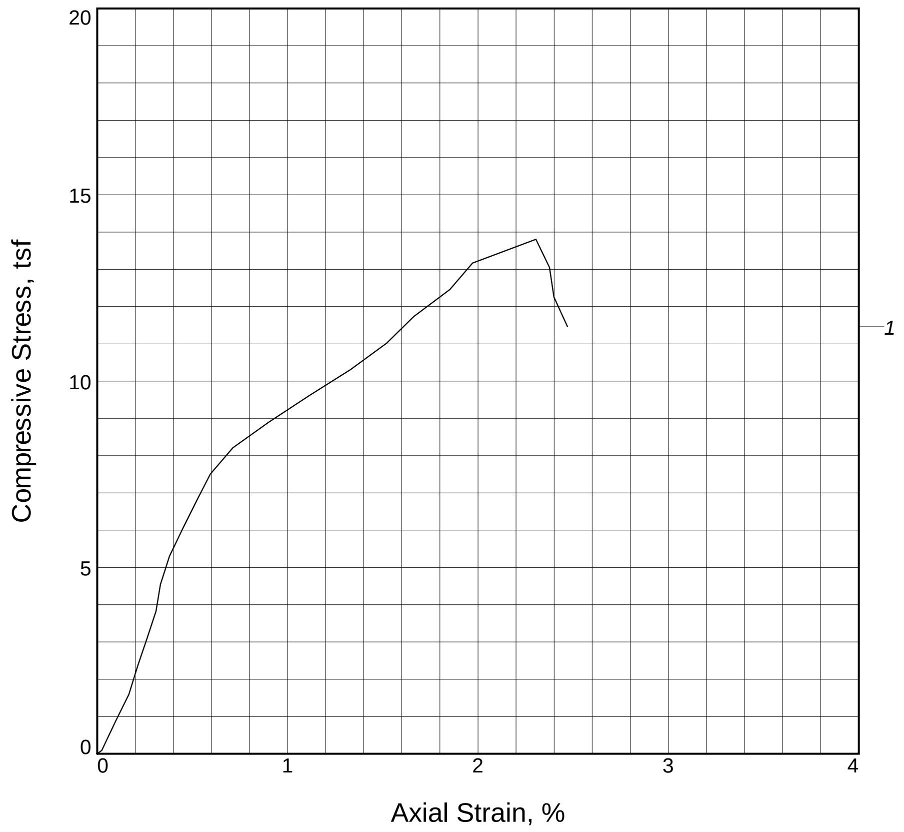
Location: DS-01

Sample Number: U13 **Depth:** (23.0-25.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Jack **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	13.806			
Undrained shear strength, tsf	6.903			
Failure strain, %	2.3			
Strain rate, %/min.	0.50			
Water content, %	19.6			
Wet density, pcf	134.2			
Dry density, pcf	112.2			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.02			
Specimen height, in.	4.21			
Height/diameter ratio	2.08			

Description:

LL =	**PL =**	**PI =**	**GS=**	**Type:** Rock Core

Project No.: CHM16420

Date Sampled: 10/13/16

Remarks:

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

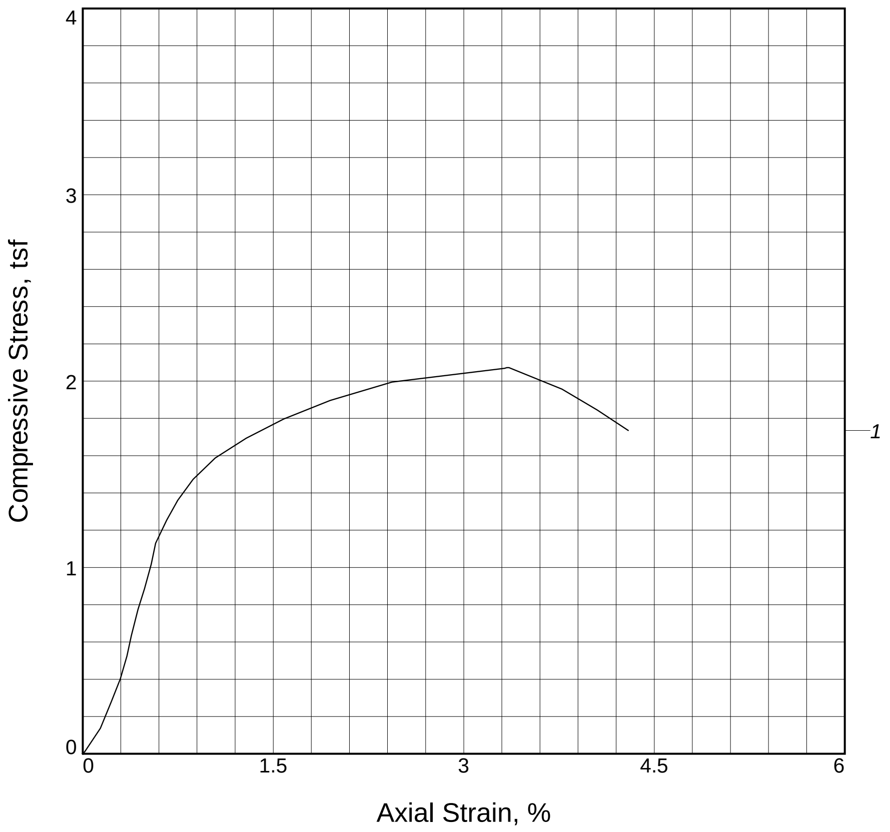
Location: DS-01

Sample Number: C1 **Depth:** (35.0-36.7) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Jack **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	2.072			
Undrained shear strength, tsf	1.036			
Failure strain, %	3.3			
Strain rate, %/min.	1.00			
Water content, %	27.1			
Wet density, pcf	140.7			
Dry density, pcf	110.7			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.60			
Specimen height, in.	5.75			
Height/diameter ratio	2.21			

Description:

LL = 80	**PL =** 27	**PI =** 53	**GS=**	**Type:** Shelby Tube

Project No.: CHM16420

Date Sampled: 10/13/16

Remarks:
Shear Plane Failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

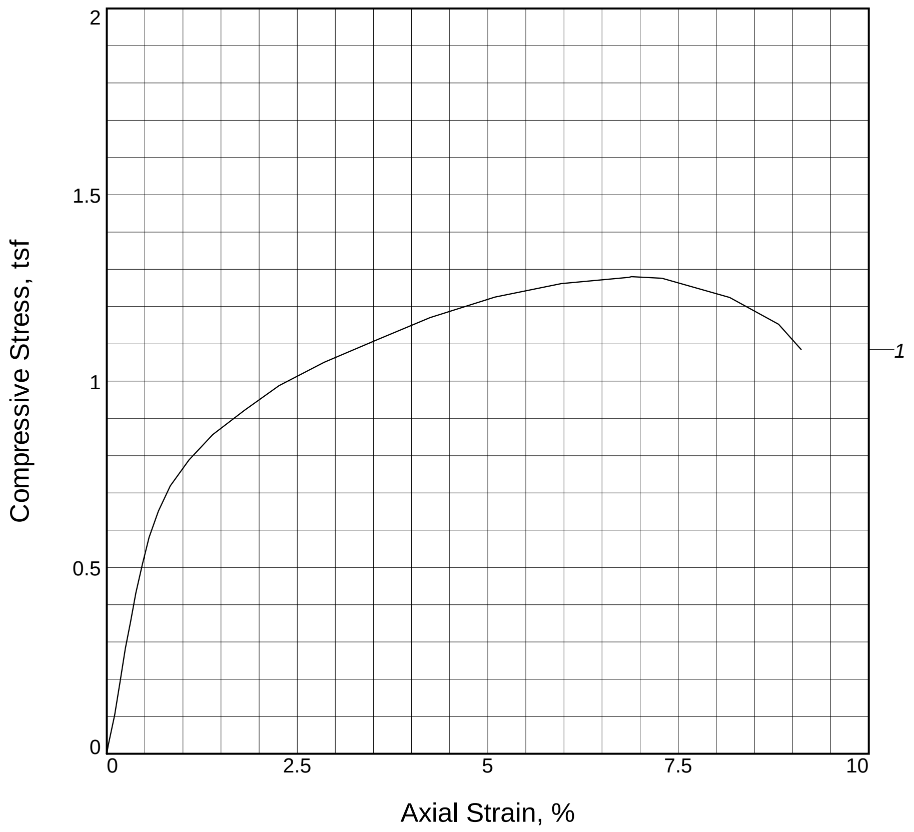
Location: DS-02

Sample Number: U11 **Depth:** (13.0-15.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Jack **Checked By:** Sayak

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, tsf	1.280			
Undrained shear strength, tsf	0.640			
Failure strain, %	6.9			
Strain rate, %/min.	1.00			
Water content, %	28.8			
Wet density, pcf	125.2			
Dry density, pcf	97.2			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.77			
Specimen height, in.	5.75			
Height/diameter ratio	2.08			

Description:

LL = 77	**PL =** 24	**PI =** 53	**GS=**	**Type:** Shelby Tube

Project No.: CHM16420

Date Sampled: 10/13/16

Remarks:
Bulge Failure

Figure _______

Client: Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

Location: DS-02

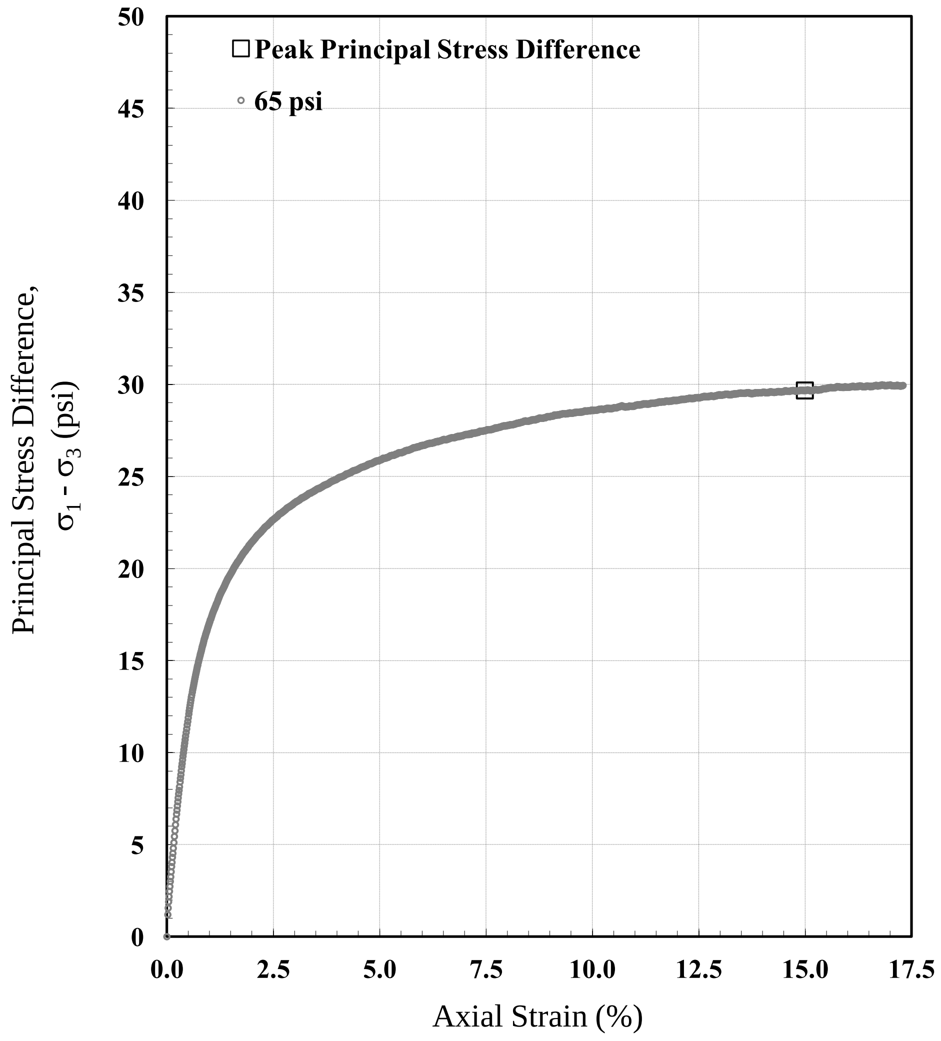
Sample Number: U15 **Depth:** (33.0-35.0) ft.

UNCONFINED COMPRESSION TEST
Gorrondona & Associates, Inc.
Houston, Texas

Tested By: Jack **Checked By:** Sayak

Unconsolidated-Undrained (Q) Triaxial Compression

Client:	Gorrondona & Associates	TRI Log #:	24670
Project:	UTRWD Lake Ralph Hall	Test Method:	ASTM D2850
Sample:	D-02 (9-10)		



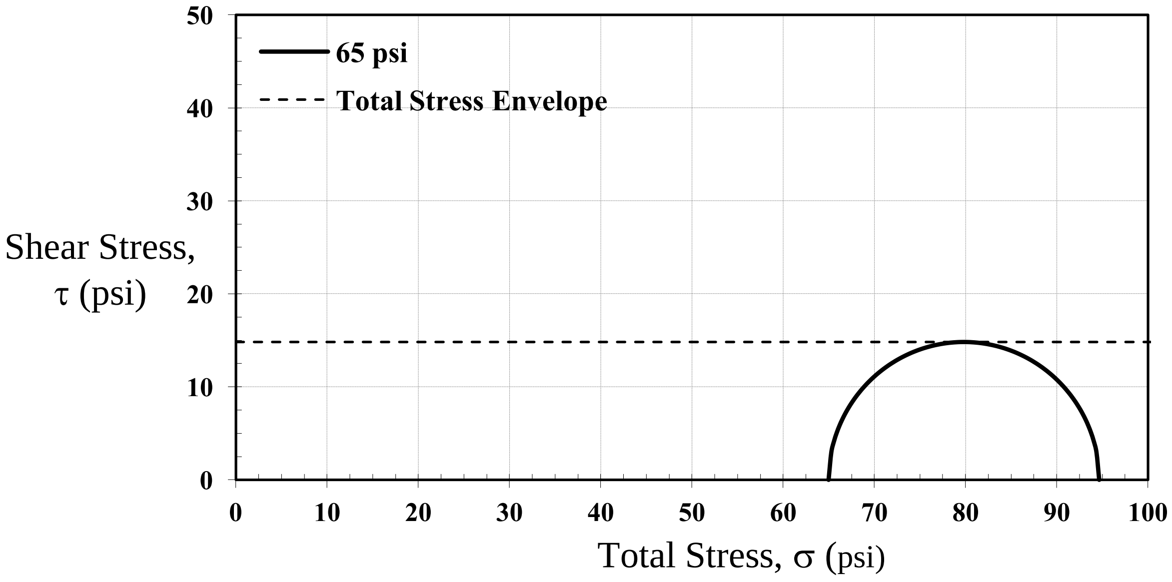
Test Parameters	
Minor Principal Stress (psi)	65.0
Rate of Strain (%/hr)	60

Initial Properties	
Avg. Diameter (in)	2.72
Avg. Height (in)	5.70
Avg. Water Content (%)	22.5
Bulk Density (pcf)	126.6
Dry Density (pcf)	103.4
Saturation (%)	99.2
Void Ratio	0.60
Specific Gravity (Assumed)	2.65

At Failure - Maximum Deviator Stress	
Axial Strain at Failure (%)	15.0
Minor Total Stress (psi)	65.0
Major Total Stress (psi)	94.7
Principal Stress Diff. (psi)	29.7

Total Stress Envelope	
Friction Angle (deg)	0
Undrained Shear Strength, S_u (psi)	14.8
S_u / σ_3	0.2

Note: The Mohr failure envelope was taken as a horizontal straight line. It should, however, be noted that the specimen was partially saturated.

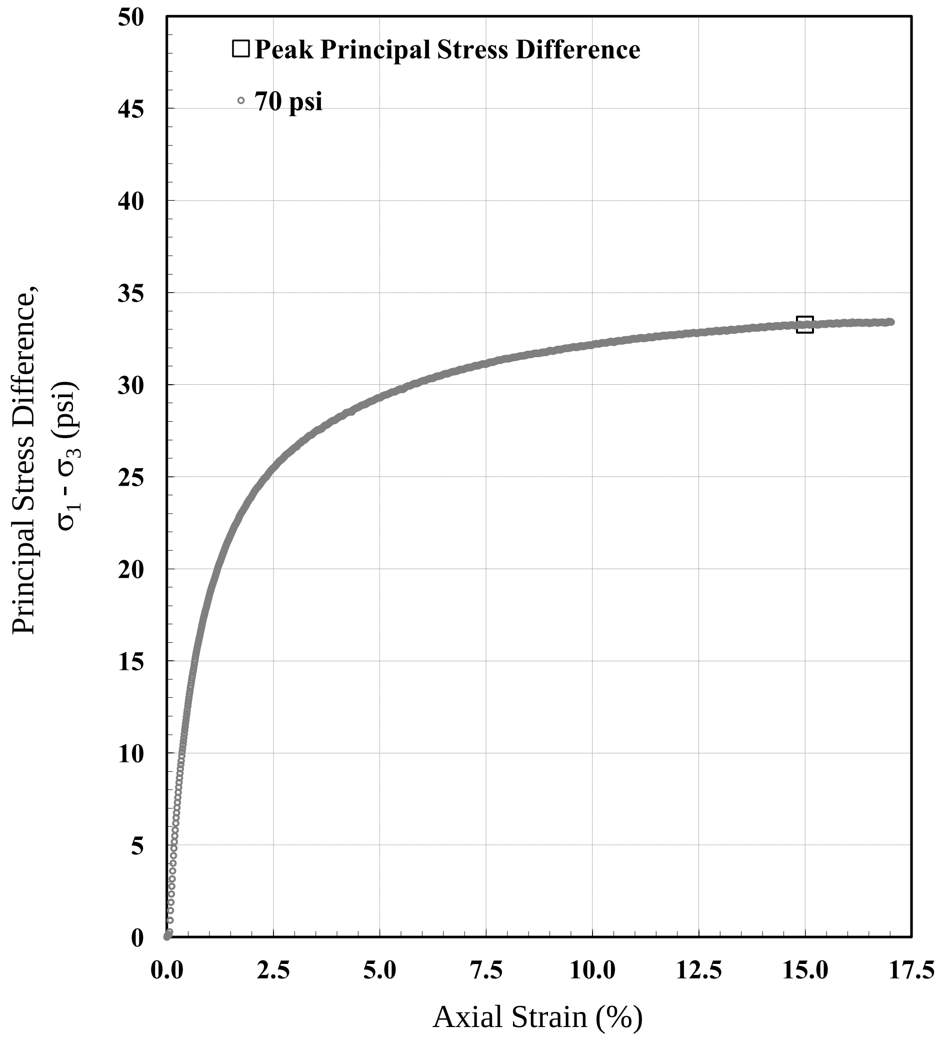


Jeffrey A. Kuhn , Ph.D., P.E., 11/16/2016
Analysis & Quality Review/Date
Laboratory Staff: LC

Unconsolidated-Undrained (Q) Triaxial Compression

Client: Gorrondona & Associates
Project: UTRWD Lake Ralph Hall
Sample: D-03 (7-8)

TRI Log #: 24670
Test Method: ASTM D2850



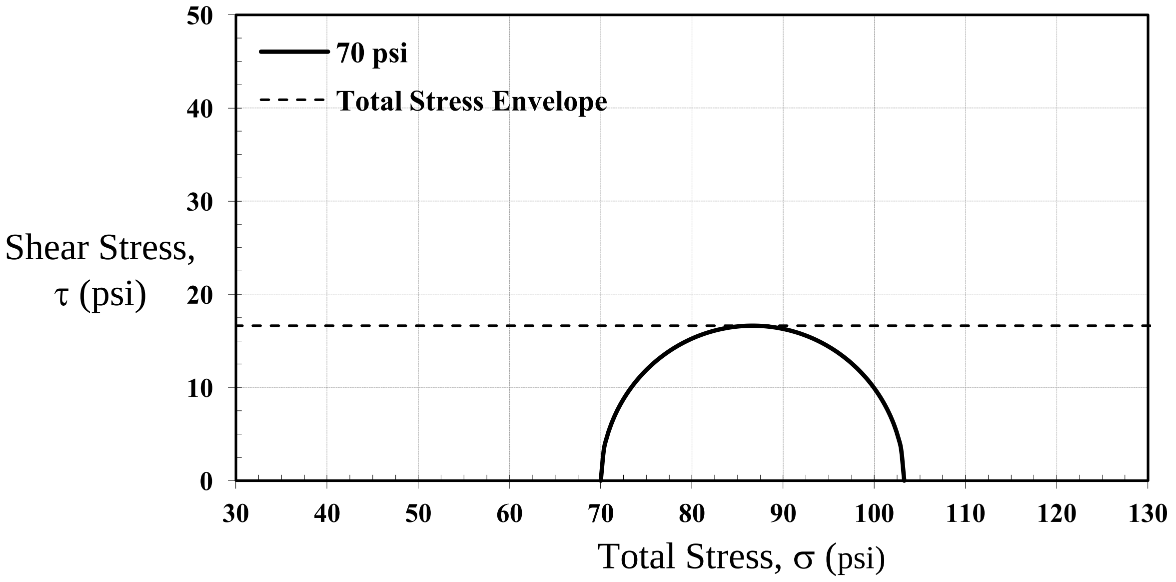
Test Parameters	
Minor Principal Stress (psi)	70.0
Rate of Strain (%/hr)	60

Initial Properties	
Avg. Diameter (in)	2.73
Avg. Height (in)	5.63
Avg. Water Content (%)	23.8
Bulk Density (pcf)	123.8
Dry Density (pcf)	100.0
Saturation (%)	96.4
Void Ratio	0.65
Specific Gravity (Assumed)	2.65

At Failure - Maximum Deviator Stress	
Axial Strain at Failure (%)	15.0
Minor Total Stress (psi)	70.0
Major Total Stress (psi)	103.3
Principal Stress Diff. (psi)	33.3

Total Stress Envelope	
Friction Angle (deg)	0
Undrained Shear Strength, S_u (psi)	16.6
S_u / σ_3	0.2

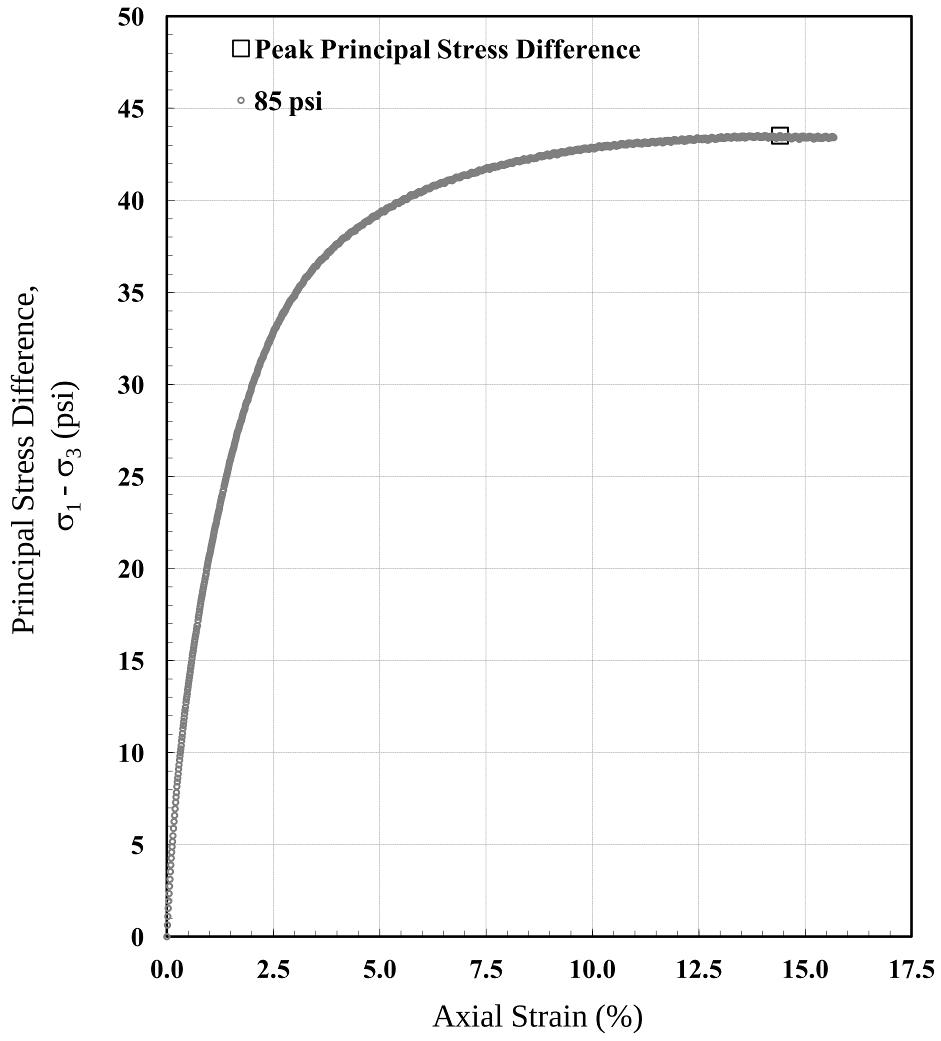
Note: The Mohr failure envelope was taken as a horizontal straight line. It should, however, be noted that the specimen was partially saturated.



Jeffrey A. Kuhn , Ph.D., P.E., 11/16/2016
Analysis & Quality Review/Date
Laboratory Staff: LC

Unconsolidated-Undrained (Q) Triaxial Compression

Client:	Gorrondona & Associates	TRI Log #:	24670
Project:	UTRWD Lake Ralph Hall	Test Method:	ASTM D2850
Sample:	D-03 (23-25)		



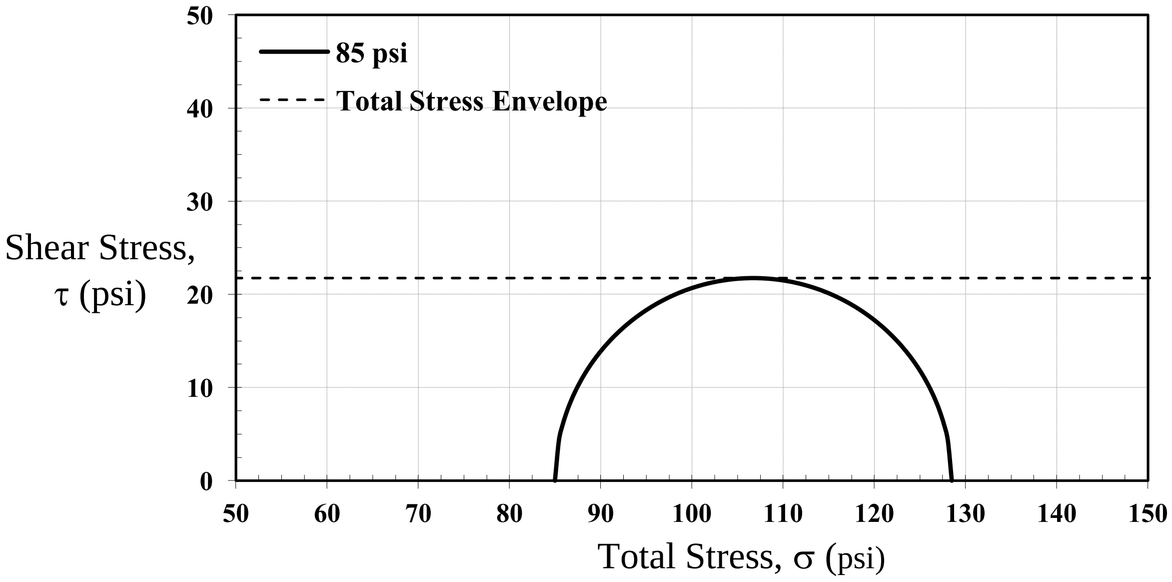
Test Parameters	
Minor Principal Stress (psi)	85.0
Rate of Strain (%/hr)	60

Initial Properties	
Avg. Diameter (in)	2.78
Avg. Height (in)	5.63
Avg. Water Content (%)	23.2
Bulk Density (pcf)	123.7
Dry Density (pcf)	100.4
Saturation (%)	94.9
Void Ratio	0.65
Specific Gravity (Assumed)	2.65

At Failure - Maximum Deviator Stress	
Axial Strain at Failure (%)	14.4
Minor Total Stress (psi)	85.0
Major Total Stress (psi)	128.5
Principal Stress Diff. (psi)	43.5

Total Stress Envelope	
Friction Angle (deg)	0
Undrained Shear Strength, S_u (psi)	21.8
S_u / σ_3	0.3

Note: The Mohr failure envelope was taken as a horizontal straight line. It should, however, be noted that the specimen was partially saturated.



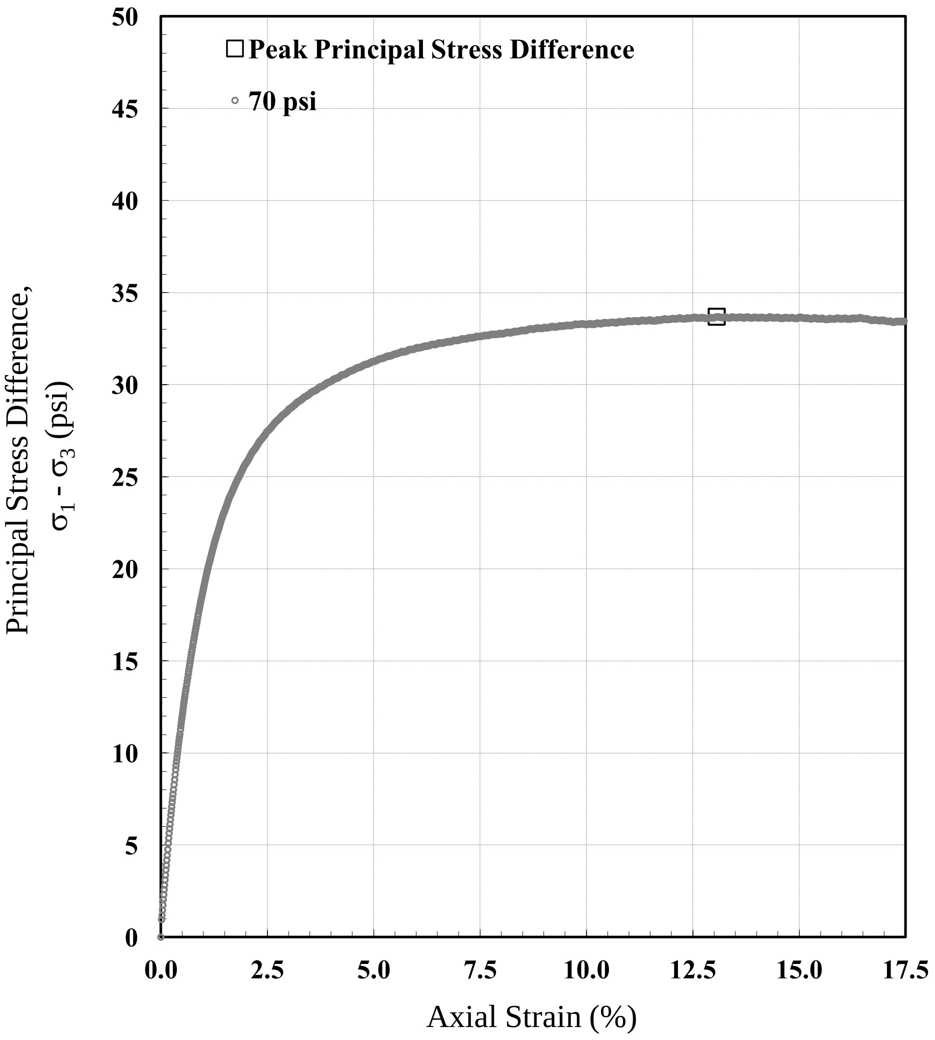
Jeffrey A. Kuhn , Ph.D., P.E., 11/16/2016

Analysis & Quality Review/Date

Laboratory Staff: LC

Unconsolidated-Undrained (Q) Triaxial Compression

Client:	Gorrondona & Associates	TRI Log #:	24670
Project:	UTRWD Lake Ralph Hall	Test Method:	ASTM D2850
Sample:	D-04 (6-7)		



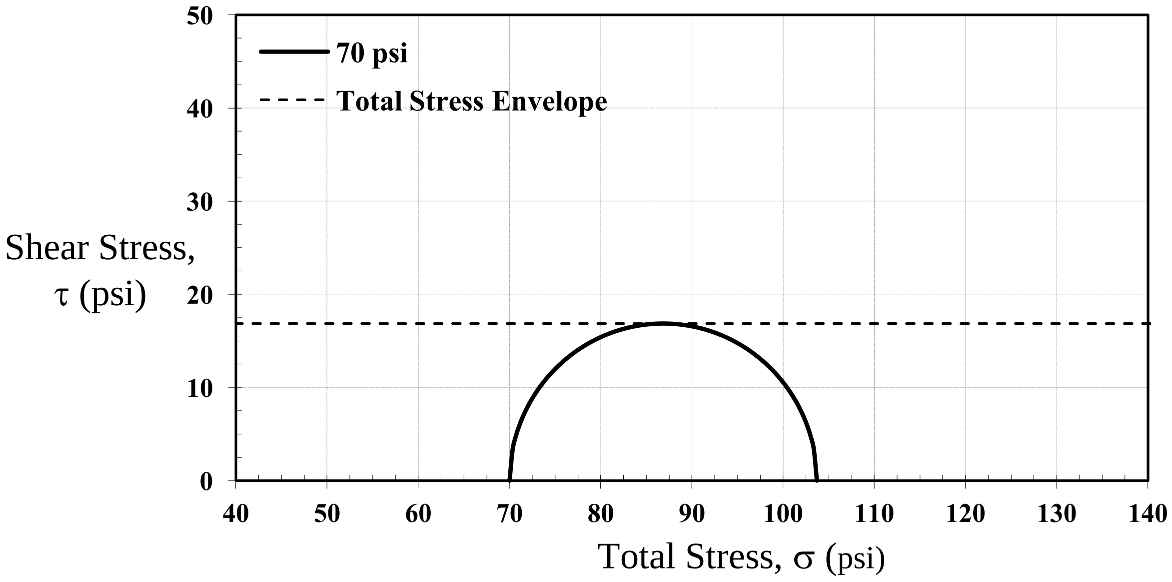
Test Parameters	
Minor Principal Stress (psi)	70.0
Rate of Strain (%/hr)	60

Initial Properties	
Avg. Diameter (in)	2.76
Avg. Height (in)	5.65
Avg. Water Content (%)	26.0
Bulk Density (pcf)	121.1
Dry Density (pcf)	96.2
Saturation (%)	95.5
Void Ratio	0.72
Specific Gravity (Assumed)	2.65

At Failure - Maximum Deviator Stress	
Axial Strain at Failure (%)	13.1
Minor Total Stress (psi)	70.0
Major Total Stress (psi)	103.7
Principal Stress Diff. (psi)	33.7

Total Stress Envelope	
Friction Angle (deg)	0
Undrained Shear Strength, S_u (psi)	16.8
S_u / σ_3	0.2

Note: The Mohr failure envelope was taken as a horizontal straight line. It should, however, be noted that the specimen was partially saturated.



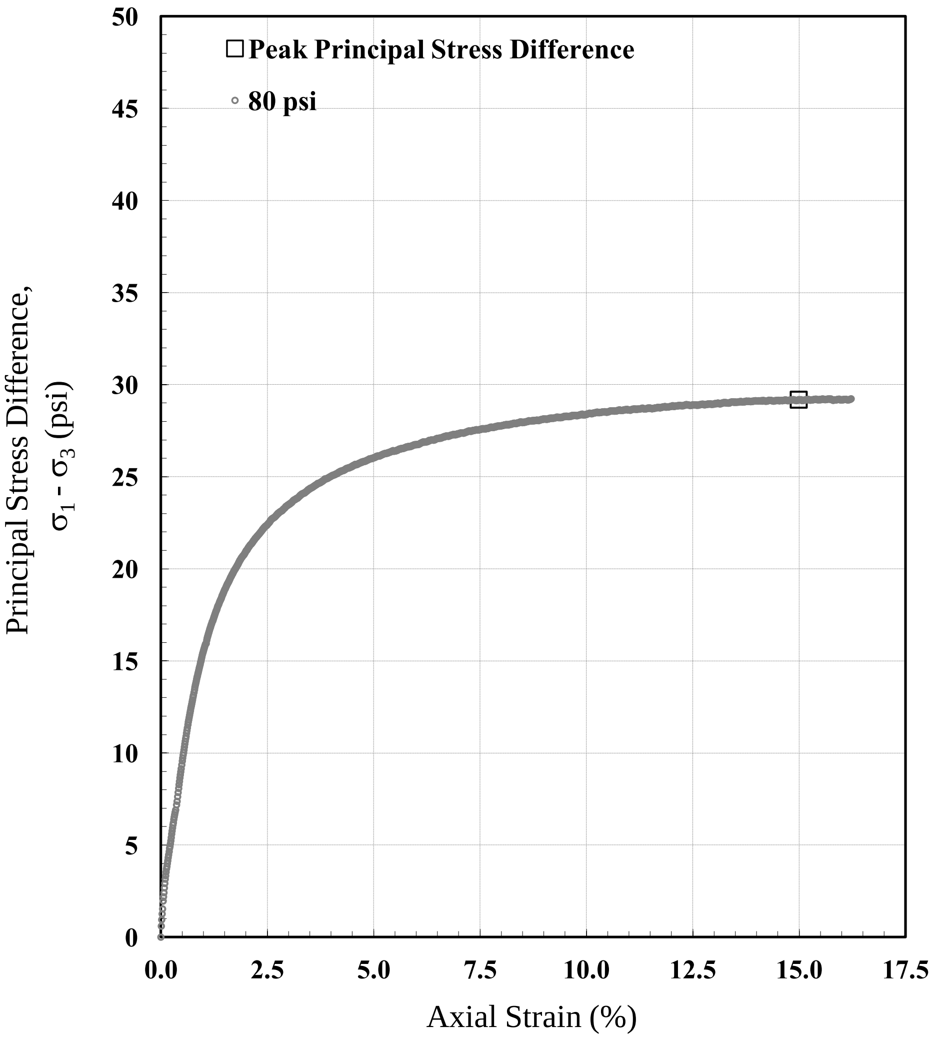
Jeffrey A. Kuhn , Ph.D., P.E., 11/16/2016

Analysis & Quality Review/Date

Laboratory Staff: LC

Unconsolidated-Undrained (Q) Triaxial Compression

Client:	Gorrondona & Associates	TRI Log #:	24670
Project:	UTRWD Lake Ralph Hall	Test Method:	ASTM D2850
Sample:	D-04 (18-20)		



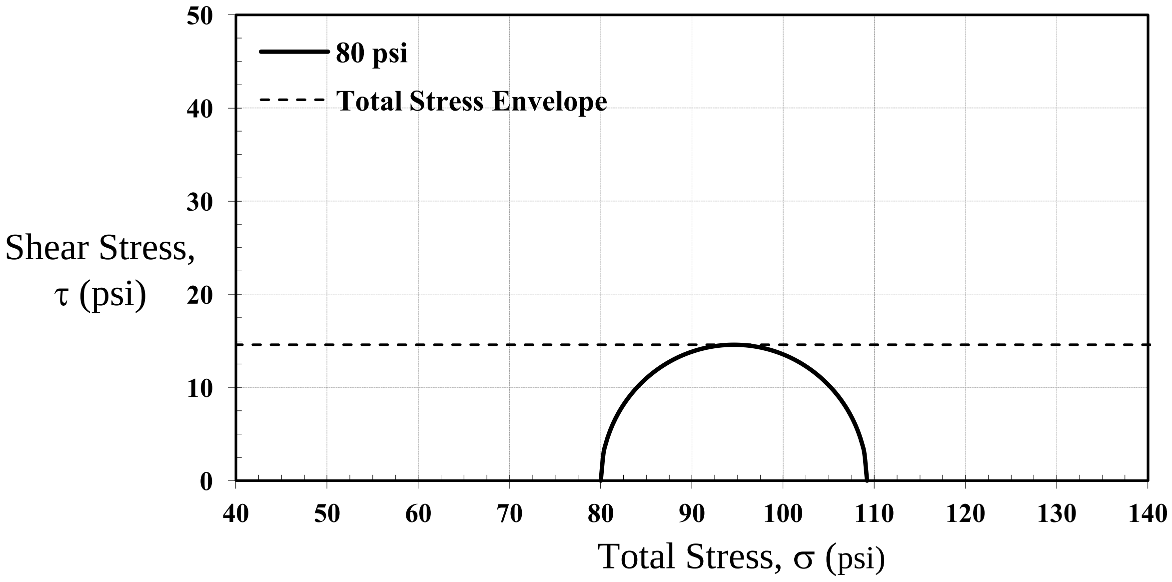
Test Parameters	
Minor Principal Stress (psi)	80.0
Rate of Strain (%/hr)	60

Initial Properties	
Avg. Diameter (in)	2.76
Avg. Height (in)	5.62
Avg. Water Content (%)	22.6
Bulk Density (pcf)	124.5
Dry Density (pcf)	101.5
Saturation (%)	95.2
Void Ratio	0.63
Specific Gravity (Assumed)	2.65

At Failure - Maximum Deviator Stress	
Axial Strain at Failure (%)	15.0
Minor Total Stress (psi)	80.0
Major Total Stress (psi)	109.2
Principal Stress Diff. (psi)	29.2

Total Stress Envelope	
Friction Angle (deg)	0
Undrained Shear Strength, S_u (psi)	14.6
S_u / σ_3	0.2

Note: The Mohr failure envelope was taken as a horizontal straight line. It should, however, be noted that the specimen was partially saturated.

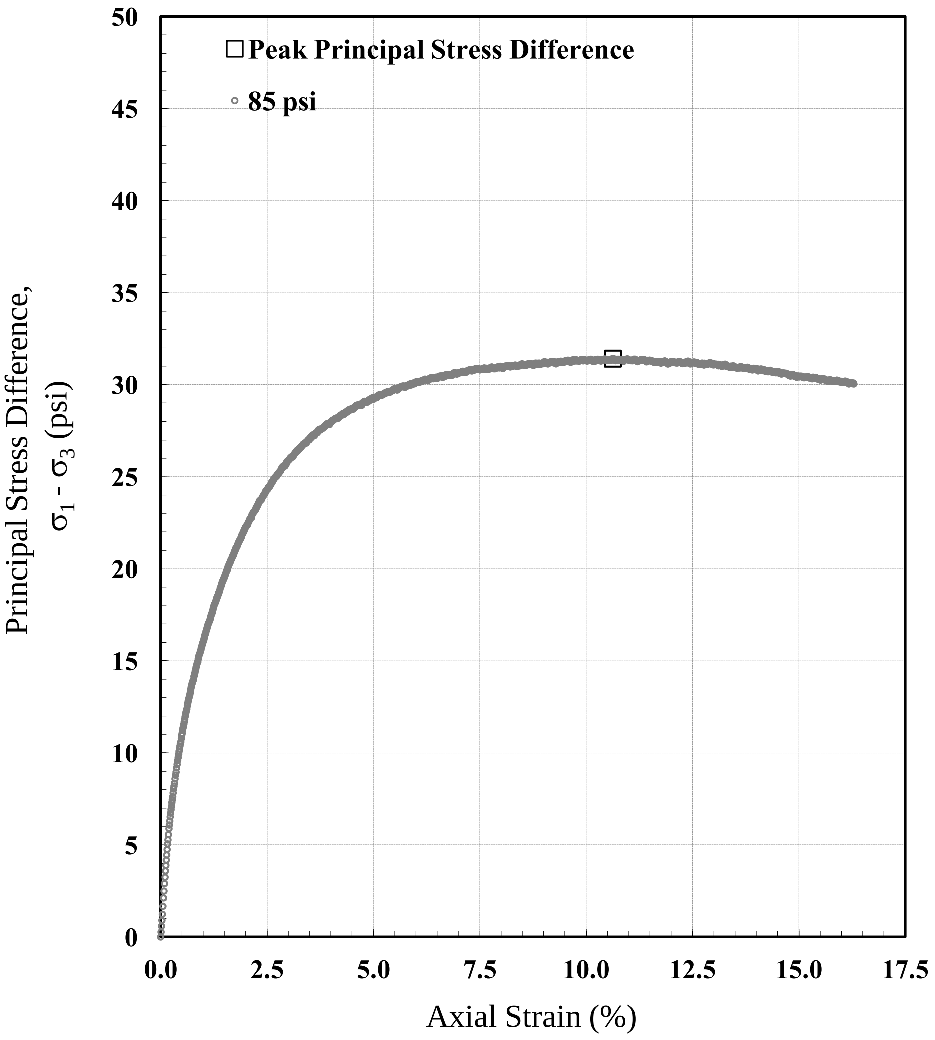


Jeffrey A. Kuhn , Ph.D., P.E., 11/16/2016
Analysis & Quality Review/Date
Laboratory Staff: LC

Unconsolidated-Undrained (Q) Triaxial Compression

Client: Gorrondona & Associates
Project: UTRWD Lake Ralph Hall
Sample: D-05 (29-30)

TRI Log #: 24670
Test Method: ASTM D2850



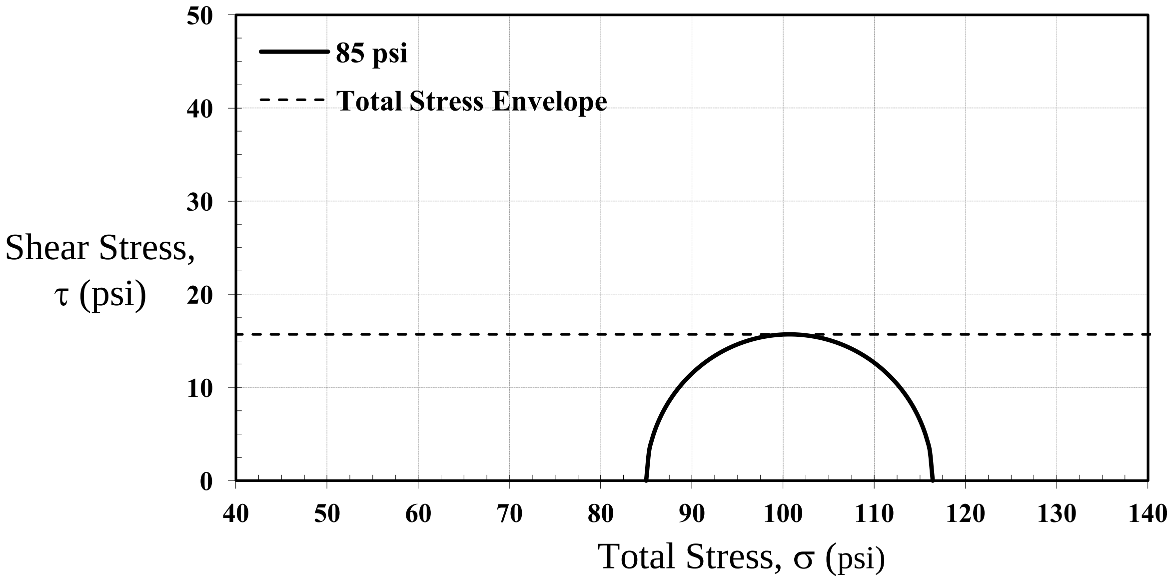
Test Parameters	
Minor Principal Stress (psi)	85.0
Rate of Strain (%/hr)	60

Initial Properties	
Avg. Diameter (in)	2.80
Avg. Height (in)	5.64
Avg. Water Content (%)	27.2
Bulk Density (pcf)	123.4
Dry Density (pcf)	97.0
Saturation (%)	100.0
Void Ratio	0.71
Specific Gravity (Assumed)	2.65

At Failure - Maximum Deviator Stress	
Axial Strain at Failure (%)	10.6
Minor Total Stress (psi)	85.0
Major Total Stress (psi)	116.4
Principal Stress Diff. (psi)	31.4

Total Stress Envelope	
Friction Angle (deg)	0
Undrained Shear Strength, S_u (psi)	15.7
S_u / σ_3	0.2

Note: The Mohr failure envelope was taken as a horizontal straight line.

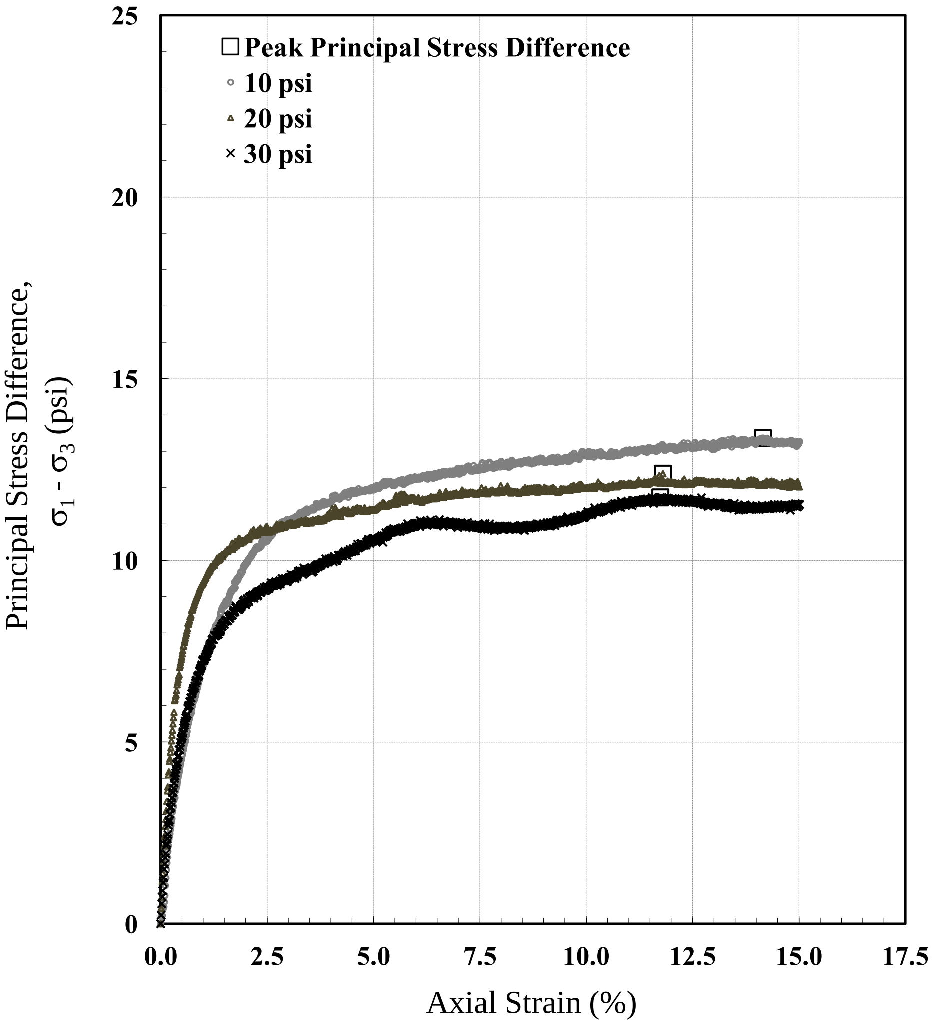


Jeffrey A. Kuhn , Ph.D., P.E., 11/16/2016
Analysis & Quality Review/Date
Laboratory Staff: LC

Unconsolidated-Undrained (Q) Triaxial Compression

Client: Gorrondona & Associates
Project: UTRWD Lake Ralph Hall
Sample: Composite BA-03 (4-20)

TRI Log #: 24670.37
Test Method: ASTM D2850

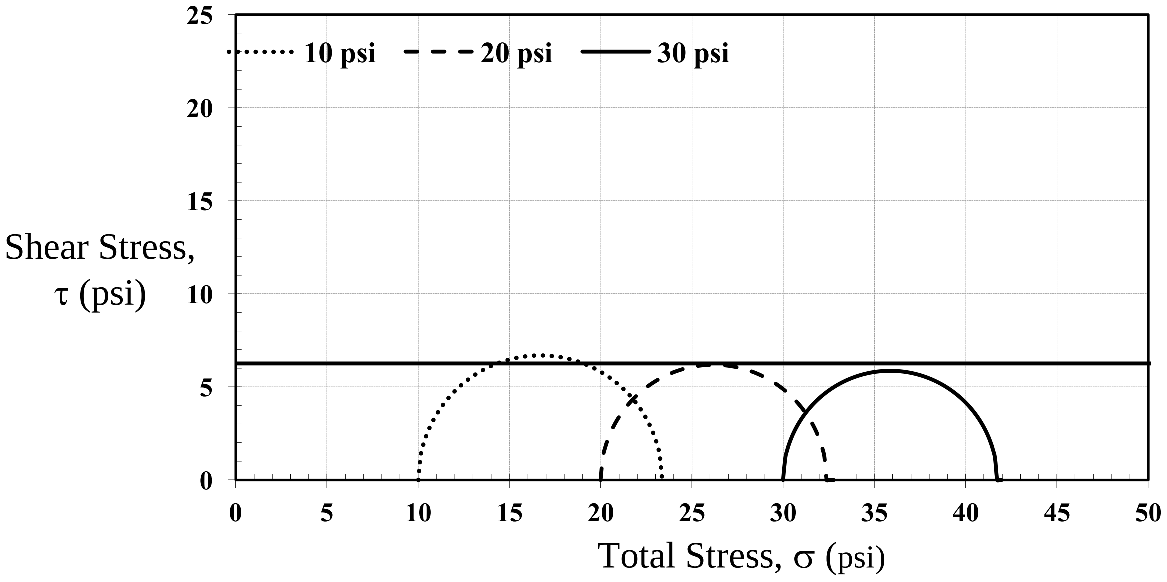


Samples			
Sample I.D.	Composite BA-03		
Depth/Elev. (ft)	4-20		
Minor Principal Stress (psi)	10.0	20.0	30.0
Initial Properties			
Avg. Diameter (in)	2.00	2.01	1.99
Avg. Height (in)	4.42	4.35	4.49
Avg. Water Content (%)	30.0	30.0	30.0
Bulk Density (pcf)	119.7	119.1	117.9
Dry Density (pcf)	92.1	91.6	90.7
Saturation (%)	99.8	98.6	96.4
Void Ratio	0.80	0.81	0.82
Specific Gravity (Assumed)	2.65	2.65	2.65

At Failure			
Failure Criterion	Maximum Deviator Stress		
Rate of Strain (%/hr)	30	30	30
Axial Strain at Failure (%)	14.2	11.8	11.7
Minor Total Stress (psi)	10.0	20.0	30.0
Major Total Stress (psi)	23.4	32.4	41.7
Principal Stress Diff. (psi)	13.4	12.4	11.7

Note: Remolded samples with target dry density of 90 pcf and moisture content of 30%.

Total Stress Envelope	
Friction Angle (deg)	0.0
Cohesion (psi)	6.2

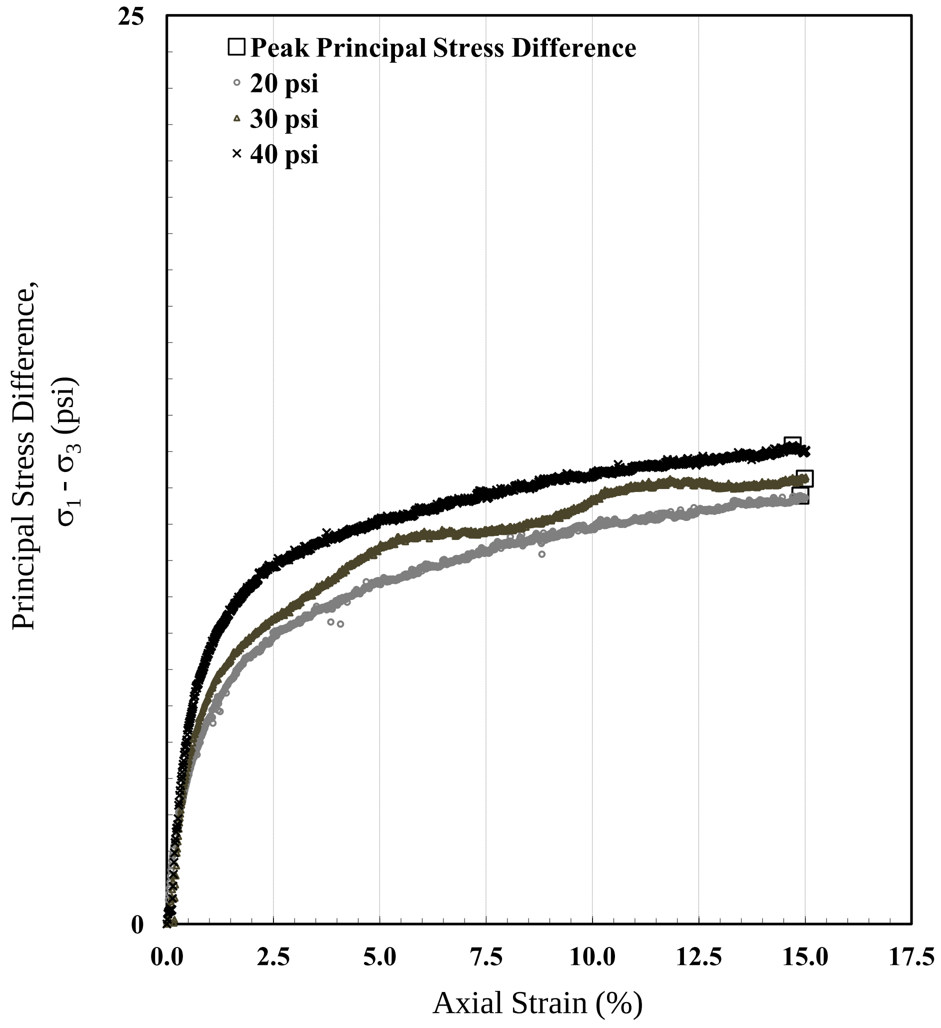


Note: A linear fit tangent to the Mohr circles results in a total stress envelope with a negative friction angle. The total stress envelope provide is the average of the undrained shear strengths of the three tests performed.

Shawn Hutcherson, P.E. 12/1/2016
Analysis & Quality Review/Date
Laboratory Staff: LC

Unconsolidated-Undrained (Q) Triaxial Compression

Client:	Gorrondona & Associates	TRI Log #:	24670.38
Project:	UTRWD Lake Ralph Hall	Test Method:	ASTM D2850
Sample:	Composite BA-04 (0-15)		

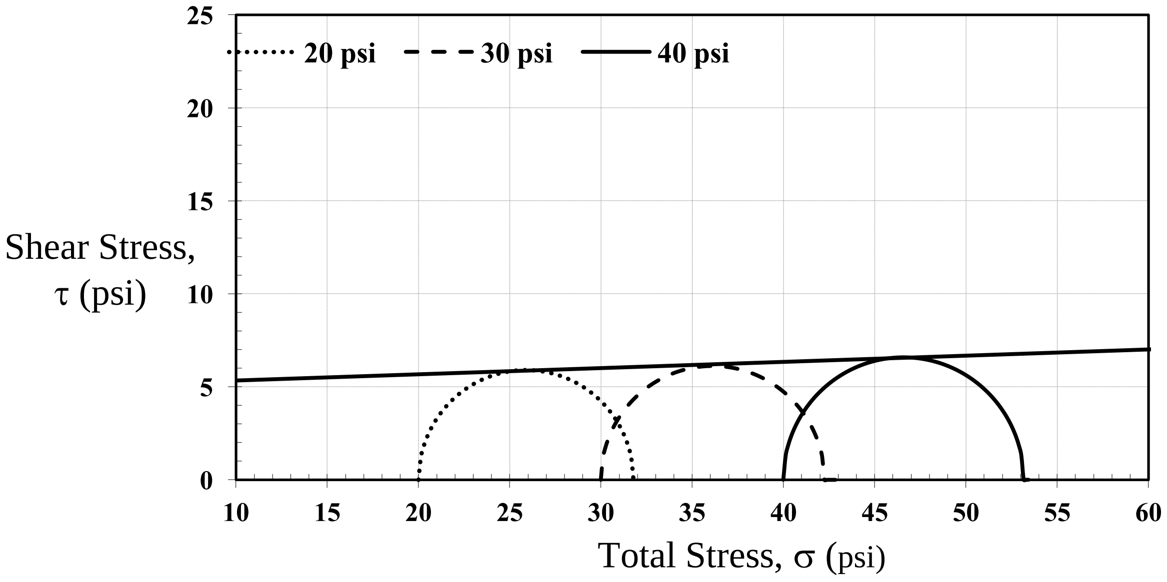


Samples			
Sample I.D.	Composite BA-04		
Depth/Elev. (ft)	0-15		
Minor Principal Stress (psi)	20.0	30.0	40.0
Initial Properties			
Avg. Diameter (in)	1.99	1.99	2.01
Avg. Height (in)	4.47	4.44	4.65
Avg. Water Content (%)	29.0	29.0	29.0
Bulk Density (pcf)	118.1	119.1	117.6
Dry Density (pcf)	91.6	92.3	91.2
Saturation (%)	95.3	97.0	94.3
Void Ratio	0.81	0.79	0.81
Specific Gravity (Assumed)	2.65	2.65	2.65

At Failure			
Failure Criterion	Maximum Deviator Stress		
Rate of Strain (%/hr)	30	30	30
Axial Strain at Failure (%)	14.9	15.0	14.7
Minor Total Stress (psi)	20.0	30.0	40.0
Major Total Stress (psi)	31.8	42.3	53.2
Principal Stress Diff. (psi)	11.8	12.3	13.2

Note: Remolded samples with target dry density of 90 pcf and moisture content of 29%.

Total Stress Envelope	
Friction Angle (deg)	1.9
Cohesion (psi)	5.0



Shawn Hutcherson, P.E. 12/1/2016

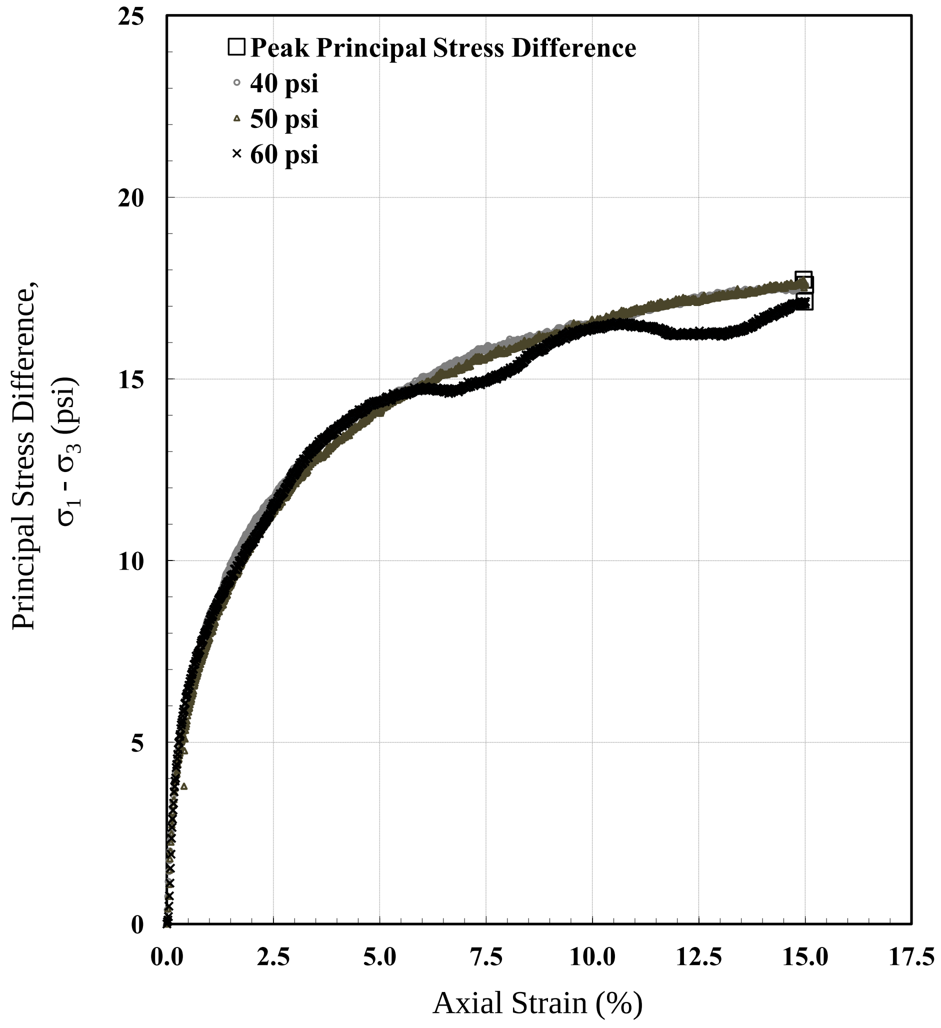
Analysis & Quality Review/Date

Laboratory Staff: LC

Unconsolidated-Undrained (Q) Triaxial Compression

Client: Gorrondona & Associates
Project: UTRWD Lake Ralph Hall
Sample: Composite BA-05-1 (0-7)

TRI Log #: 24670.39
Test Method: ASTM D2850

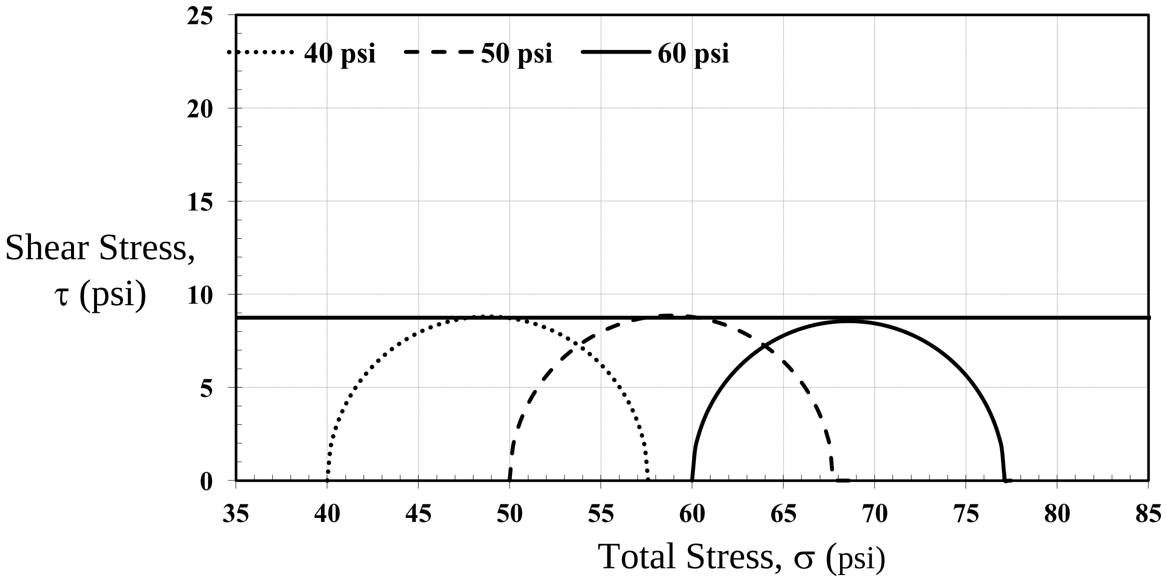


Samples			
Sample I.D.	Composite BA-05-1		
Depth/Elev. (ft)	0-7		
Minor Principal Stress (psi)	40.0	50.0	60.0
Initial Properties			
Avg. Diameter (in)	1.99	2.00	2.00
Avg. Height (in)	4.55	4.54	4.57
Avg. Water Content (%)	30.0	30.0	30.0
Bulk Density (pcf)	116.5	116.6	115.6
Dry Density (pcf)	89.6	89.7	88.9
Saturation (%)	93.9	94.1	92.4
Void Ratio	0.85	0.85	0.86
Specific Gravity (Assumed)	2.65	2.65	2.65

At Failure			
Failure Criterion	Maximum Deviator Stress		
Rate of Strain (%/hr)	30	30	30
Axial Strain at Failure (%)	15.0	15.0	15.0
Minor Total Stress (psi)	40.0	50.0	60.0
Major Total Stress (psi)	57.6	67.7	77.1
Principal Stress Diff. (psi)	17.6	17.7	17.1

Note: Remolded samples with target dry density of 90 pcf and moisture content of 30%.

Total Stress Envelope	
Friction Angle (deg)	0.0
Cohesion (psi)	8.7



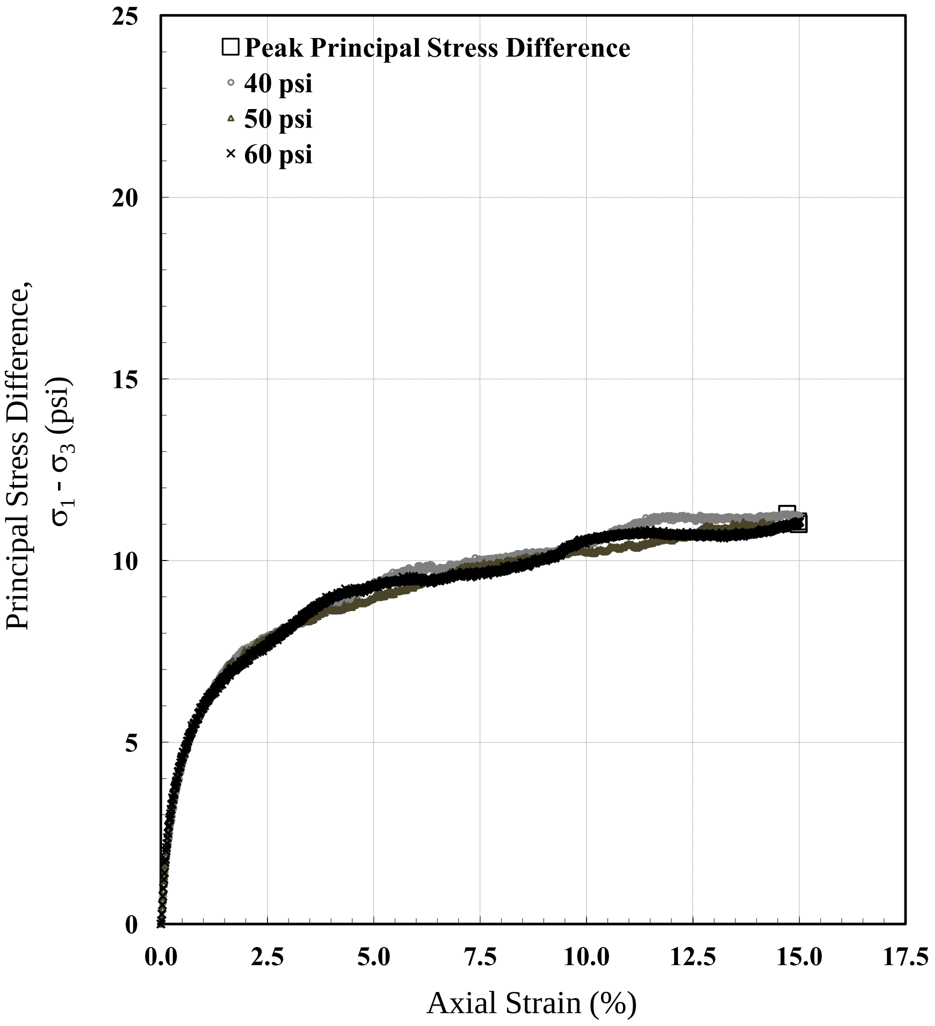
Note: A linear fit tangent to the Mohr circles results in a total stress envelope with a negative friction angle. The total stress envelope provide is the average of the undrained shear strengths of the three tests performed.

Shawn Hutcherson, P.E. 12/1/2016
Analysis & Quality Review/Date
Laboratory Staff: LC

Unconsolidated-Undrained (Q) Triaxial Compression

Client: Gorrondona & Associates
Project: UTRWD Lake Ralph Hall
Sample: Composite BA-05-2 (7-14)

TRI Log #: 24670.40
Test Method: ASTM D2850

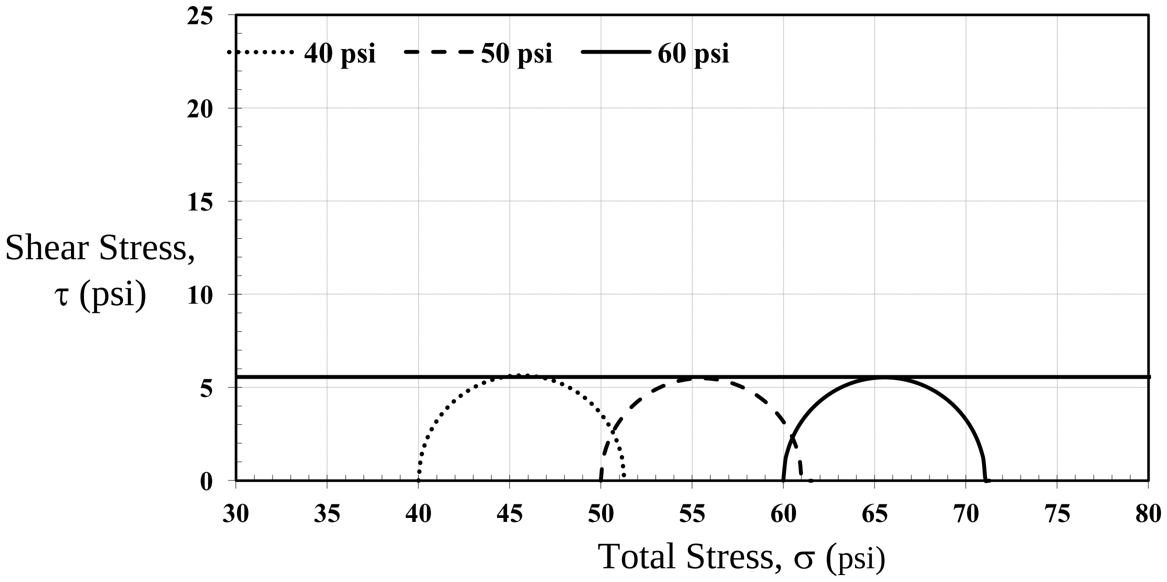


Samples			
Sample I.D.	Composite BA-05-2		
Depth/Elev. (ft)	7-14		
Minor Principal Stress (psi)	40.0	50.0	60.0
Initial Properties			
Avg. Diameter (in)	1.99	1.99	1.99
Avg. Height (in)	4.29	4.34	4.30
Avg. Water Content (%)	27.0	27.0	27.0
Bulk Density (pcf)	120.6	119.7	121.3
Dry Density (pcf)	95.0	94.3	95.5
Saturation (%)	96.4	94.8	97.7
Void Ratio	0.74	0.76	0.73
Specific Gravity (Assumed)	2.65	2.65	2.65

At Failure			
Failure Criterion	Maximum Deviator Stress		
Rate of Strain (%/hr)	30	30	30
Axial Strain at Failure (%)	14.7	15.0	15.0
Minor Total Stress (psi)	40.0	50.0	60.0
Major Total Stress (psi)	51.3	61.0	71.1
Principal Stress Diff. (psi)	11.3	11.0	11.1

Note: Remolded samples with target dry density of 90 pcf and moisture content of 27%.

Total Stress Envelope	
Friction Angle (deg)	0.0
Cohesion (psi)	5.6



Note: A linear fit tangent to the Mohr circles results in a total stress envelope with a negative friction angle. The total stress envelope provide is the average of the undrained shear strengths of the three tests performed.

Shawn Hutcherson, P.E. 12/1/2016
Analysis & Quality Review/Date
Laboratory Staff: LC

Crumb Test for Dispersibility of Clayey Soils

Client:	Gorrondona & Associates	TRI Log #:	24670
Project:	UTRWD Lake Ralph Hall	Test Method:	ASTM D6572-B

Sample Identification	Moisture Content (%)		Temp. (°C)			Grade			Dispersive Classification (1 hr)
	Initial	Adjusted	2 min	1 hr	6 hr	2 min	1 hr	6 hr	
Composite BA-03 (4-20)	37.3	-	21.0	20.0	19.0	1	1	1	1
Composite BA-03 (4-20)	41.9	-	20.0	20.0	19.0	1	1	1	1
Composite BA-03 (4-20)	43.5	-	20.0	20.0	19.0	1	1	1	1
Composite BA-04 (0-15)	49.0	-	21.0	20.0	20.0	1	1	1	1
Composite BA-04 (0-15)	29.1	-	20.0	20.0	19.0	1	1	1	1
Composite BA-05-1 (0-7)	88.6	-	21.1	19.8	19.0	1	1	1	1
Composite BA-05-1 (0-7)	42.3	-	20.1	19.8	19.0	1	1	1	1
Composite BA-05-2 (7-14)	106.7	-	20.1	19.5	19.0	1	1	1	1
Composite BA-05-2 (7-14)	101.3	-	20.0	19.5	19.0	1	2	2	2

Grade 1, (Nondispersive): No Reaction; There is no turbid water created by colloids suspended in the water. All particles settle during the first hour.If the cloud is easily visible, assign Grade 3. If the cloud is faintly seen in only small area, assign Grade 1.
Grade 2, (Intermediate): Slight Reaction; A faint, barely visible colloidal suspension causes turbid water near or around the soil crumb surface.
Grade 3, (Dispersive): Moderate Reaction; an easily visible cloud of suspended clay colloids is seen around all of the soil crumb surface. The cloud may extend up to 10 mm (¾ in.) away from the soil crumb mass along the bottom of dish.
Grade 4, (Highly Dispersive): Strong Reaction; a dense, profuse cloud of suspended clay colloids is seen around the entire bottom of dish. The soil crumb dispersion is so extensive that it is difficult to determine the interface of the original soil crumb . Often, the colloidal suspension is easily visible on the sides of the dish.

Shawn Hutcherson, P.E. 12/1/2016
Quality Review/Date
Tested by: MF & PC

Crumb Test for Dispersibility - ASTM (D6572)

Project Name L a UTRWD Lake Ralph Hall **Project No.** CHM16420 **Date** 10/19/2016

Boring No. BA-01 **Sample No.** Composite U3, U4 **Sample Depth (ft.)** 1.5-4.0

Sample Description Brown FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type Natural Cube	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Time Started: Initial Temp(˚C): 21.2	1	21.3	4	23.6	4	21.4	4	21.1

Boring No. BA-01 **Sample No.** Composite U5-U10 **Sample Depth (ft.)** 4.0-5.0

Sample Description Gray FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type Natural Cube	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Time Started: Initial Temp(˚C): 21.7	1	21.6	1	21.3	1	22.3	1	21.1

Boring No. BA-01 **Sample No.** Composite U5-U10 **Sample Depth (ft.)** 7.0-10.0

Sample Description Gray FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type Natural Cube	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Time Started: Initial Temp(˚C): 22.1	1	21.8	1	21.4	3	22.2	4	21.1

Boring No. BA-01 **Sample No.** Composite U11, U12 **Sample Depth (ft.)** 14.0-20.0

Sample Description Light Brown SANDY FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type Natural Cube	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Time Started: Initial Temp(˚C): 23.2	1	23.4	2	23.8	2	20.9	2	20.9

Boring No. BA-02 **Sample No.** Composite U2-U10 **Sample Depth (ft.)** 1.0-7.0

Sample Description Gray FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type Natural Cube	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Time Started: Initial Temp(˚C): 21.5	1	22.8	1	23.5	1	20.8	1	20.9

Crumb Test for Dispersibility - ASTM (D6572)

Project Name UTRWD Lake Ralph Hall **Project No.** CHM16420 **Date** 10/18/2016

Boring No. BA-02 **Sample No.** Composite U2-U10 **Sample Depth (ft.)** 7.0-10.0
Sample Description Gray FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	21.4	1	23	1	20.9	1	21
Time Started:								
Initial Temp(˚C): 21.3								

Boring No. BA-03 **Sample No.** Composite U1-U4 **Sample Depth (ft.)** 0.0-4.0
Sample Description Gray FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	21.3	1	22.6	1	21.0	1	20.9
Time Started:								
Initial Temp(˚C): 21.3								

Boring No. BA-05 **Sample No.** Composite U11, U12 **Sample Depth (ft.)** 14.0-20.0
Sample Description Brown LEAN CLAY (CL)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	22.5	1	21.9	1	21.2	1	21.1
Time Started:								
Initial Temp(˚C): 22.5								

Boring No. ES-01 **Sample No.** Composite U1-U3 **Sample Depth (ft.)** 0.0-3.0
Sample Description Tan FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	23.1	1	21.3	1	21.0	1	20.1
Time Started:								
Initial Temp(˚C): 21.9								

Boring No. ES-01 **Sample No.** Composite U4-U9 **Sample Depth (ft.)** 3.0-9.0
Sample Description Brown FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	21.5	1	21.5	1	22.1	1	21.2
Time Started:								
Initial Temp(˚C): 21.6								

Crumb Test for Dispersibility - ASTM (D6572)

Project Name UTRWD Lake Ralph Hall **Project No.** CHM16420 **Date** 10/18/2016

Boring No. ES-01 **Sample No.** Composite U10-U12 **Sample Depth (ft.)** 10.0-20.0
Sample Description Brown FAT CLAY (CH)

Moisture Content								
	2 minutes		1 hour		6 hours		24 hours	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	21.3	1	23.2	1	20.9	1	20.9
Time Started:								
Initial Temp(˚C): 21.4								

Boring No. ES-02 **Sample No.** Composite U2-U10 **Sample Depth (ft.)** 1.0-4.0
Sample Description Brown FAT CLAY (CH)

Moisture Content								
	2 minutes		1 hour		6 hours		24 hours	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	21.1	1	22.4	1	21.1	1	21.0
Time Started:								
Initial Temp(˚C): 21.2								

Boring No. ES-02 **Sample No.** Composite U2-U10 **Sample Depth (ft.)** 4.0-7.0
Sample Description Brown FAT CLAY (CH)

Moisture Content								
	2 minutes		1 hour		6 hours		24 hours	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	21.4	1	21.3	1	21.1	1	20.9
Time Started:								
Initial Temp(˚C): 21.4								

Boring No. ES-02 **Sample No.** Composite U2-U10 **Sample Depth (ft.)** 7.0-10.0
Sample Description Tan FAT CLAY (CH)

Moisture Content								
	2 minutes		1 hour		6 hours		24 hours	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	23.9	1	23.7	1	20.9	1	21.0
Time Started:								
Initial Temp(˚C): 22.4								

Boring No. ES-02 **Sample No.** U-11 **Sample Depth (ft.)** 13.0-15.0
Sample Description Brown LEAN CLAY (CL)

Moisture Content								
	2 minutes		1 hour		6 hours		24 hours	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube	1	21.3	1	22.3	1	21.2	1	20.9
Time Started:								
Initial Temp(˚C): 21.4								

Crumb Test for Dispersibility - ASTM (D6572)

Project Name UTRWD Lake Ralph Hall **Project No.** CHM16420 **Date** 10/18/2016

Boring No. ES-03 **Sample No.** Composite U3-U10 **Sample Depth (ft.)** 3.0-6.0

Sample Description Brown FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube								
Time Started:	1	21.4	1	21.5	1	21.2	1	21.1
Initial Temp(˚C): 21.1								

Boring No. ES-03 **Sample No.** Composite U3-U10 **Sample Depth (ft.)** 6.0-10.0

Sample Description Brown FAT CLAY (CH)

Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube								
Time Started:	1	22.9	1	21.6	1	21.1	1	21.1
Initial Temp(˚C): 22.8								

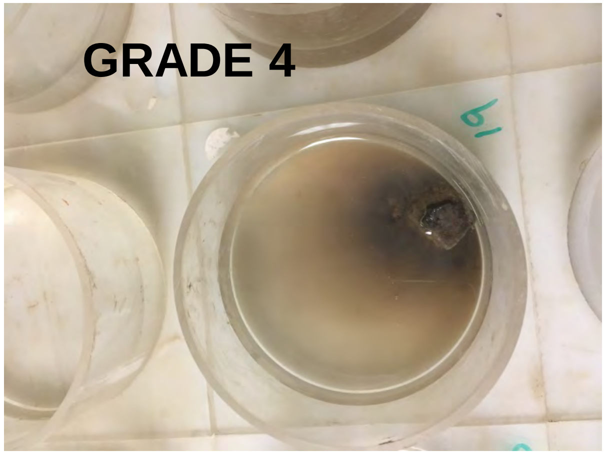
Boring No. ES-03 **Sample No.** Composite U11, U12 **Sample Depth (ft.)** 14.0-20.0

Sample Description Brown FAT CLAY (CH)

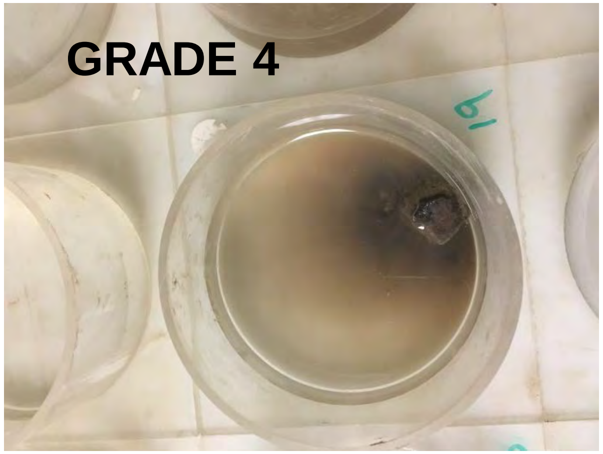
Moisture Content								
	2 minutes		**1 hour**		**6 hours**		**24 hours**	
Specimen Type	Grade	˚C	Grade	˚C	Grade	˚C	Grade	˚C
Natural Cube								
Time Started:	1	21.3	1	21.5	1	21.5	1	21.2
Initial Temp(˚C): 21.2								

CRUMB TEST PHOTOGRAPHS

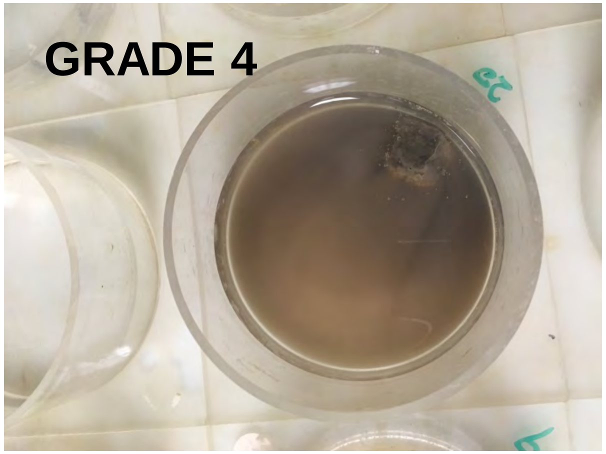
BA-01 (1.5-4.0 feet) – 2 Min.



BA-01 (1.5-4.0 feet)– 1 hour

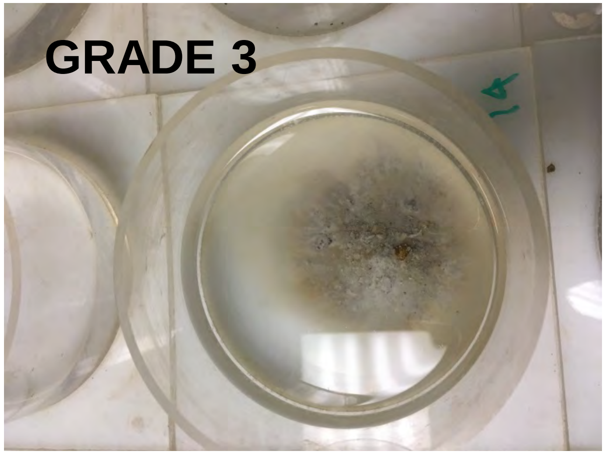


BA-01 (1.5-4.0 feet)– 6 hour



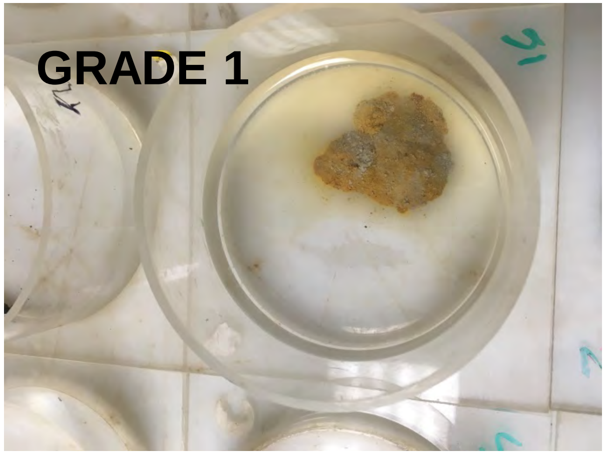
BA-01 (1.5-4.0 feet)– 24 hour

CRUMB TEST PHOTOGRAPHS



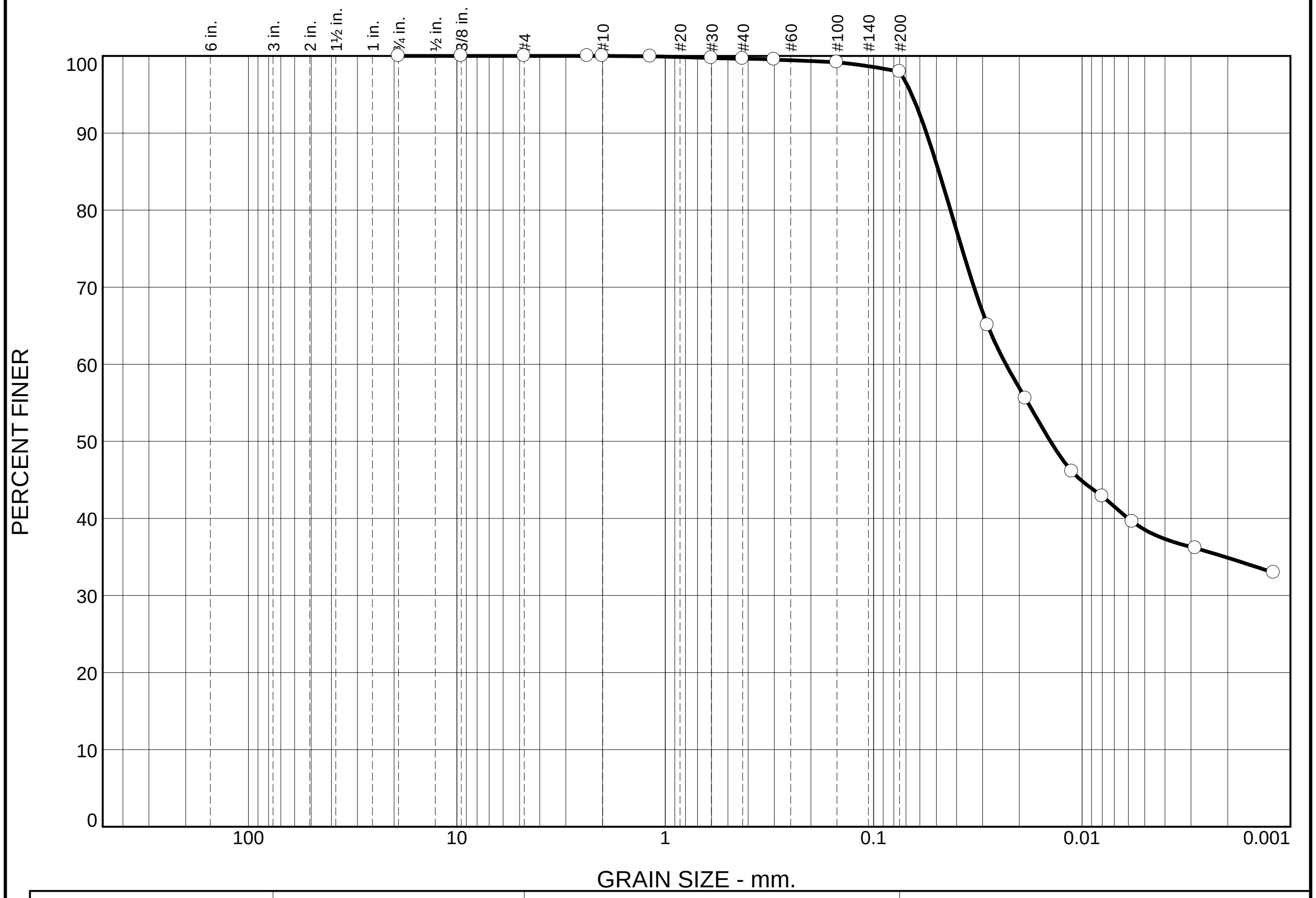
BA-01 (7-10 feet) – 6 hour

BA-05 (14-20 feet) – 24 hour



ES-02 (7-10 feet) – 6 hour

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.0	0.4	1.6	59.5	38.5

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	63	17	0.0486	0.0232	0.0142					

	Material Description	USCS	AASHTO
○		CH	A-7-6(50)

Project No. CHM16420 **Client:** Freese and Nichols, Inc.
Project: UTRWD Lake Ralph Hall

○ **Loc.:** BA-01 **Depth:** (4.0-10.0) ft. **Sample No.:** Composite U5-U10

Remarks:

Gorrondona & Associates, Inc.

Houston, Texas

Figure

GRAIN SIZE DISTRIBUTION TEST DATA

10/27/2016

Client: Freese and Nichols, Inc.
Project: UTRWD Lake Ralph Hall
Project Number: CHM16420
Location: BA-01
Depth: (4.0-10.0) ft.
Sample Number: Composite U5-U10
Liquid Limit: 63
Plastic Limit: 17
USCS Classification: CH
AASHTO Classification: A-7-6(50)

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
203.17	0.00	0.00	0.75"	0.00	100.0
			3/8"	0.00	100.0
			#4	0.00	100.0
			#8	0.00	100.0
			#10	0.00	100.0
			#16	0.11	99.9
			#30	0.53	99.7
			#40	0.74	99.6
			#50	0.98	99.5
			#100	1.67	99.2
			#200	4.16	98.0

Hydrometer Test Data

Hydrometer test uses material passing #40
Percent passing #40 based upon complete sample = 99.6
Weight of hydrometer sample =50
Automatic temperature correction
Composite correction (fluid density and meniscus height) at 20 deg. C = -4
Meniscus correction only = 1.0
Specific gravity of solids = 2.69
Hydrometer type = 151H
Hydrometer effective depth equation: L = 16.294964 - 0.2645 **x Rm**

Elapsed Time (min.)	Temp. (deg. C.)	Actual Reading	Corrected Reading	K	Rm	Eff. Depth	Diameter (mm.)	Percent Finer
2.00	23.6	1.0240	1.0205	0.0129	25.0	9.7	0.0284	65.1
5.00	23.6	1.0210	1.0175	0.0129	22.0	10.5	0.0187	55.6
15.00	23.7	1.0180	1.0145	0.0129	19.0	11.3	0.0112	46.1
30.00	23.6	1.0170	1.0135	0.0129	18.0	11.5	0.0080	42.9
60.00	23.4	1.0160	1.0125	0.0129	17.0	11.8	0.0057	39.6
250.00	22.9	1.0150	1.0114	0.0130	16.0	12.1	0.0029	36.1
1440.00	22.9	1.0140	1.0104	0.0130	15.0	12.3	0.0012	33.0

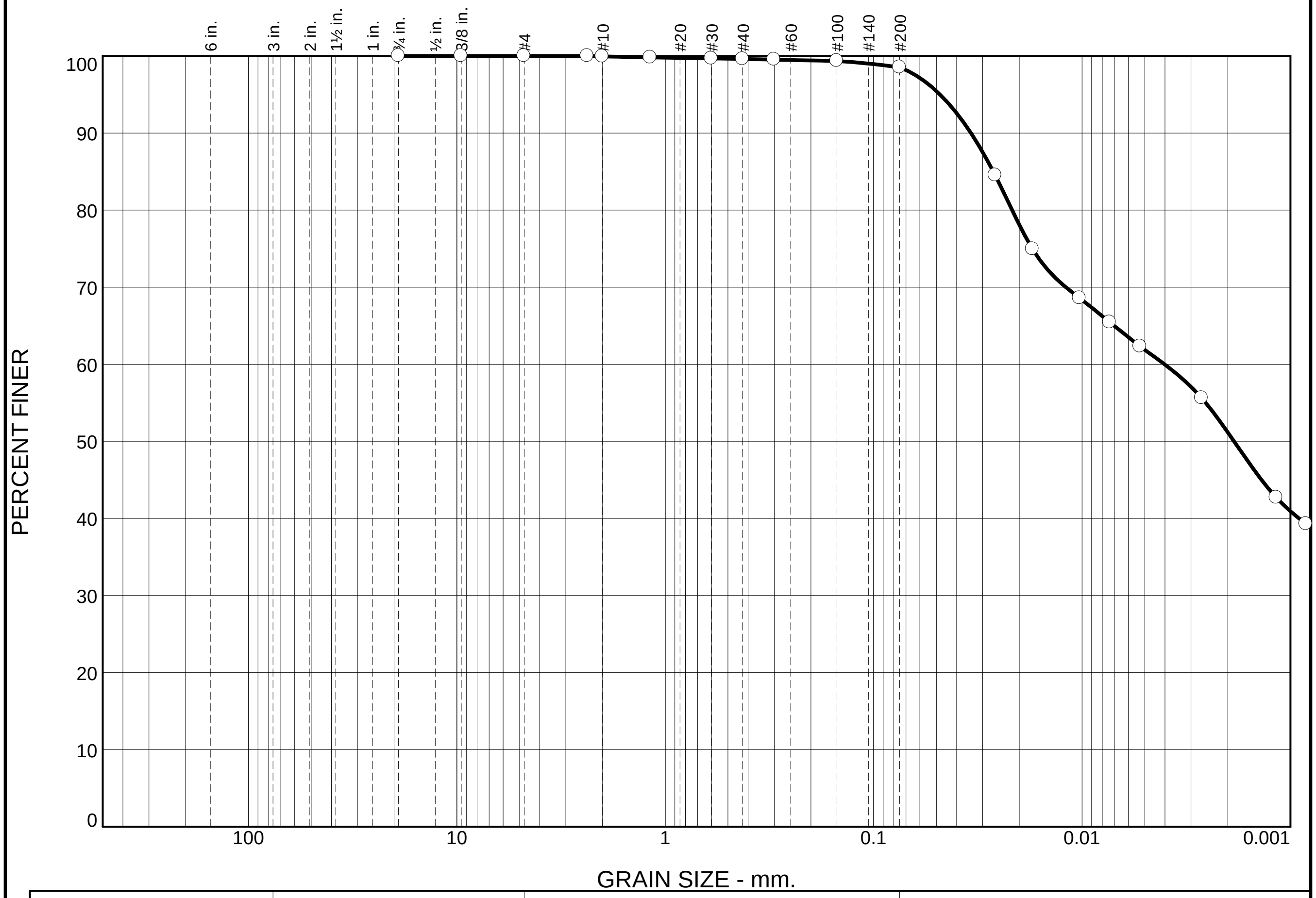
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	0.0	0.4	1.6	2.0	59.5	38.5	98.0

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
					0.0060	0.0142	0.0232	0.0428	0.0486	0.0558	0.0656

Fineness Modulus
0.02

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.1	0.3	1.1	36.6	61.9

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	67	21	0.0267	0.0040	0.0019					

	Material Description	USCS	AASHTO
○		CH	A-7-6(51)

Project No. CHM16420 **Client:** Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

○ **Location:** D-01 **Depth:** (23.0-25.0) ft. **Sample Number:** U13

Remarks:

Gorrondona & Associates, Inc.

Houston, Texas

Figure

GRAIN SIZE DISTRIBUTION TEST DATA

10/27/2016

Client: Freese and Nichols, Inc.
Project: UTRWD Lake Ralph Hall
Project Number: CHM16420
Location: D-01
Depth: (23.0-25.0) ft. **Sample Number:** U13
Liquid Limit: 67 **Plastic Limit:** 21
USCS Classification: CH **AASHTO Classification:** A-7-6(51)

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
178.38	0.00	0.00	0.75"	0.00	100.0
			3/8"	0.00	100.0
			#4	0.00	100.0
			#8	0.00	100.0
			#10	0.09	99.9
			#16	0.33	99.8
			#30	0.58	99.7
			#40	0.70	99.6
			#50	0.86	99.5
			#100	1.16	99.3
			#200	2.65	98.5

Hydrometer Test Data

Hydrometer test uses material passing #40
Percent passing #40 based upon complete sample = 99.6
Weight of hydrometer sample =50
Automatic temperature correction
Composite correction (fluid density and meniscus height) at 20 deg. C = -4
Meniscus correction only = 1.0
Specific gravity of solids = 2.67
Hydrometer type = 151H
Hydrometer effective depth equation: L = 16.294964 - 0.2645 **x Rm**

Elapsed Time (min.)	Temp. (deg. C.)	Actual Reading	Corrected Reading	K	Rm	Eff. Depth	Diameter (mm.)	Percent Finer
2.00	23.7	1.0300	1.0265	0.0130	31.0	8.1	0.0261	84.5
5.00	23.7	1.0270	1.0235	0.0130	28.0	8.9	0.0173	75.0
15.00	23.7	1.0250	1.0215	0.0130	26.0	9.4	0.0103	68.6
30.00	23.8	1.0240	1.0206	0.0130	25.0	9.7	0.0074	65.5
60.00	23.9	1.0230	1.0196	0.0129	24.0	9.9	0.0053	62.3
250.00	23.3	1.0210	1.0175	0.0130	22.0	10.5	0.0027	55.6
1440.00	23.0	1.0170	1.0134	0.0131	18.0	11.5	0.0012	42.7
2880.00	22.5	1.0160	1.0123	0.0132	17.0	11.8	0.0008	39.3

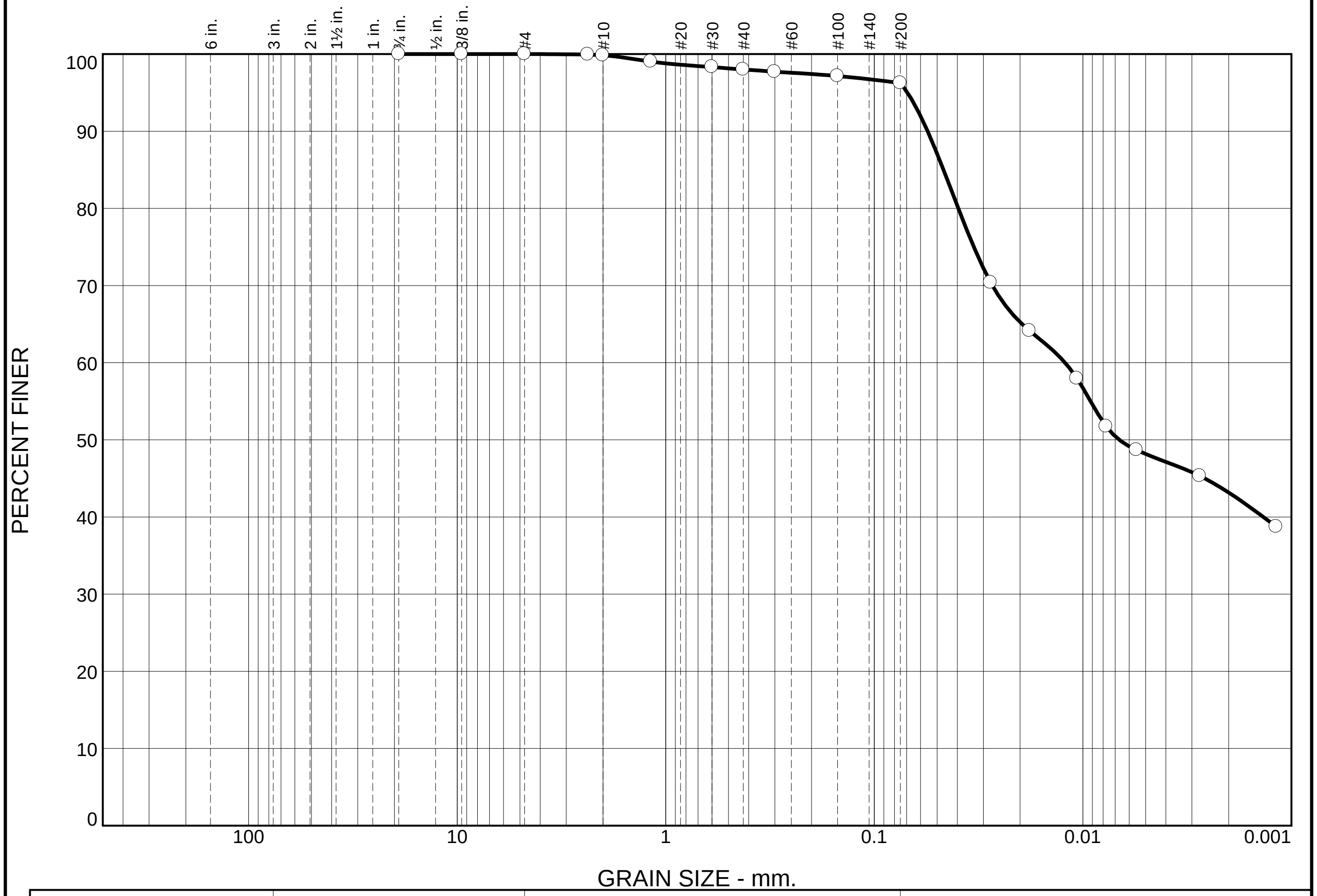
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	0.1	0.3	1.1	1.5	36.6	61.9	98.5

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
					0.0009	0.0019	0.0040	0.0217	0.0267	0.0341	0.0480

Fineness Modulus
0.02

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.2	1.8	1.8	48.0	48.2

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	70	23	0.0466	0.0122	0.0067					

	Material Description	USCS	AASHTO
○		CH	A-7-6(51)

Project No. CHM16420 **Client:** Freese and Nichols, Inc.
Project: UTRWD Lake Ralph Hall

○ **Location:** D-04 **Depth:** (9.0-10.0) ft. **Sample Number:** U10

Remarks:

Gorrondona & Associates, Inc.

Houston, Texas

Figure

GRAIN SIZE DISTRIBUTION TEST DATA

10/27/2016

Client: Freese and Nichols, Inc.
Project: UTRWD Lake Ralph Hall
Project Number: CHM16420
Location: D-04
Depth: (9.0-10.0) ft.
Sample Number: U10
Liquid Limit: 70
Plastic Limit: 23
USCS Classification: CH
AASHTO Classification: A-7-6(51)

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
178.07	0.00	0.00	0.75"	0.00	100.0
			3/8"	0.00	100.0
			#4	0.00	100.0
			#8	0.14	99.9
			#10	0.28	99.8
			#16	1.73	99.0
			#30	3.01	98.3
			#40	3.57	98.0
			#50	4.12	97.7
			#100	5.07	97.2
			#200	6.70	96.2

Hydrometer Test Data

Hydrometer test uses material passing #40
Percent passing #40 based upon complete sample = 98.0
Weight of hydrometer sample =50.0
Automatic temperature correction
Composite correction (fluid density and meniscus height) at 20 deg. C = -4
Meniscus correction only = 1.0
Specific gravity of solids = 2.68
Hydrometer type = 151H
Hydrometer effective depth equation: L = 16.294964 - 0.2645 **x Rm**

Elapsed Time (min.)	Temp. (deg. C.)	Actual Reading	Corrected Reading	K	Rm	Eff. Depth	Diameter (mm.)	Percent Finer
2.00	23.6	1.0260	1.0225	0.0129	27.0	9.2	0.0277	70.4
5.00	23.6	1.0240	1.0205	0.0129	25.0	9.7	0.0180	64.1
15.00	23.7	1.0220	1.0185	0.0129	23.0	10.2	0.0107	57.9
30.00	23.8	1.0200	1.0166	0.0129	21.0	10.7	0.0077	51.7
60.00	23.9	1.0190	1.0156	0.0129	20.0	11.0	0.0055	48.7
250.00	23.5	1.0180	1.0145	0.0130	19.0	11.3	0.0028	45.3
1440.00	22.9	1.0160	1.0124	0.0131	17.0	11.8	0.0012	38.7

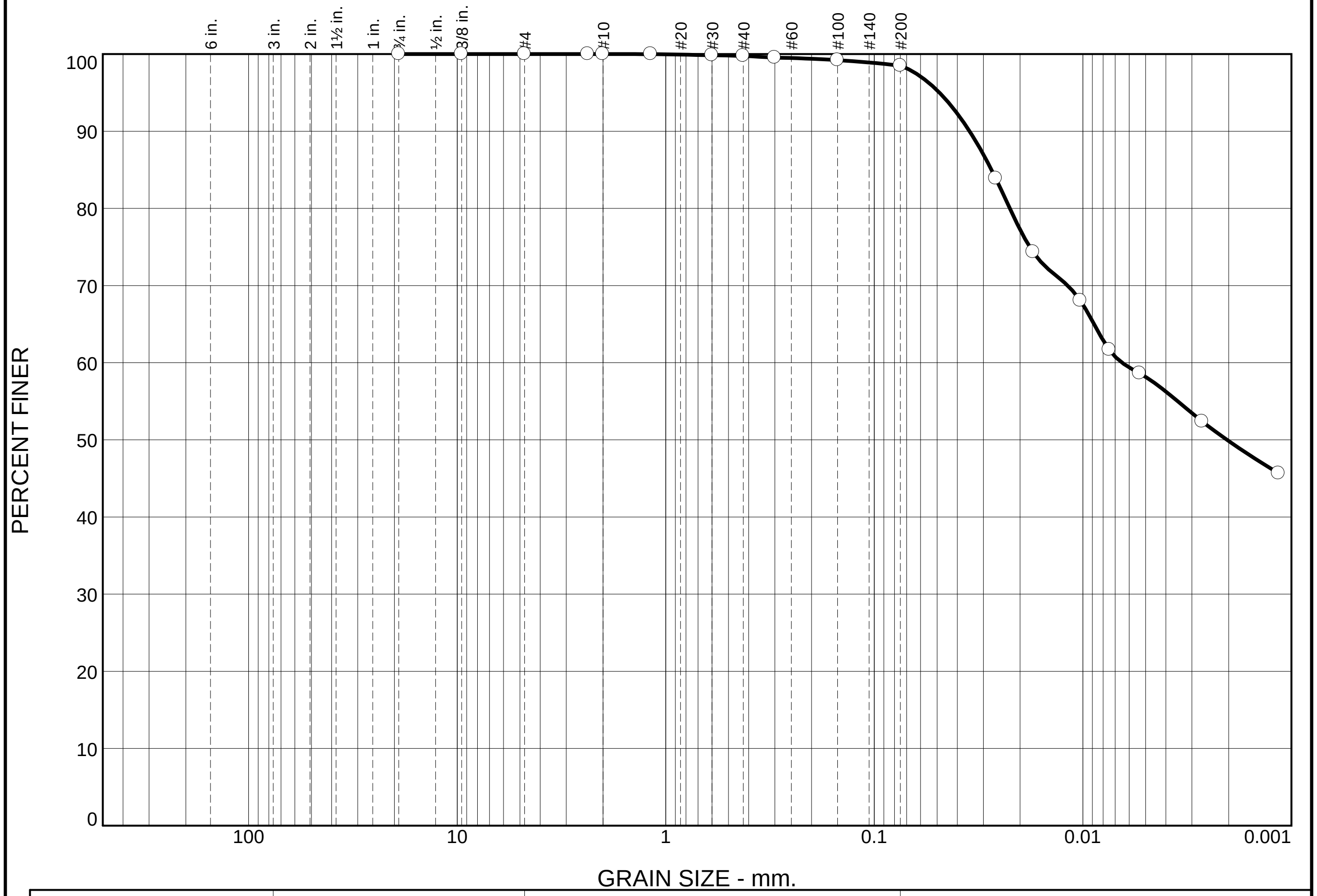
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	0.2	1.8	1.8	3.8	48.0	48.2	96.2

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
					0.0014	0.0067	0.0122	0.0395	0.0466	0.0555	0.0693

Fineness Modulus
0.08

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.0	0.2	1.3	40.3	58.2

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	75	27	0.0274	0.0065	0.0020					

	Material Description	USCS	AASHTO
○		CH	A-7-6(55)

Project No. CHM16420 **Client:** Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

○ **Loc.:** ES-01 **Depth:** (10.0-20.0) ft. **Sample No.:** Composite U10-U12

Remarks:

Gorrondona & Associates, Inc.

Houston, Texas

Figure

GRAIN SIZE DISTRIBUTION TEST DATA

10/27/2016

Client: Freese and Nichols, Inc.
Project: UTRWD Lake Ralph Hall
Project Number: CHM16420
Location: ES-01
Depth: (10.0-20.0) ft.
Sample Number: Composite U10-U12
Liquid Limit: 75
Plastic Limit: 27
USCS Classification: CH
AASHTO Classification: A-7-6(55)

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
175.33	0.00	0.00	0.75"	0.00	100.0
			3/8"	0.00	100.0
			#4	0.00	100.0
			#8	0.00	100.0
			#10	0.00	100.0
			#16	0.02	100.0
			#30	0.26	99.9
			#40	0.43	99.8
			#50	0.82	99.5
			#100	1.38	99.2
			#200	2.62	98.5

Hydrometer Test Data

Hydrometer test uses material passing #40
Percent passing #40 based upon complete sample = 99.8
Weight of hydrometer sample =50.0
Automatic temperature correction
Composite correction (fluid density and meniscus height) at 20 deg. C = -4
Meniscus correction only = 1.0
Specific gravity of solids = 2.69
Hydrometer type = 151H
Hydrometer effective depth equation: L = 16.294964 - 0.2645 **x Rm**

Elapsed Time (min.)	Temp. (deg. C.)	Actual Reading	Corrected Reading	K	Rm	Eff. Depth	Diameter (mm.)	Percent Finer
2.00	23.0	1.0300	1.0264	0.0130	31.0	8.1	0.0261	83.9
5.00	23.0	1.0270	1.0234	0.0130	28.0	8.9	0.0173	74.3
15.00	23.1	1.0250	1.0214	0.0130	26.0	9.4	0.0103	68.0
30.00	23.1	1.0230	1.0194	0.0130	24.0	9.9	0.0075	61.7
60.00	23.3	1.0220	1.0185	0.0130	23.0	10.2	0.0053	58.6
250.00	23.5	1.0200	1.0165	0.0129	21.0	10.7	0.0027	52.4
1440.00	22.8	1.0180	1.0144	0.0130	19.0	11.3	0.0012	45.7

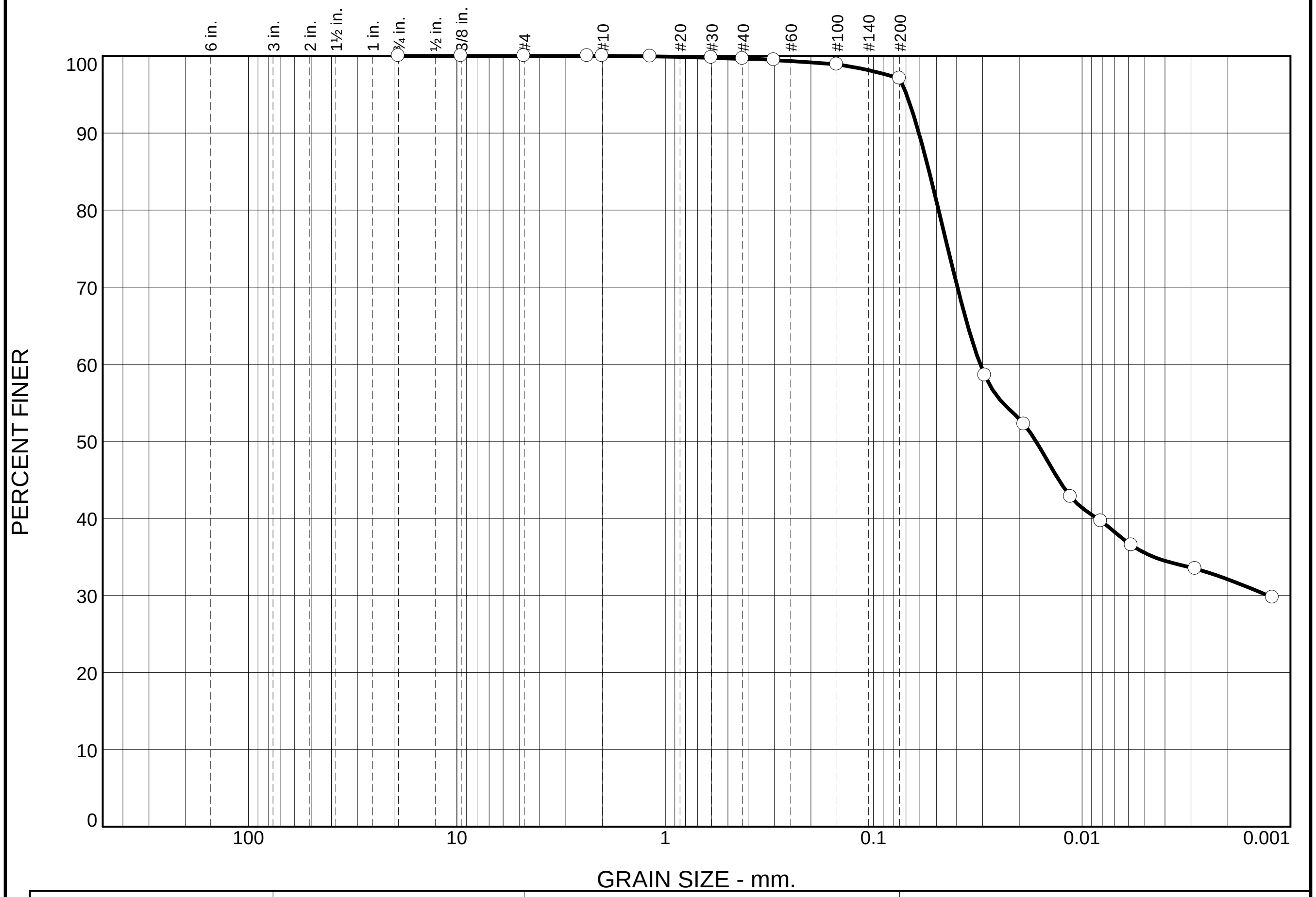
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	0.0	0.2	1.3	1.5	40.3	58.2	98.5

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
						0.0020	0.0065	0.0224	0.0274	0.0349	0.0487

Fineness Modulus
0.01

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.0	0.4	2.5	61.6	35.5

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	63	21	0.0542	0.0308	0.0166	0.0013				

	Material Description	USCS	AASHTO
○		CH	A-7-6(46)

Project No. CHM16420 **Client:** Freese and Nichols, Inc.

Project: UTRWD Lake Ralph Hall

○ **Loc.:** ES-02 **Depth:** (1.0-13.0) ft. **Sample No.:** Composite U2-U10

Remarks:

Gorrondona & Associates, Inc.

Houston, Texas

Figure

GRAIN SIZE DISTRIBUTION TEST DATA

10/27/2016

Client: Freese and Nichols, Inc.
Project: UTRWD Lake Ralph Hall
Project Number: CHM16420
Location: ES-02
Depth: (1.0-13.0) ft.
Sample Number: Composite U2-U10
Liquid Limit: 63
Plastic Limit: 21
USCS Classification: CH
AASHTO Classification: A-7-6(46)

Sieve Test Data

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
354.61	0.00	0.00	0.75"	0.00	100.0
			3/8"	0.00	100.0
			#4	0.00	100.0
			#8	0.00	100.0
			#10	0.00	100.0
			#16	0.18	99.9
			#30	0.87	99.8
			#40	1.33	99.6
			#50	1.94	99.5
			#100	3.88	98.9
			#200	10.33	97.1

Hydrometer Test Data

Hydrometer test uses material passing #40
Percent passing #40 based upon complete sample = 99.6
Weight of hydrometer sample =50.0
Automatic temperature correction
Composite correction (fluid density and meniscus height) at 20 deg. C = -4
Meniscus correction only = 1.0
Specific gravity of solids = 2.69
Hydrometer type = 151H
Hydrometer effective depth equation: L = 16.294964 - 0.2645 **x Rm**

Elapsed Time (min.)	Temp. (deg. C.)	Actual Reading	Corrected Reading	K	Rm	Eff. Depth	Diameter (mm.)	Percent Finer
2.00	23.3	1.0220	1.0185	0.0130	23.0	10.2	0.0293	58.6
5.00	23.3	1.0200	1.0165	0.0130	21.0	10.7	0.0190	52.2
15.00	23.5	1.0170	1.0135	0.0129	18.0	11.5	0.0113	42.8
30.00	23.5	1.0160	1.0125	0.0129	17.0	11.8	0.0081	39.6
60.00	23.6	1.0150	1.0115	0.0129	16.0	12.1	0.0058	36.5
250.00	23.8	1.0140	1.0106	0.0129	15.0	12.3	0.0029	33.5
1440.00	22.8	1.0130	1.0094	0.0130	14.0	12.6	0.0012	29.7

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	0.0	0.4	2.5	2.9	61.6	35.5	97.1

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
				0.0013	0.0085	0.0166	0.0308	0.0488	0.0542	0.0607	0.0696

Fineness Modulus
0.02

APPENDIX A-4

EXISTING DATA

PRELIMINARY
SUBSURFACE EXPLORATION

Ralph Hall Dam
Fannin County, Texas

Project 53882
June 21, 2005

KLEINFELDER
An employee owned company

June 21, 2005
Project 53882

Mr. John Levitt, P.E.
Chiang, Patel & Yerby, Inc.
1820 Regal Row, Suite 200
Dallas, Texas 75235

Subject: **Preliminary Subsurface Exploration**
Ralph Hall Dam
Fannin County, Texas

Dear Mr. Levitt:

Attached are results of field exploration and laboratory testing performed at the proposed site of the Ralph Hall Dam in Fannin County, Texas. This report actually constitutes a data report regarding initial site subsurface exploration. The site appears to be consistent with anticipated materials and an initial Geological Characteristics report written by Chiang, Patel & Yerby in February 2004. The primary foundation materials are suitable for construction of the dam, according to the preliminary core borings.

As the design planning proceeds, we shall be available to assist you.

Sincerely,

KLEINFELDER

Mike Shiflett

Michael M. Shiflett, P.E.

Copies Submitted: 5

Preliminary Subsurface Exploration

Ralph Hall Dam
Fannin County, Texas

Prepared for

Chiang, Patel & Yerby, Inc.

June 21, 2005

M. M. SHIFLETT
43763

DONALD D. JAMES
GEOLOGY
350

Michael M. Shiflett, P.E.

Donald D. James, P.G.

Kleinfelder
Fort Worth, Texas

An employee owned company

Project 53882

Photograph No. 1

Viewing easterly at Boring 1. Electrical restivity log equipment shown.

April 7, 2005

Photograph No. 2

Viewing easterly at Boring 3. Electrical restivity log equipment shown.

April 9, 2005

KLEINFELDER

SITE PHOTOGRAPHS
Ralph Hall Dam Preliminary
Fannin County, Texas
Project 53882 June 2005

Photograph No. 3

Arcuate parallel jointing in unweathered Ozan, south of channel at Merrill Creek.

April 9, 2005

Photograph No. 4

Orthogonal limonitic stained joints in Ozan at Merrill Creek.

April 9, 2005

Photograph No. 5

Slaked, unweathered Ozan at Merrill Creek.

April 9, 2005

KLEINFELDER

SITE PHOTOGRAPHS
Ralph Hall Dam Preliminary
Fannin County, Texas
Project 53882 June 2005

Important Information About Your
Geotechnical Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

The following information is provided to help you manage your risks.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared *solely* for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply the report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. *Do not rely on a geotechnical engineering report* whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. *Always* contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are *Not* Final

Do not overrely on the construction recommendations included in your report. *Those recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.*

A Geotechnical Engineering Report Is Subject to Misinterpretation

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Contractors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure contractors have sufficient time* to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform a *geoenvironmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, a number of mold prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; ***none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.***

Rely, on Your ASFE-Member Geotechncial Engineer for Additional Assistance

Membership in ASFE/The Best People on Earth exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you ASFE-member geotechnical engineer for more information.

ASFE
The Best People on Earth

8811 Colesville Road/Suite G106, Silver Spring, MD 20910
Telephone: 301/565-2733 Facsimile: 301/589-2017
e-mail: info@asfe.org www.asfe.org

TABLE OF CONTENTS

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1. INTRODUCTION

The Upper Trinity Regional Water District is in the preliminary stages of planning for Lake Ralph Hall. The proposed site of the dam and reservoir is on the North Sulphur River near Ladonia, Texas in southeastern Fannin County. Chiang, Patel & Yerby, Inc. is under contract with the District to provide initial planning and engineering for the dam and reservoir. A portion of the initial phases has been to provide preliminary subsurface, exploratory borings along the dam alignment to observe the subsurface conditions. Chiang, Patel & Yerby contracted with Kleinfelder to perform the subsurface borings and laboratory testing, which are being reported in this document.

In February 2004, CP&Y submitted a report, Geological Characteristics, to the District. This preliminary report presented general information regarding Regional Geologic Setting, Site Geology, Foundation Considerations, Surface and Groundwater discussions, and Natural Resources. While this current preliminary subsurface investigation has been limited to drilling four exploratory borings along the proposed dam centerline alignment and has therefore provided limited information and data, the subsurface information developed at the site is consistent with anticipated materials and the CP&Y report.

The Geologic Characteristics report states that for planning purposes, the dam will be a zoned earth-fill embankment, with a principal spillway, an emergency overflow spillway outlet, and a gated low-flow outlet structure. An embankment at this site with a crest elevation of 560 feet will be approximately 12,000 feet in length.

This preliminary report presents information regarding site exploration and methods, as well as results of laboratory tests performed on samples recovered from the borings. As the subsurface information is developed, design information and data will evolve regarding abutment slopes and core or slurry trench in the valley section.

2. FIELD EXPLORATION

Subsurface materials at the project site were explored by four borings drilled to depths of 60 to 100 feet along the proposed alignment of the dam. The borings were drilled on April 6, 7, 8, and 9, 2005 at the approximate locations shown on the Plan of Borings in the Appendix, Plate 2. The boring logs are also included in the Appendix on Plates 4 through 7, and a key to terms and descriptions on the logs is provided on Plate 3.

The four borings drilled along the proposed embankment alignment were located on property that had provided permission for access and also provided boring coverage near both the north and south abutments, as well as two borings within the valley section.

Table 1. Boring Locations

Boring No.	Ground Surface Elevation, feet	State Plane Coordinates		Station along Centerline
		Northing	Easting	
1	550	7221152.2556	2760734.7425	25+00 ±
2	502.6	7223918.0356	2760674.3652	53+00 ±
3	506.3	7226935.2921	2760645.3818	82+70 ±
4	564.2	7232423.3545	2760451.3557	North end

The borings locations were surveyed after the field operations were completed. The field survey was provided by The Wallace Group, Inc.

The borings were drilled using rotary drilling procedures and water as the drilling fluid. The drilling rig was mounted upon an articulating all-terrain vehicle (ATV) for access across the undeveloped property. The drilling operations were overseen by Mr. Donald James, P.G. Samples were logged and preserved in the field by Mr. James. Samples were logged for material type, color, and consistency; sealed in sheet plastic for moisture preservation; and transferred to the geotechnical laboratory.

Relatively undisturbed samples of cohesive soils encountered in the borings were taken by rapidly pushing a 3-inch OD thin-wall Shelby tube sampler (ASTM D 1587) a distance of approximately 1 foot into the soil using hydraulic pressure from the drill rig. Depths at which these samples were taken are designated "U" in the "Samples" column of the boring logs. After a Shelby tube was recovered from a boring, the sample was extruded in the field, examined visually and logged. A representative portion was selected, wrapped and sealed to prevent loss of moisture and to protect the sample during transportation. Estimates of the consistency of the cohesive soil samples were obtained in the field using a hand penetrometer. The result of a hand penetrometer reading is recorded at a corresponding depth in the "Hand Penetrometer, tsf" column of the boring logs. When the capacity of the hand penetrometer is exceeded, the value of 4.5+ is recorded.

The primary materials of the formation at the site are marl and were sampled using an NX-size double-tube core barrel fitted with a carbide bit. The lengths of marl cored by each “core run” are indicated within the “Samples” column, and the percents of core recovery are recorded on the boring logs in the appropriately marked columns. Rock Quality Designations (RQD) were measured for each core run, calculated and recorded in the field. The percent recovery is defined as the total length of material recovered in a specific core run divided by the total length of the core run. The RQD is a modified core recovery percentage in which all pieces of sound core over 4 inches long are summed and divided by the length of the core run. Core breaks caused by the drilling process were fitted together and counted as one piece. Where it was difficult to discern natural breaks from drilling breaks, the break was considered a natural break. The RQD designation is a method of quantifying the integrity or competency of the material being cored, being based upon the weathered or fractured condition of the material. The RQD values are presented on the Logs of Borings for each core run interval. The core run intervals for the project were typically 5 feet in length and are delineated on the boring logs.

Table 2. Classification of Rock by RQD Value

RQD	Rock Quality
Less than 25	Very Poor
25 – 50	Poor
50 – 75	Fair
75 – 90	Good
90 - 100	Excellent

All samples were extruded in the field, visually classified, sealed and packaged for transportation.

During coring of the marl in Boring 4, the catcher that secures the rock core within the core barrel became damaged and prevented core recovery below 60 feet. Therefore, in-place penetrometer tests were performed within the marl as the boring was advanced as a method of measuring marl consistency within the explored depth. The Texas Department of Transportation (TxDOT) cone penetrometer test utilizes a 3-inch steel cone driven by a 170-pound hammer dropped 24 inches. Either the number of blows required to produce 12 inches of penetration, or the inches of penetration due to 100 blows of the hammer are noted on the boring logs designated "T" in the "Penetration Resistance" column.

The general drilling procedures for these 4 preliminary borings included using a single flight auger to advance the boring between the undisturbed soil samples in the upper 15 feet, and then introducing water as drilling fluid to assist drilling advancement below the 15-foot depth.

After drilling and sampling, each borehole was electric logged for spontaneous potential, natural gamma, and resistivity. The electric logging was accomplished using a Century Geophysics 9060 logging tool. Although the electric logs were run for the entire length of each boring, the encoder value resulted in the lower halves of the borings, within the primary marl, being logged and recorded. The results of the Electrical Resistivity Readings are presented on a series of Logs of Borings presented in the Appendix on Plates 8 through 11.

Each boring was backfilled with soil cuttings, incorporating bentonite chips for a surface seal.

3. LABORATORY TESTING

Selected laboratory soil tests were performed on representative samples recovered from the borings. In addition to the classification tests (liquid limits, plastic limits, and percent passing #200 sieve), selected samples were tested for unconfined compressive strength, unit dry weight, and moisture content. Results of the laboratory tests are provided on each boring log, a summary table and on individual Plates presented in the Appendix.

Soil and rock descriptions used on the boring logs result from field data as well as from laboratory test data.

4. ANALYSIS AND RECOMMENDATIONS

4.1 SITE GEOLOGY

The regional geology was presented by Chiang, Patel & Yerby in the Geological Characteristics Report. A brief discussion of the geology across the proposed alignment of the earthen dam is now being presented as observed within the four coring borings. The proposed site is situated across a mature stream valley, the North Sulphur River Basin. The North Sulphur River trends west to east with gently rolling grade breaks bounding the northern and southern banks. The original North Sulphur River was bypassed with rechannelization during the 1920s resulting in rejuvenation of the river hydraulics and incisement of the current river channel.

The primary material beneath this river valley is documented as Cretaceous age Taylor Group, particularly the Ozan Formation. Younger sediments of Quarternary age line and fill the scour zone within the Ozan made by the original North Sulphur River.

The Ozan Formation is the lowest member of the Taylor Group and forms most of the “primary “ bedrock beneath the study area. The Ozan consists of up to 425 feet of bluish-gray, calcareous clays (marl) and mudstones with occasional thin, sandy layers. The basal portion contains phosphate nodules. Unweathered Ozan is indurated, rock-like material. The Ozan weathers into light gray shale and light yellow-brown shaly clay and judging from exposures in the creek bottoms, ravels rather quickly once exposed to weathering.

Joints observed in the Ozan occur in several modes as observed during our site visits including: orthogonal joints that intersected at relatively high angles (see photograph no. 4) and were often weathered with limonite staining and gypsum infills; platy joints more or less emulating shaly cleavage upon weathering; and arcuate jointing observed in sub-parallel sets with low angle dip (see photograph no. 3). A joint and fracture trace analysis was beyond the scope of this study. These observations were made upstream from the proposed dam within the Merrill Creek channel crossing at FM 1550. The channel erosion had exposed Ozan marl within the bottom of the tributary and it was within this channel that photographs were taken and the above observations made.

4.2 STRATIGRAPHY

Boring 1 (located at the southern end of the site) encountered a thick sequence of colluvial and alluvial sandy clay and clay to a depth of approximately 47 feet. From 47 feet to approximately 53 feet the boring encountered weathered Ozan formation material, which consists of a yellow-brown and light gray indurated calcareous clay (marl) exhibiting high angle joints and stained with limonite. Fossil Inoceramus clam imprints were observed in this weathered zone material. From 53 feet to the total depth of 85 feet the boring encountered unweathered marl that is gray to dark gray, massive, and very indurated.

Boring 2 (located just south of the original river channel) encountered dark brown alluvial clay with occasional sand partings and clay infilled burrows (probably from crayfish). Calcareous accretions (caliche) were observed from approximately 4 to 8 feet depth. Below 22 feet the soil became sandier with sand partings and seams, and soil color turned to light yellow-brown and light brown. From 32 feet to the total depth the boring encountered unweathered marl that is gray to dark gray, massive, and indurated.

Boring 3 (located north of the realigned river channel and on the raised, earthen county road) encountered approximately 3 feet of hard road fill clay. Below 3 feet the boring encountered light brownish-gray and light yellow-brown firm to stiff alluvial clay to approximately 12 feet. From 12 to 14½ feet the boring encountered medium dense alluvial clayey sand. From 14½ to approximately 23 feet the boring encountered weathered Ozan formation material that consists of hard yellow-brown and gray indurated calcareous clay (marl) that was fissile and contained root-invaded joints and gypsum infills. Hard dark gray unweathered Ozan marl was encountered from 23 feet to the total depth of 60 feet. Below 57 feet the marl exhibited weak cementation, contained a high angle joint and some coarse phosphatic sand grains.

Boring 4 was drilled approximately 30 feet west of the dam centerline to avoid a possible phone utility. The surficial 3 feet encountered sandy clay that had been reworked as probable fill material. From 3¼ feet to approximately 12 feet depth the boring encountered colluvial and alluvial brown to light brown-gray hard clay. Calcareous accretions (caliche) were observed in the soil samples from approximately 4 to 8 feet depth. From 12 feet to approximately 40 feet the boring encountered weathered Ozan formation material that consists of hard yellow-brown and gray indurated calcareous clay (marl) that was fissile. Gypsum infills were observed in the weathered Ozan samples below 24 feet depth. Below 40 feet the boring encountered hard dark gray unweathered Ozan marl.

The surficial soils vary between clay of low plasticity, CL, to clay of high plasticity, CH, according to the Unified Soil Classification System. As is expected within alluvial soils, the material types vary, and thus the plasticity of the recovered soil samples was observed to vary.

Boring 1 near the southern abutment encountered a thin layer of coarse subrounded gravel overlying the weathered marl. Boring 3 revealed a layer of clayey sand atop the weathered marl, while Borings 2 and 4 did not encounter a distinct, identifiable layer of coarse material above the marl. Boring 2 drilled near the original river channel encountered 32 feet of CH clay over dark gray marl, indicating that at some previous time, the river channel had cut through the weathered marl exposing the unweathered gray marl. These preliminary borings have not exposed well-defined, coarse-grained strata deposits above the primary marl, as is commonly found within alluvial soils.

4.3 TESTING OF STRATA

Field electrical resistivity tests were performed within the core borings in an attempt to identify geologic marker beds within the subsurface materials across the river valley and to determine if subsurface anomalies, including faulting, occur within the valley that would influence design of the dam.

The downhole electrical testing performed in the widely spaced borings did not identify discernable discontinuities or anomalies with sufficient signature definition to correlate the strata across the valley. However, electrical surveys obtained from the preliminary borings will be useful in comparing to electric log data obtained from future, more closely spaced borings along the centerline. This information will be helpful in determining geologic structure at the project site.

The readings as presented upon the logs of borings are fairly consistent for the depths tested. The Gamma log is generally useful for defining shale beds when the SP curve is rounded. The Gamma log reflects the proportion of shale and can occasionally be used as an indicator of shale content. The Spontaneous-Potential (SP) curve is useful to detect permeable beds and to give qualitative indications of bed shalyness. The Resistivity log can identify differing beds of material and thickness. Since the electrical resistivity readings were basically taken within one material type, discontinuities or material differences would be expected to be slight and difficult to discern. The fluctuations recorded from these electrical resistivity readings are considered to be slight and within the normal variance ranges for the marl.

Recovered samples from the marl were tested in the laboratory for unit weight, moisture content, and unconfined compression. The variance within the unconfined compressive strength is commonly observed and is attributed to joints within the material that provide preferential shearing paths during compression loads when the sample is unconfined in this particular test. The higher values are indicative of the competent marl that does not include a joint set, while the lower strength values indicate failure of the test specimen along a fracture, joint surface. Of interest and probably more indicative of the marl condition is the unit dry weight values as measured in the laboratory test. Although not drastically different, the unit weights of the weathered marl are slightly less than the unit weights of the unweathered marl. The weathered marl is yellow-brown and light gray while the unweathered marl is gray. The unit weights are indicators of the higher strength and consistency of the unweathered portion of the formation.

4.4 GROUNDWATER OBSERVATIONS

A detailed groundwater study has not been performed as a portion of this preliminary subsurface exploration. However, a few observations and comments are provided. Observation wells and piezometers will be installed during the design phase subsurface exploration program that will allow measurements of groundwater. Specific remarks regarding drilling and groundwater observations are presented at the bottoms of the logs of borings.

Each of the borings introduced water used as drilling fluid into the core borings.

- Boring 1 lost drilling fluid at the 26-foot depth, indicating a sand layer or fracture zone through which the drilling fluid was lost.

- Boring 2 was bailed of drilling fluid to the 21-foot depth upon completion of the drilling and sampling; after 20 hours, water was measured near 8 feet. As noted by the hand penetrometer readings, the soils between 25 and 32 feet (marl), are moist and probably indicative of groundwater within the valley section perched upon the less permeable underlying marl. Also note some sandy zones directly above the marl.

- Boring 3 encountered seepage at 14 feet prior to the introduction of water as drilling fluid. A layer of light gray-brown clayey sand occurs between 12 and 14½ feet and it is within this permeable layer, atop the less permeable marl that groundwater seepage was noted.

- Boring 4 was bailed to 44 feet and after 20 hours, the boring contained water up to the 39-foot depth. This water was likely drill water seeping from the clay mass. There was no distinct permeable sand or gravel layer encountered by Boring 4.

Within the lower valley section, we would expect to be able to measure a distinct groundwater zone atop the less permeable marl, which will serve as an underlying aquitard or boundary upon which shallow groundwater will be perched. A definite groundwater study will provide information on the presence of groundwater, depth, pressure, and fluctuations during seasonal moisture cycles.

5. CONCLUSIONS

While the main purpose of this preliminary geotechnical data report has been to develop preliminary subsurface data, there are several items that have been observed and can be stated as conclusions.

The referenced Geological Characteristics of Proposed Lake Ralph Hall by Chiang, Patel & Yerby (February 6, 2004) presents general overview information of the area. This data report has confirmed the types of information that was presented in the CP&Y report.

The soil types revealed by the four preliminary borings are predominantly CL and CH clays. Boring 3 revealed a clayey sand layer that was 2½ feet thick, and this was the only clayey sand encountered by these preliminary borings. Only minimal amounts of coarse sand and subrounded gravel were found deposited upon the primary marl.

Therefore, based upon the completion of the four preliminary core borings, the site appears to be consistent with anticipated materials and the mentioned report. The subsurface materials are suitable for construction of the earth-fill dam and appurtenant structures, according to the preliminary core borings. There also appears to be soils within the proposed reservoir area that are low permeability. The alluvial soils and the primary materials of the Ozan Formation appear to be suitably tight and of low permeability to retain water.

6. RECOMMENDATIONS

Four exploratory borings have been drilled to provide preliminary subsurface conditions across the river valley. Detailed design memorandum drilling and laboratory testing will be required to provide detailed subsurface conditions necessary for design.

Numerous detailed design issues regarding subsurface conditions will be addressed during design of the dam. As the design details are considered, it is recommended that a joint and fracture trace analysis be performed. The discussion regarding the visual observations of the exposed marl in the bottom of a tributary explains the recommendation for performing the joint and fracture trace analysis.

Suitable borrow areas for clay core and various material zones within the earthen dam will need to be located and classified during the detailed design stages. Normally it is attempted to locate these soil borrow areas within the lake area. From the preliminary borings, and from site observations and published geologic maps, it appears that sufficient suitable materials to construct the earthen dam are present on site, but this must be confirmed with additional exploratory borings and testing.

The geotechnical design issues for the dam will be similar to other sites. This preliminary data report has not revealed unusual conditions that would require specialized services not normally performed for projects of this magnitude. As additional geologic and geotechnical information develops, there may arise specific issues that require particular tests and analysis. At this time, such specific items have not been identified.

7. REPORT CLOSURE

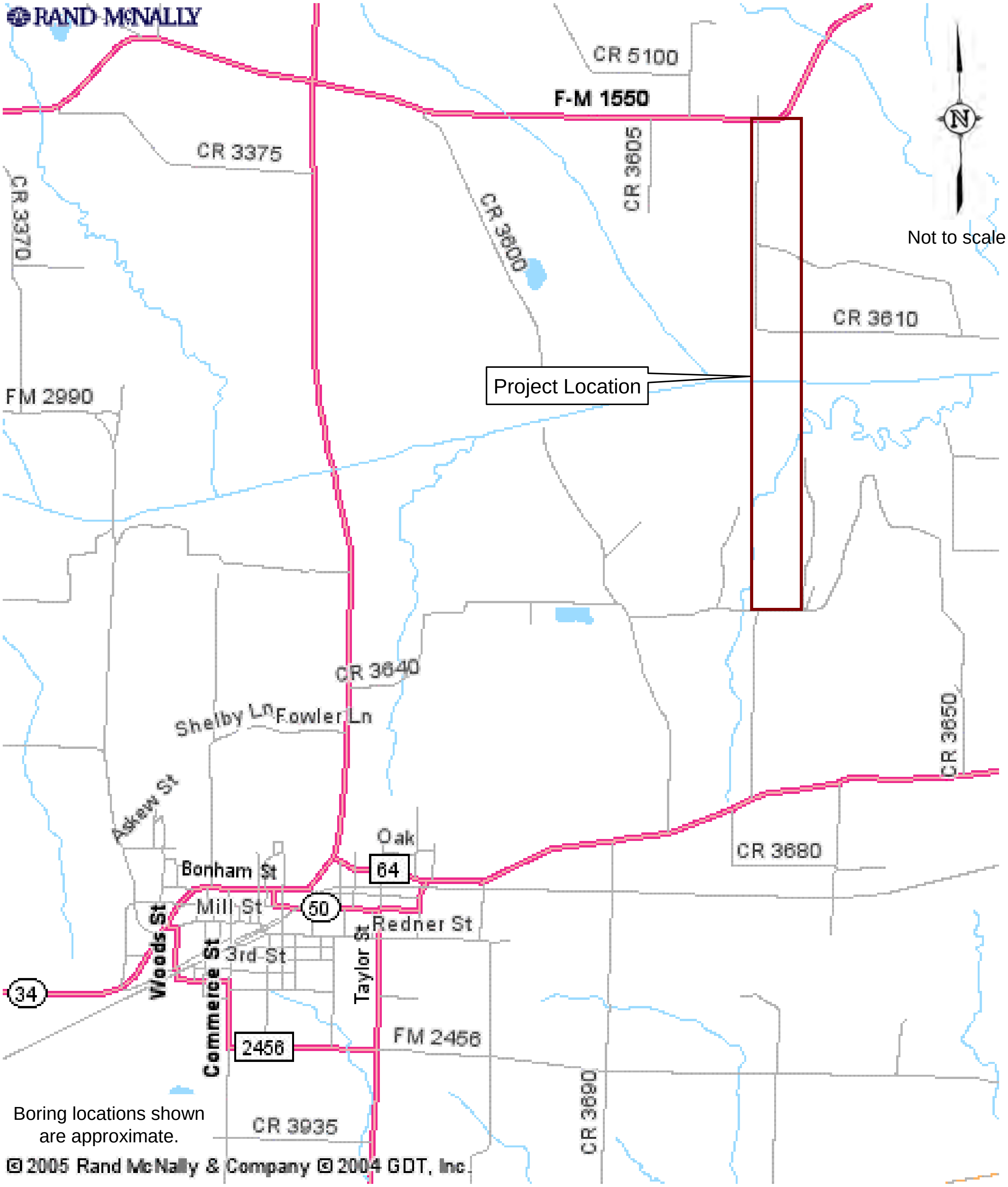
Recommendations contained in this report are based on our field observations and subsurface explorations, limited laboratory tests, and our present knowledge of the proposed construction. It is possible that soil conditions could vary between or beyond the points explored. If soil conditions are encountered during construction, which differ from those described herein, we should be notified immediately in order that a review may be made and any supplemental recommendations provided. If the scope of the proposed construction, including the proposed loads or structural locations, changes from that described in this report, our recommendations should also be reviewed.

We have prepared this report in substantial accordance with the generally accepted geotechnical engineering practice, as it exists in the site area at the time of our study. No warranty is expressed or implied. The recommendations provided in this report are based on the assumption that an adequate program of tests and observations will be conducted by Kleinfelder during the construction phase in order to evaluate compliance with our recommendations.

This report may be used only by the client and only for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both on-site and off-site) or other factors may change over time, and additional work may be required. Based on the intended use of the report, Kleinfelder may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the client or anyone else, unless specifically agreed to in advance by Kleinfelder in writing, will release Kleinfelder from any liability resulting from the use of this report by any unauthorized party.

Other standards or documents referenced in any given standard cited in this report, or otherwise relied upon by the authors of this report, are only mentioned in the given standard; they are not incorporated into it or "included by reference," as that latter term is used relative to contracts or other matters of law.

APPENDIX



Project Location

Not to scale

Boring locations shown are approximate.

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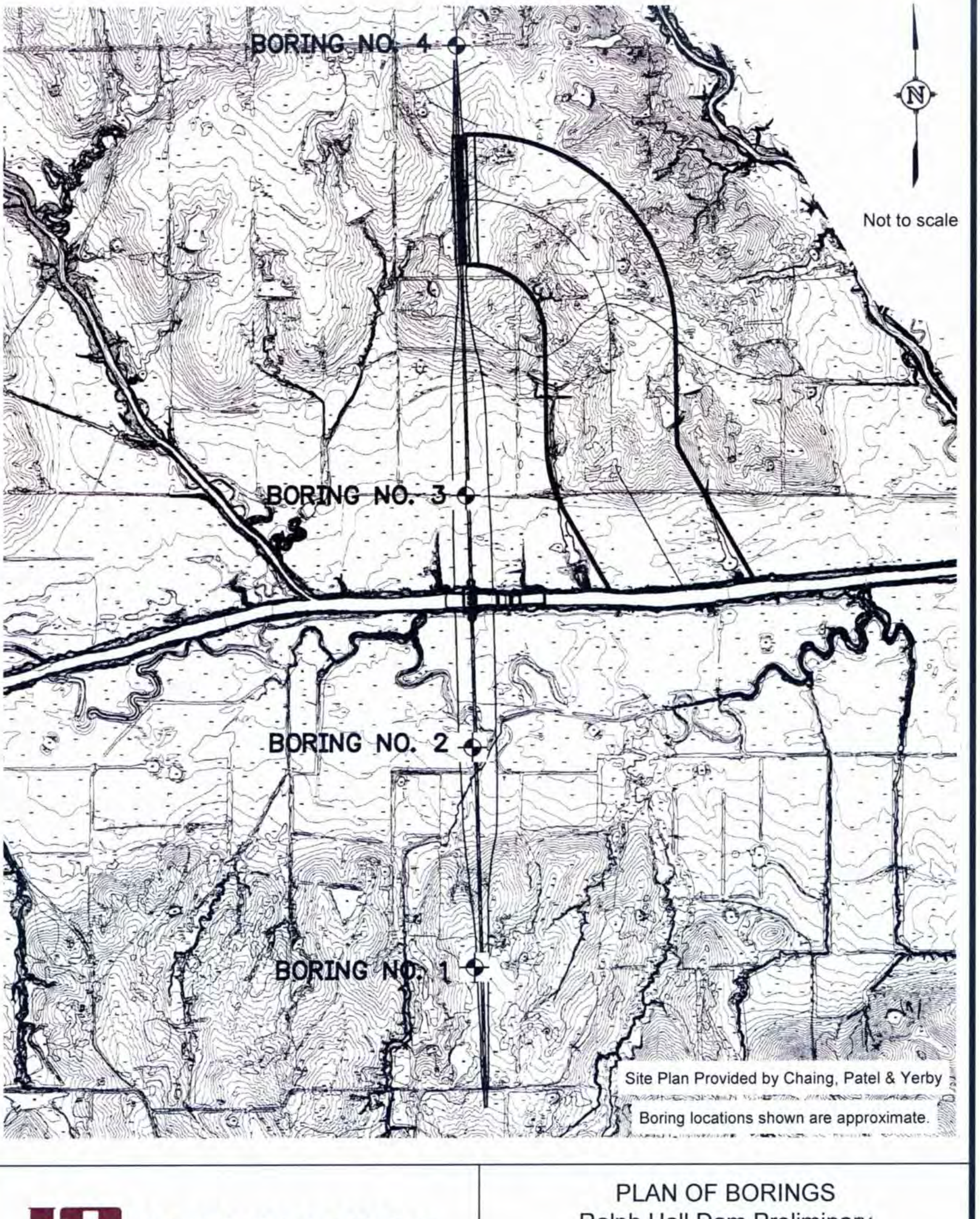
VICINITY MAP
Ralph Hall Dam Preliminary
Ladonia, Texas
Project 53882 June 2005

Plate 1



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PLAN OF BORINGS
Ralph Hall Dam Preliminary
Ladonia, Texas
Project 53882 June 2005

GENERAL NOTES

DRILLING AND SAMPLING SYMBOLS:

U / UD	Thin-Walled Tube - 3” O.D., Unless otherwise noted
A	Auger Sample
S	Split Spoon - 2” O.D., Unless otherwise noted
W	Wash Sample
C	Continuous Core Sample
P	Push Sample
T	THD Cone penetrometer
D	Denison Sample
B	Bag Sample

▽ Water Level Initial Measurement

▼ Water Level Subsequent Measurement

RELATIVE DENSITY OF COARSE-GRAINED SOILS:

Penetration Resistance Blows/foot	Relative Density
0-4	Very Loose
4-10	Loose
10-30	Medium Dense
30-50	Dense
over 50	Very Dense

CONSISTENCY OF FINE-GRAINED SOILS:

Hand Penetrometer Readings, tsf	Consistency
<1	Soft
1-2	Firm
2-3	Stiff
3-4	Very Stiff
4.5+	Hard

TERMS CHARACTERIZING SOIL STRUCTURE:

Slickensided : Having inclined planes of weakness that are slick and glossy in appearance.
Fissured : Containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical
Laminated : Composed of thin layers of varying color and texture.
Interbedded : Composed of alternate layers of different soil types.
Calcareous : Containing appreciable quantities of calcium carbonate.
Well graded : Having wide range in grain sizes and substantial amounts of all intermediate particle sizes.
Poorly graded : Predominantly of one grain size, or having a range of sizes with some intermediate size missing.

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths because of planes of weakness or cracks in the soil. The consistency rating of such soils are based on penetrometer readings.

DEGREE OF WEATHERING:

Unweathered : Rock in its natural state before being exposed to atmospheric agents.
Slightly weathered : Noted predominantly by color change with no disintegrated zones.
Weathered : Complete color change with zones of slightly decomposed rock.
Severely weathered : Complete color change with consistency, texture, and general appearance approaching soil.

SUBSURFACE CONDITIONS:

Soil and rock descriptions on the boring logs are a compilation of field data as well as from laboratory testing of samples. The stratification lines represent the approximate boundary between materials and the transition can be gradual.

Water level observations have been made in the borings at the times indicated. It must be noted that fluctuations in the groundwater level may occur due to variations in rainfall, hydraulic conductivity of soil strata, construction activity, and other factors.

LOG OF BORING NO. B-01

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 25+00 +/-
Surface El.: 550.0'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION	Hand Penetrometer, TSF	Penetration Blows / Foot	Core Drilled, ft.	Core Recovered, %	Core RQD	Liquid Limit	Plasticity Index	% Passing No. 200 Sieve	Moisture Content, %	Unit Dry Weight, lb / cu ft	Unc. Compressive Strength, tsf	Strain at Failure, %
0	U-1		SANDY CLAY, dark yellow-brown, soft, with root filaments	0.6											
			El. 549.0; 1.0'												
	U-2		CLAY, light brown and dark brown, with yellow-brown, hard, with iron oxide stains with root filaments, with occasional sand - with limonitic stains below 4.5 feet	1.5											
	U-3			4.5+											
	U-4			4.5+											
5	U-5			4.5+											
	U-6			4.5+								15	112	7.8	1.7
10	U-7			4.5+					52	35	89	17			
			El. 538.0; 12.0'												
15	U-8		SANDY CLAY, silty, light brown, light yellow-brown and light brown-gray, medium dense, mottled with limonite	4.5+					40	21	63	13			
20	U-9		- laminated cross-bedded, less mottled below 20 feet	4.5+								17	110		
			El. 526.0; 24.0'												
25	U-10		CLAY with sand, yellow-brown and light gray-brown, stiff to very stiff, with calcareous webbing and infills, with iron oxide infills	4.1					35	14	86	18	96		
30	U-11			2.9								18	113	4.3	7.8
35	U-12			4.2								19	109		
			El. 513.0; 37.0'												
40	U-13		SANDY CLAY, light gray-brown, gray and yellow-brown, firm to hard, mottled with limonite, with iron oxide infills, with root filament holes, faint blocky structure	1.9					31	9	67	21	107	0.9	3.9
45	U-14		- with silty fine sand partings, infilled burrows - with coarse subrounded gravel	4.5+											
			El. 503.0; 47.0'												
50	U-15		MARL, yellow-brown and gray, hard, jointed, stained with limonite, weathered	4.5+					60	37	98	23	104	4.4	4.1

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Completion Depth: 85 ft.
Date Boring Started: 4/7/05
Date Boring Completed: 4/7/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring lost 350 gallons of drilling water at 26 feet during drilling. Groundwater at 25 feet 16 hours after completion. Boring not bailed at completion of drilling. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-01 (cont'd)

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 25+00 +/-
Surface El.: 550.0'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION	Hand Penetrometer, TSF	Penetration Blows / Foot	Core Drilled, ft.	Core Recovered, %	Core RQD	Liquid Limit	Plasticity Index	% Passing No. 200 Sieve	Moisture Content, %	Unit Dry Weight, lb / cu ft	Unc. Compressive Strength, tsf	Strain at Failure, %
			El. 497.0; 53.0'												
		▨	MARL, gray to dark gray, hard, unweathered												
	T-16	▨			86/ 11¼"										
55	C-17	▨				5.0	32	16				18	113		
60	C-18	▨				1.0	90	90							
	C-19	▨				4.0	100	93							
		▨										16	114	19.6	3.4
65	C-20	▨				5.0	42	42							
70	C-21	▨				5.0	98	76							
		▨	- with moderate to high angle slickenside												
75	C-22	▨				5.0	100	34							
80	C-23	▨				5.0	0	-							
85			El. 465.0; 85.0'												

Completion Depth:	85 ft.
Date Boring Started:	4/7/05
Date Boring Completed:	4/7/05
Engineer / Geologist:	D. James
Project No.:	53882

Remarks: Boring lost 350 gallons of drilling water at 26 feet during drilling. Groundwater at 25 feet 16 hours after completion. Boring not bailed at completion of drilling. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries.
In situ, the transition may be gradual.

LOG OF BORING NO. B-02

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 53+00 +/-
Surface El.: 502.6'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION	Hand Penetrometer, TSF	Penetration Blows / Foot	Core Drilled, ft.	Core Recovered, %	Core RQD	Liquid Limit	Plasticity Index	% Passing No. 200 Sieve	Moisture Content, %	Unit Dry Weight, lb / cu ft	Unc. Compressive Strength, tsf	Strain at Failure, %
0	U-1	▨	CLAY, dark brown, brown, yellow-brown and gray, soft to very stiff	0.5											
	U-2			0.5											
	U-3			1.25											
	U-4			3.0											
5	U-5		- with occasional calcareous accretions	2.6											
	U-6		- with root filaments, with occasional silty sand pockets, with limonitic stains	2.75					61	43	96	22			
10	U-7		- with sand infilled burrows	3.8											
15	U-8			3.0											
			- occasionally jointed below 19 feet												
20	U-9		- with manganese dioxide stains	3.4											
			El. 480.6; 22.0'												
		▨	CLAY, yellow-brown, gray and light brown, firm, intercalated with fine to coarse subrounded sand partings and seams												
25	U-10			1.9					59	40	92	24			
			El. 475.6; 27.0'												
		▨	CLAY with sand, yellow-brown, gray and light brown, firm, intercalated with fine to coarse subrounded sand partings and seams												
30	U-11			1.0					57	35	75	25	102	0.9	3.4
			El. 470.6; 32.0'												
		▩	MARL, dark gray, hard, jointed, occassionally fissile, unweathered												
35	U-12			4.5+											
	C-13					5.0	66	98	57	36	95	12	127	22.3	2.4
40	C-14					5.0	88	88							
												17	115		
45	C-15					5.0	66	-							
50	C-16					5.0	66	66							

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Completion Depth: 60 ft.
Date Boring Started: 4/6/05
Date Boring Completed: 4/6/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring bailed to 21 feet. Groundwater measured after 20 hours at 8.1 feet. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries.
In situ, the transition may be gradual.

LOG OF BORING NO. B-02 (cont'd)

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 53+00 +/-
Surface El.: 502.6'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION	Hand Penetrometer, TSF	Penetration Blows / Foot	Core Drilled, ft.	Core Recovered, %	Core RQD	Liquid Limit	Plasticity Index	% Passing No. 200 Sieve	Moisture Content, %	Unit Dry Weight, lb / cu ft	Unc. Compressive Strength, tsf	Strain at Failure, %
		▨	MARL, dark gray, hard, jointed, occassionally fissile, unweathered									16	115		
55	C-17	▨				5.0	70	60							
		▨										16	117		
60			El. 442.6; 60.0'												

Completion Depth: 60 ft.
Date Boring Started: 4/6/05
Date Boring Completed: 4/6/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring bailed to 21 feet. Groundwater measured after 20 hours at 8.1 feet. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries.
In situ, the transition may be gradual.

LOG OF BORING NO. B-03

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 82+70 +/-
Surface El.: 506.3'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION	Hand Penetrometer, TSF	Penetration Blows / Foot	Core Drilled, ft.	Core Recovered, %	Core RQD	Liquid Limit	Plasticity Index	% Passing No. 200 Sieve	Moisture Content, %	Unit Dry Weight, lb / cu ft	Unc. Compressive Strength, tsf	Strain at Failure, %
0	U-1	▨	CLAY with sand, brown and dark brown, very stiff to hard, fill	4.5+											
	U-2	▨		4.5+											
	U-3	▨	El. 503.3; 3.0'	4.5+											
	U-4	▨	CLAY, light brown-gray with yellow-brown, firm to stiff, mottled with limonite, with weathered ironstone sand	2.6					54	37	92	20			
5	U-5	▨													
	U-6	▨		1.5											
10	U-7	▨	El. 494.3; 12.0'	2.0											
		░	CLAYEY SAND, light gray-brown and ▽ variegated, medium dense El. 491.8; 14.5'												
15	U-8	▩	MARL, yellow-brown and gray, hard, jointed, fissile, with root invaded joints, with gypsum infills, weathered	4.5+								25	100	1.6	6.9
20	U-9	▩	El. 483.3; 23.0'	4.5+								22	96	4.8	7.1
25	T-10	▩	MARL, dark gray, hard, jointed, occasionally fissile, unweathered		100/ 2½"										
	C-11	▩				5.0	98	98							
		▩										18	112	14.2	3.0
30	C-12	▩				5.0	68	66							
		▩										18	112	22.1	2.3
35	C-13	▩				5.0	96	94							
		▩										25	105		
40	C-14	▩				5.0	94	92							
		▩										18	118		
45	C-15	▩				5.0	96	94							
		▩										18	112		
50	C-16	▩				5.0	100	86							

continued on next page

Completion Depth: 60 ft.
Date Boring Started: 4/9/05
Date Boring Completed: 4/9/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring not bailed at completion of drilling. Groundwater seepage measured at 14 feet during. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-03 (cont'd)

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 82+70 +/-
Surface El.: 506.3'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION	Hand Penetrometer, TSF	Penetration Blows / Foot	Core Drilled, ft.	Core Recovered, %	Core RQD	Liquid Limit	Plasticity Index	% Passing No. 200 Sieve	Moisture Content, %	Unit Dry Weight, lb / cu ft	Unc. Compressive Strength, tsf	Strain at Failure, %
		▨	MARL, dark gray, hard, jointed, occasionally fissile, unweathered												
55	C-17	▨				5.0	86	78				19	111	9.5	2.8
		▨	- with high angle joint or slickensides - with phosphatic sand, well indurated, slightly weakly cemented El. 446.3; 60.0'												
60															

Completion Depth: 60 ft.
Date Boring Started: 4/9/05
Date Boring Completed: 4/9/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring not bailed at completion of drilling. Groundwater seepage measured at 14 feet during. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-04

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Northend
Surface El.: 564.2'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION	Hand Penetrometer, TSF	Penetration Blows / Foot	Core Drilled, ft.	Core Recovered, %	Core RQD	Liquid Limit	Plasticity Index	% Passing No. 200 Sieve	Moisture Content, %	Unit Dry Weight, lb / cu ft	Unc. Compressive Strength, tsf	Strain at Failure, %
0	U-1	▨	SANDY CLAY, brown and light brown, firm to very stiff, with silty fine sand, infilled joints El. 561.0; 3.2'	1.9											
	U-2			1.2											
	U-3			1.2											
	U-4	▨	CLAY, brown, yellow-brown and light brown-gray, hard, with iron oxide accretions, limonitic stains - with calcareous accretions (caliche) below 4.5 feet - transition to light brown-gray and yellow-brown, with sand clasts below 7 feet El. 552.2; 12.0'	4.5+											
5	U-5			4.5+											
	U-6			4.5+											
10	U-7			4.5+					64	44	91	19			
		▨	MARL, yellow-brown and light gray, hard, jointed, occasionally fissile, limonitic stained, weathered												
15	U-8			4.5+								27	97		
20	U-9			4.5+								21	107		
25	U-10		- with gypsum accretion and infilled joints	4.5+								22	104		
30	U-11			4.5+								22	102		
35	U-12			4.5+								22	109		
			- with dark gray unweathered seams below 37 feet El. 524.2; 40.0'												
40	U-13			4.5+								21	105		
		▨	MARL, dark gray, hard, jointed, indurated, occasionally fissile, unweathered												
45	U-14			4.5+								22	100		
	C-15					5.0	30	30				21	107		
50	C-16					5.0	50	-							

continued on next page

Completion Depth:	100 ft.
Date Boring Started:	4/8/05
Date Boring Completed:	4/8/05
Engineer / Geologist:	D. James
Project No.:	53882

Remarks: Boring bailed to 44 feet. Groundwater measured at 39 feet after 20 hours. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-04 (cont'd)

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Northend
Surface El.: 564.2'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION	Hand Penetrometer, TSF	Penetration Blows / Foot	Core Drilled, ft.	Core Recovered, %	Core RQD	Liquid Limit	Plasticity Index	% Passing No. 200 Sieve	Moisture Content, %	Unit Dry Weight, lb / cu ft	Unc. Compressive Strength, tsf	Strain at Failure, %
			MARL, dark gray, hard, jointed, indurated, occasionally fissile, unweathered												
55	C-17					5.0	54	34				22	105		
60	T-18				100/ 3"										
65	T-19				100/ 1"										
70	T-20				100/ 2¼"										
75	T-21				100/ 2"										
80	T-22				100/ 1½"										
85	T-23				100/ 1¾"										
90	T-24				100/ 1¾"										
95	T-25 C-26				100/ 1½"	5.0	0	-							
100			El. 464.2; 100.0'												

Completion Depth: 100 ft.
Date Boring Started: 4/8/05
Date Boring Completed: 4/8/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring bailed to 44 feet. Groundwater measured at 39 feet after 20 hours. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

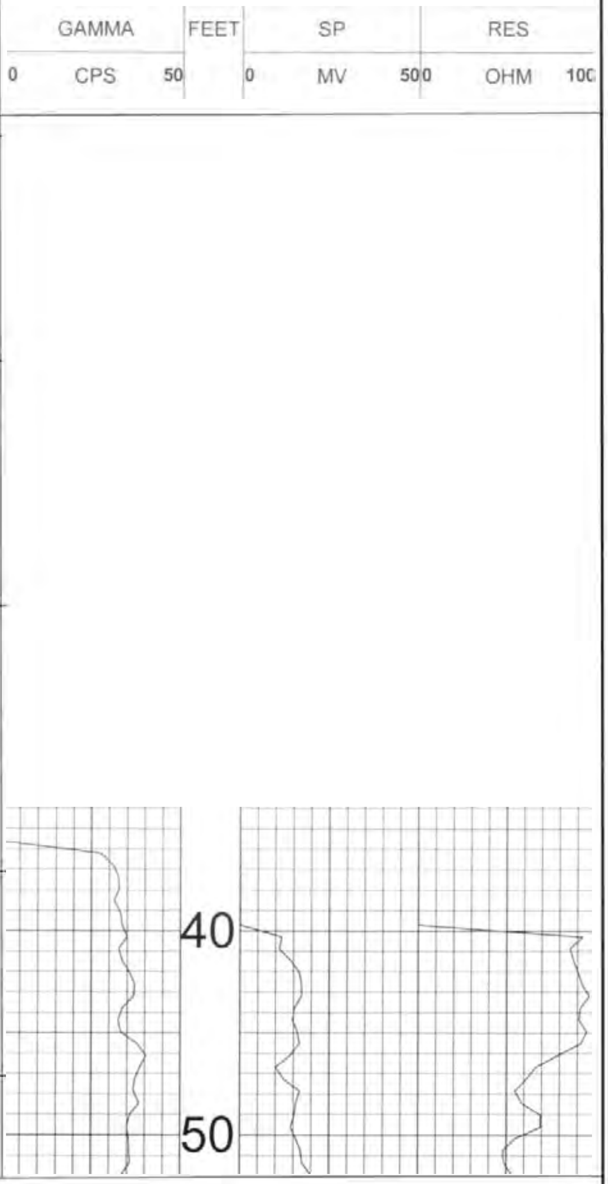
The stratification lines represent approximate strata boundaries.
In situ, the transition may be gradual.

LOG OF BORING NO. B-01

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 25+00 +/-
Surface El.: 550.0'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION
0	U-1	▨	SANDY CLAY, dark yellow-brown, soft, with root filaments El 549.0, 1.0'
5 10	U-2 U-3 U-4 U-5 U-6 U-7	▨	CLAY, light brown and dark brown, with yellow-brown, hard, with iron oxide stains with root filaments, with occasional sand - with limonitic stains below 4.5 feet El 538.0, 12.0'
15 20	U-8 U-9	▨	SANDY CLAY, silty, light brown, light yellow-brown and light brown-gray, medium dense, mottled with limonite - laminated cross-bedded, less mottled below 20 feet El 526.0, 24.0'
25 30 35	U-10 U-11 U-12	▨	CLAY with sand, yellow-brown and light gray-brown, stiff to very stiff, with calcareous webbing and infills, with iron oxide infills El 513.0, 37.0'
40 45	U-13 U-14	▨	SANDY CLAY, light gray-brown, gray and yellow-brown, firm to hard, mottled with limonite, with iron oxide infills, with root filament holes, faint blocky structure - with silty fine sand partings, infilled burrows - with coarse subrounded gravel El 503.0, 47.0'
50	U-15	▨	MARL, yellow-brown and gray, hard, jointed, stained with limonite, weathered

Electrical Resistivity Readings



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Completion Depth: 85 ft
Date Boring Started: 4/7/05
Date Boring Completed: 4/7/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring lost 350 gallons of drilling water at 26 feet during drilling. Groundwater at 25 feet 16 hours after completion. Boring not bailed at completion of drilling. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

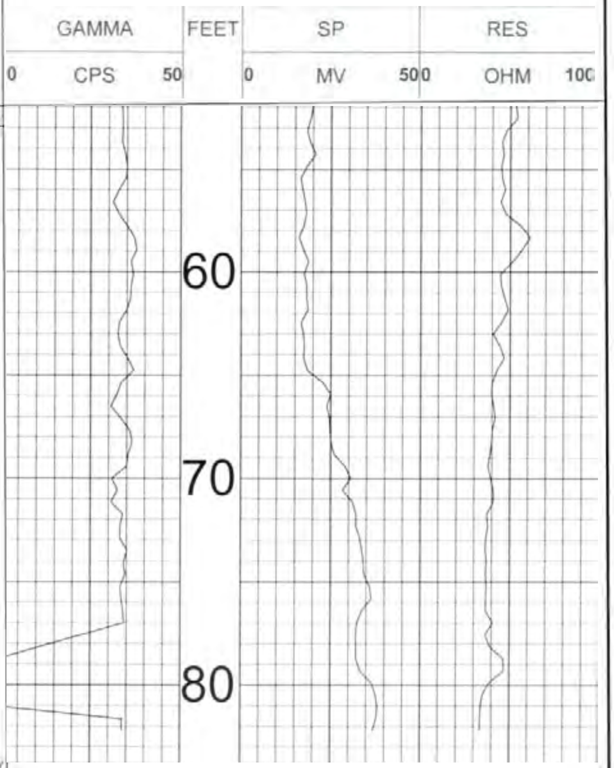
The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-01 (cont'd)

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 25+00 +/-
Surface El.: 550.0'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION
			El. 497.0, 53.0'
			MARL, gray to dark gray, hard, unweathered
55	T-16 C-17		
60	C-18 C-19		
65	C-20		
70	C-21		
			- with moderate to high angle slickenside
75	C-22		
80	C-23		
85			El. 465.0, 85.0'

Electrical Resistivity Readings



Completion Depth: 85 ft.
Date Boring Started: 4/7/05
Date Boring Completed: 4/7/05
Engineer / Geologist: D. James
Project No.: 53882

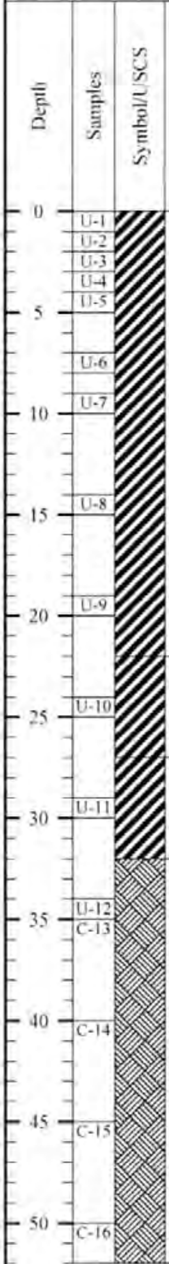
Remarks: Boring lost 350 gallons of drilling water at 26 feet during drilling. Groundwater at 25 feet 16 hours after completion. Boring not bailed at completion of drilling. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-02

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 53+00 +/-
Surface El.: 502.6'



MATERIAL DESCRIPTION

CLAY, dark brown, brown, yellow-brown and gray, soft to very stiff

- with occasional calcareous accretions

- with root filaments, with occasional silty sand pockets, with limonitic stains
- with sand infilled burrows

- occasionally jointed below 19 feet
- with manganese dioxide stains

El. 480.6; 22.0'

CLAY, yellow-brown, gray and light brown, firm, intercalated with fine to coarse subrounded sand partings and seams

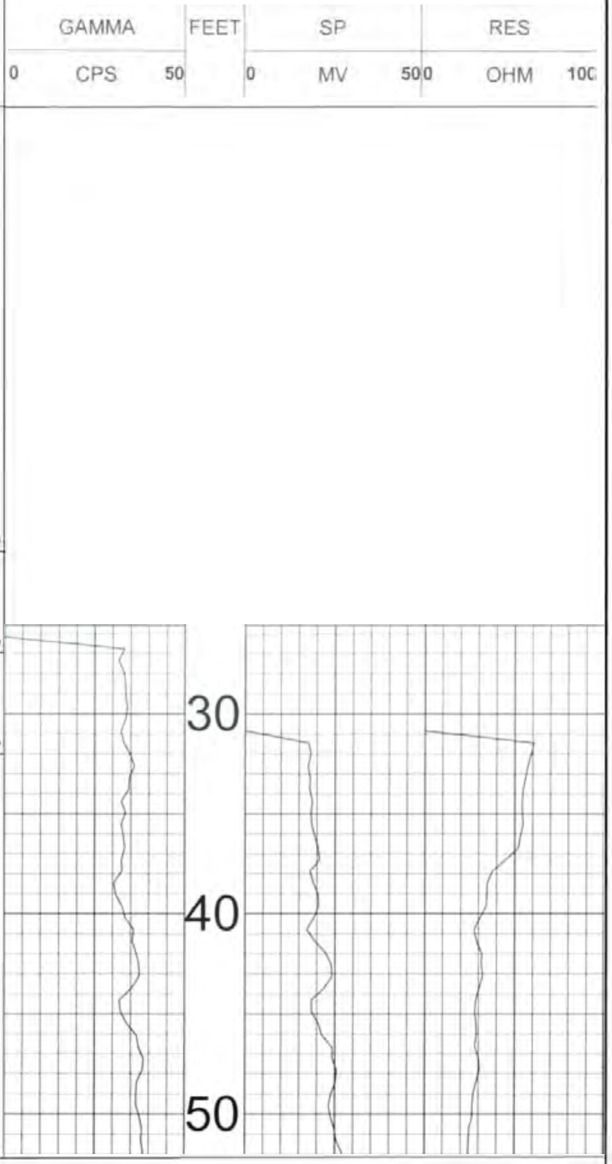
El. 475.6; 27.0'

CLAY with sand, yellow-brown, gray and light brown, firm, intercalated with fine to coarse subrounded sand partings and seams

El. 470.6; 32.0'

MARL, dark gray, hard, jointed, occassionally fissile, unweathered

Electrical Resistivity Readings



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Completion Depth: 60 ft.
Date Boring Started: 4/6/05
Date Boring Completed: 4/6/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring bailed to 21 feet. Groundwater measured after 20 hours at 8.1 feet. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

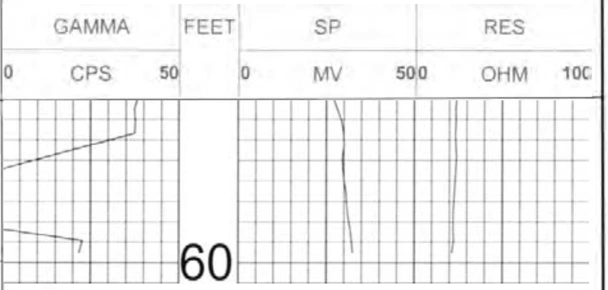
The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-02 (cont'd)

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 53+00 +/-
Surface El.: 502.6'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION
		▨	MARL, dark gray, hard, jointed, occassionally fissile, unweathered
55	C-17	▨	
60			El. 442.6, 60.0'

Electrical Resistivity Readings



Completion Depth: 60 ft.
Date Boring Started: 4/6/05
Date Boring Completed: 4/6/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring bailed to 21 feet. Groundwater measured after 20 hours at 8.1 feet. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

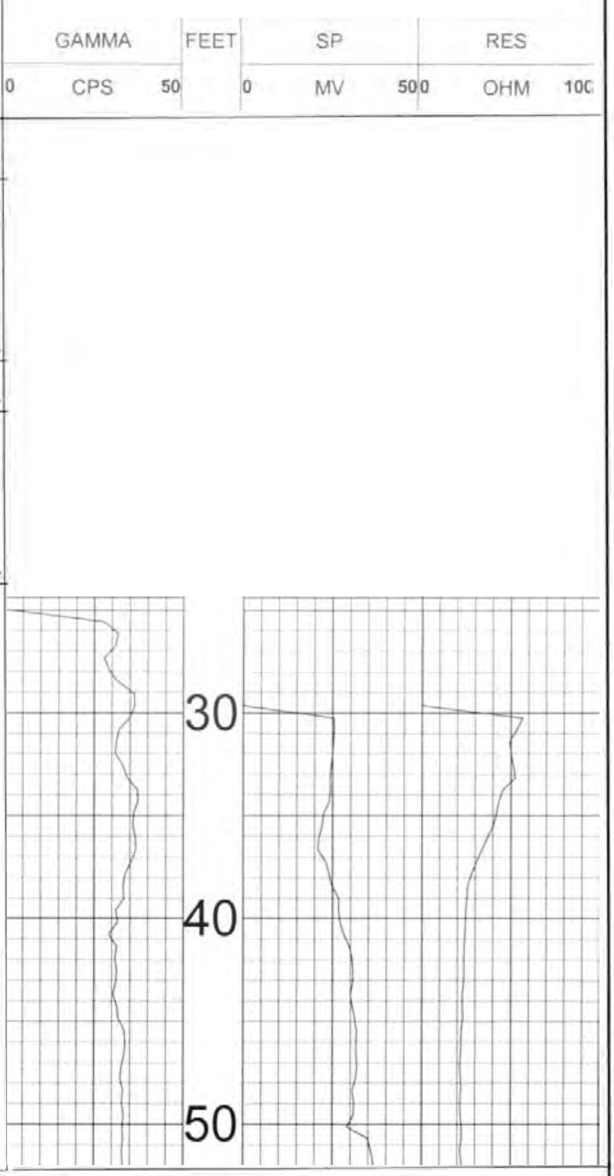
The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-03

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 82+70 +/-
Surface El.: 506.3'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION
0	U-1 U-2 U-3		CLAY with sand, brown and dark brown, very stiff to hard, fill El. 503.3, 3.0'
5 10	U-4 U-5 U-6 U-7		CLAY, light brown-gray with yellow-brown, firm to stiff, mottled with limonite, with weathered ironstone sand El. 494.3, 12.0'
		▽	CLAYEY SAND, light gray-brown and variegated, medium dense El. 491.8, 14.5'
15 20	U-8 U-9		MARL, yellow-brown and gray, hard, jointed, fissile, with root invaded joints, with gypsum infills, weathered El. 483.3, 23.0'
25 30 35 40 45 50	T-10 C-11 C-12 C-13 C-14 C-15 C-16		MARL, dark gray, hard, jointed, occasionally fissile, unweathered

Electrical Resistivity Readings



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Completion Depth: 60 ft.
Date Boring Started: 4/9/05
Date Boring Completed: 4/9/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring not bailed at completion of drilling. Groundwater seepage measured at 14 feet during. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

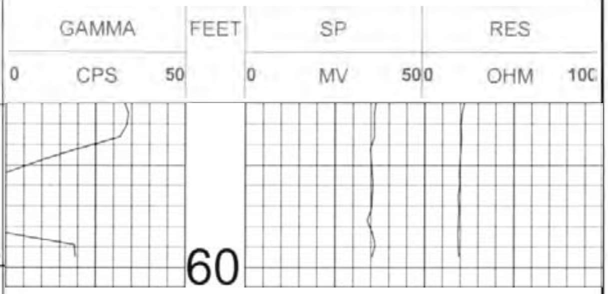
The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-03 (cont'd)

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Station 82+70 +/-
Surface El.: 506.3'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION
		▨	MARL, dark gray, hard, jointed, occasionally fissile, unweathered
55	C-17	▨	
		▨	- with high angle joint or slickensides - with phosphatic sand, well indurated, slightly weakly cemented
60			El 446.3, 60.0'

Electrical Resistivity Readings



Completion Depth: 60 ft.
Date Boring Started: 4/9/05
Date Boring Completed: 4/9/05
Engineer / Geologist: D. James
Project No.: 53882

Remarks: Boring not bailed at completion of drilling. Groundwater seepage measured at 14 feet during. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

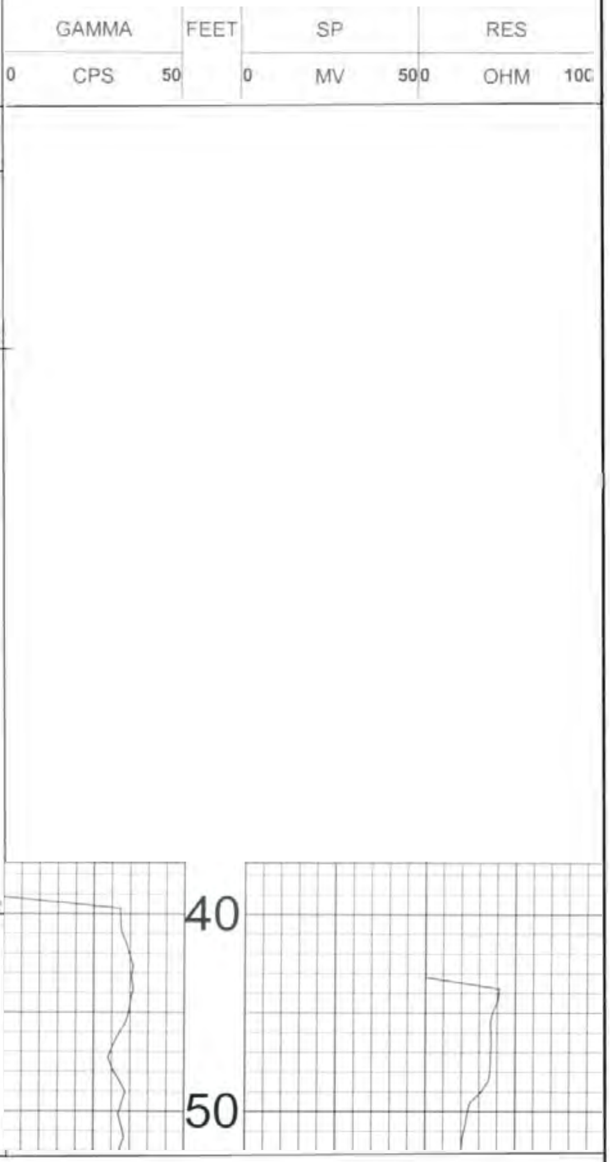
The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-04

Project Description: **Ralph Hall Dam Preliminary - Ladonia, Texas**
Location: Northend
Surface El.: 564.2'

Depth	Samples	Symbol/USCS	MATERIAL DESCRIPTION
0	U-1 U-2 U-3		SANDY CLAY, brown and light brown, firm to very stiff, with silty fine sand, infilled joints El. 561.0, 3.2'
5 10	U-4 U-5 U-6 U-7		CLAY, brown, yellow-brown and light brown-gray, hard, with iron oxide accretions, limonitic stains - with calcareous accretions (caliche) below 4.5 feet - transition to light brown-gray and yellow-brown, with sand clasts below 7 feet El. 552.2, 12.0'
15 20 25 30 35	U-8 U-9 U-10 U-11 U-12 U-13		MARL, yellow-brown and light gray, hard, jointed, occasionally fissile, limonitic stained, weathered - with gypsum accretion and infilled joints - with dark gray unweathered seams below 37 feet El. 524.2, 40.0'
40 45 50	U-14 C-15 C-16		MARL, dark gray, hard, jointed, indurated, occasionally fissile, unweathered

Electrical Resistivity Readings



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Completion Depth: 100 ft.
Date Boring Started: 4/8/05
Date Boring Completed: 4/8/05
Engineer / Geologist: D. James
Project No.: 53882

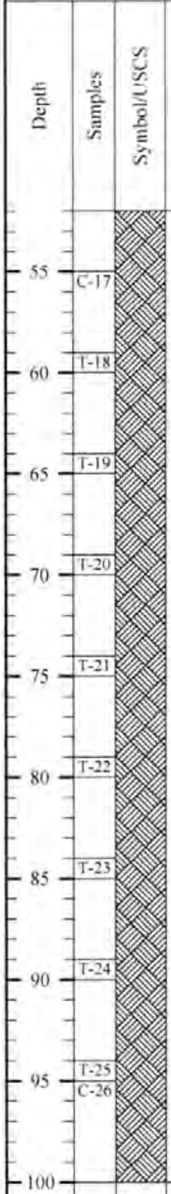
Remarks: Boring bailed to 44 feet. Groundwater measured at 39 feet after 20 hours. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

LOG OF BORING NO. B-04 (cont'd)

Project Description:	**Ralph Hall Dam Preliminary - Ladonia, Texas**
Location:	Northend
Surface El.:	564.2'

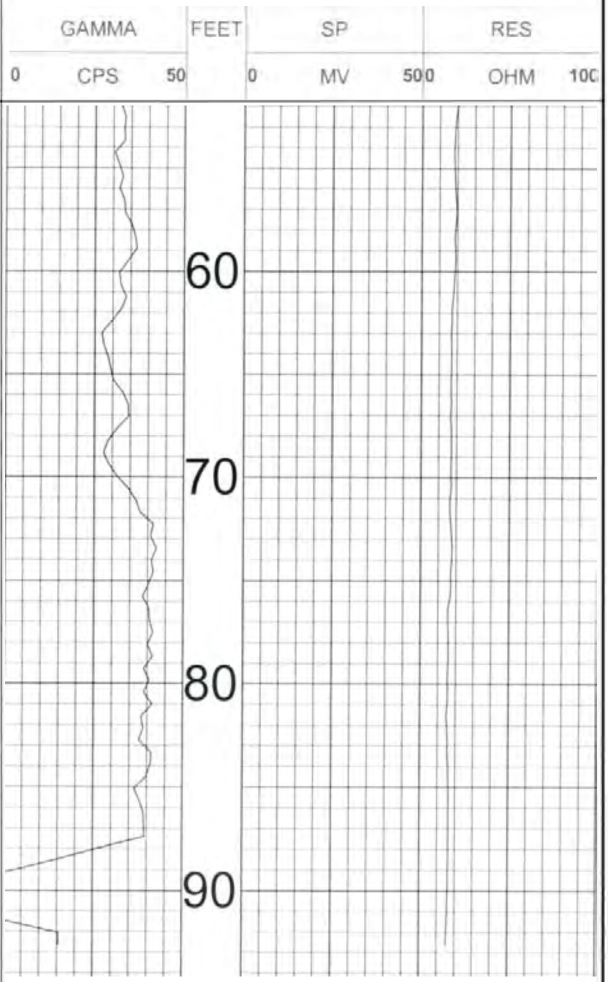


MATERIAL DESCRIPTION

MARL, dark gray, hard, jointed, indurated, occasionally fissile, unweathered

El. 464.2; 100.0'

Electrical Resistivity Readings



Completion Depth:	100 ft
Date Boring Started:	4/8/05
Date Boring Completed:	4/8/05
Engineer / Geologist:	D. James
Project No.:	53882

Remarks: Boring bailed to 44 feet. Groundwater measured at 39 feet after 20 hours. Boring backfilled upon completion. Bentonite plug placed 1 to 2 feet below ground surface.

KLEINFELDER

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

Sheet 1 of 1

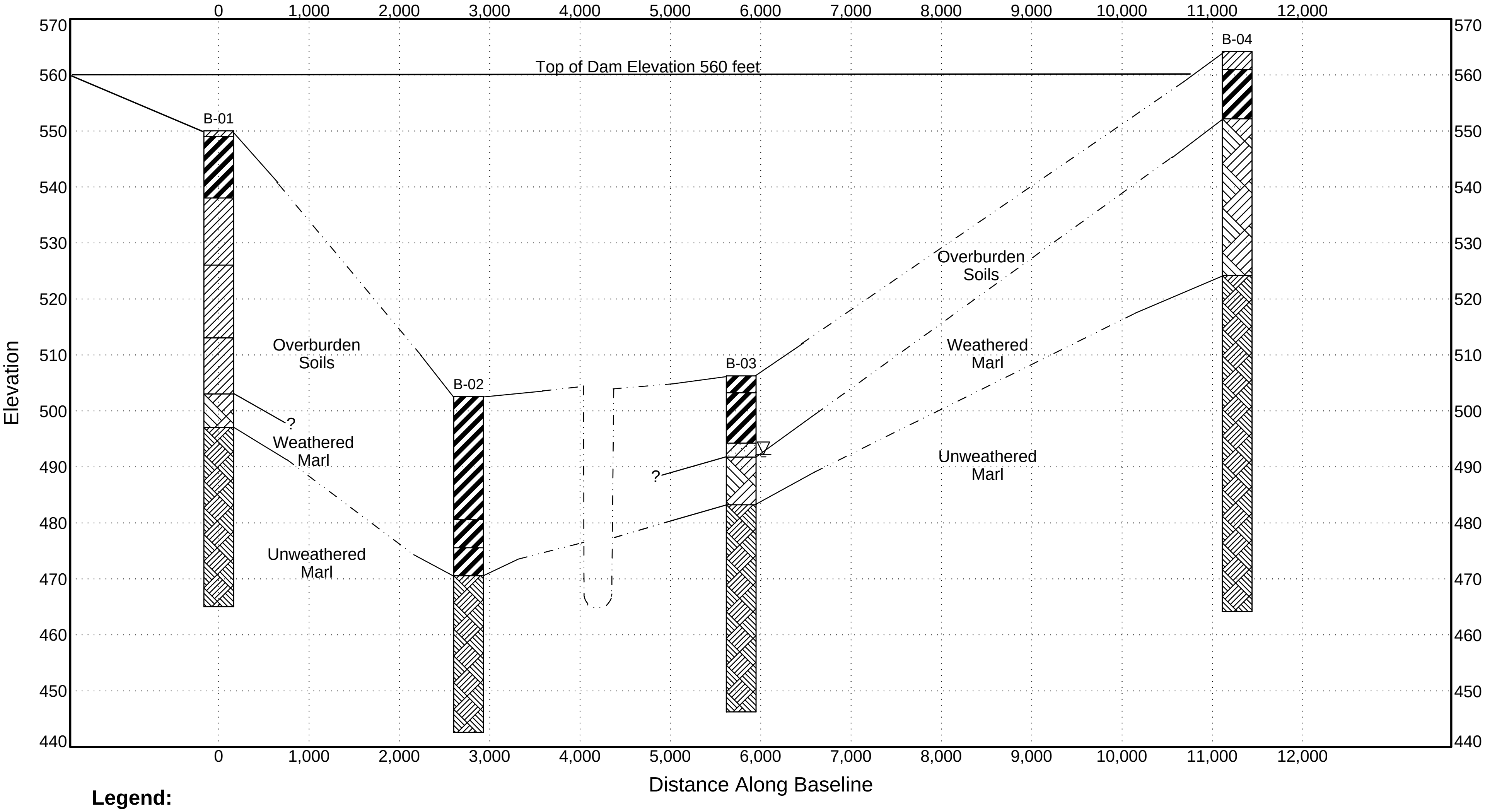
Boring No.	Sample Depth (ft.)	Liquid Limit	Plastic Limit	Plasticity Index	Percent Passing No. 200 Sieve	Moisture Content (%)	Unit Dry Weight (pcf)	Unconfined Compressive Strength (tsf)	Strain at Failure (%)
B-01	7.0 - 8.0					15	112	7.8	1.7
B-01	9.0 - 10.0	52	17	35	89	17			
B-01	14.0 - 15.0	40	19	21	63	13			
B-01	19.0 - 20.0					17	110		
B-01	24.0 - 25.0	35	21	14	86	18	96		
B-01	29.0 - 30.0					18	113	4.3	7.8
B-01	34.0 - 35.0					19	109		
B-01	39.0 - 40.0	31	22	9	67	21	107	0.9	3.9
B-01	49.0 - 50.0	60	23	37	98	23	104	4.4	4.1
B-01	55.0 - 60.0					18	113		
B-01	62.1 - 62.5					16	114	19.6	3.4
B-02	7.0 - 8.0	61	18	43	96	22			
B-02	24.0 - 25.0	59	19	40	92	24			
B-02	29.0 - 30.0	57	22	35	75	25	102	0.9	3.4
B-02	36.0 - 36.5	57	21	36	95	12	127	22.3	2.4
B-02	43.0 - 43.5					17	115		
B-02	52.0 - 52.5					16	115		
B-02	57.0 - 57.5					16	117		
B-03	3.0 - 4.0	54	17	37	92	20			
B-03	14.0 - 15.0					25	100	1.6	6.9
B-03	19.0 - 20.0					22	96	4.8	7.1
B-03	27.0 - 27.5					18	112	14.2	3.0
B-03	33.0 - 33.5					18	112	22.1	2.3
B-03	38.0 - 38.5					25	105		
B-03	43.0 - 43.5					18	118		
B-03	48.0 - 48.5					18	112		
B-03	56.0 - 56.5					19	111	9.5	2.8
B-04	9.0 - 10.0	64	20	44	91	19			
B-04	14.0 - 15.0					27	97		
B-04	19.0 - 20.0					21	107		
B-04	24.0 - 25.0					22	104		
B-04	29.0 - 30.0					22	102		
B-04	34.0 - 35.0					22	109		
B-04	39.0 - 40.0					21	105		
B-04	44.0 - 45.0					22	100		
B-04	45.0 - 50.0					21	107		
B-04	55.0 - 60.0					22	105		

KLEINFELDER

Summary of Laboratory Results

Project: Ralph Hall Dam Preliminary - Ladonia, Texas

Project Number: 53882



Legend:

▨ Overburden Soils

▰ Overburden Soils

▧ Weathered Marl

▩ Unweathered Marl

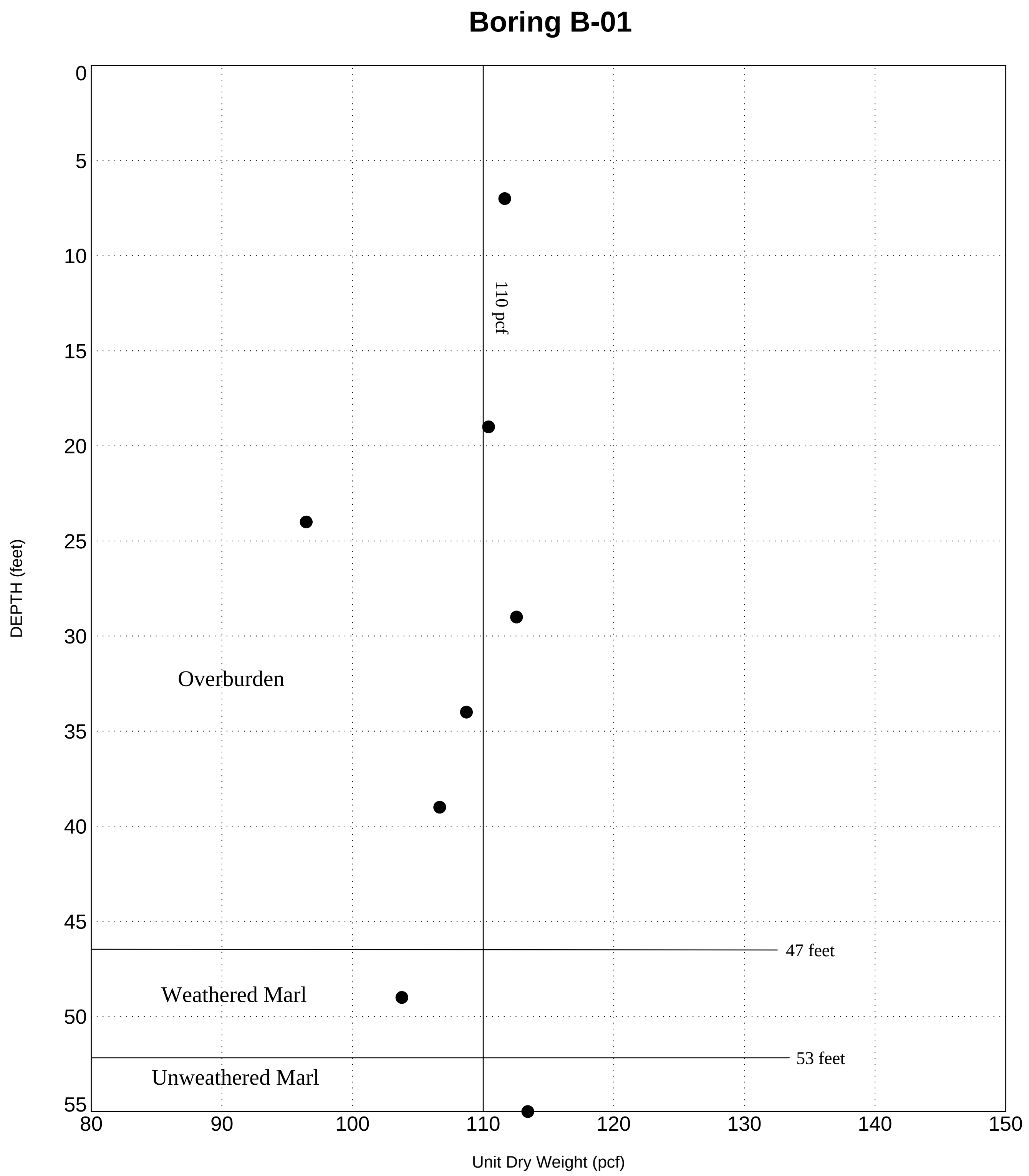
Note 1: The strata lines are based upon interpolation between borings, and may not represent actual subsurface conditions.

Note 2: See Logs of borings and report text for detailed material descriptions.

GENERALIZED SUBSURFACE PROFILE

Ralph Hall Dam Preliminary - Ladonia, Texas

PROJECT #	DATE	PLATE
53882	Jun 05	13



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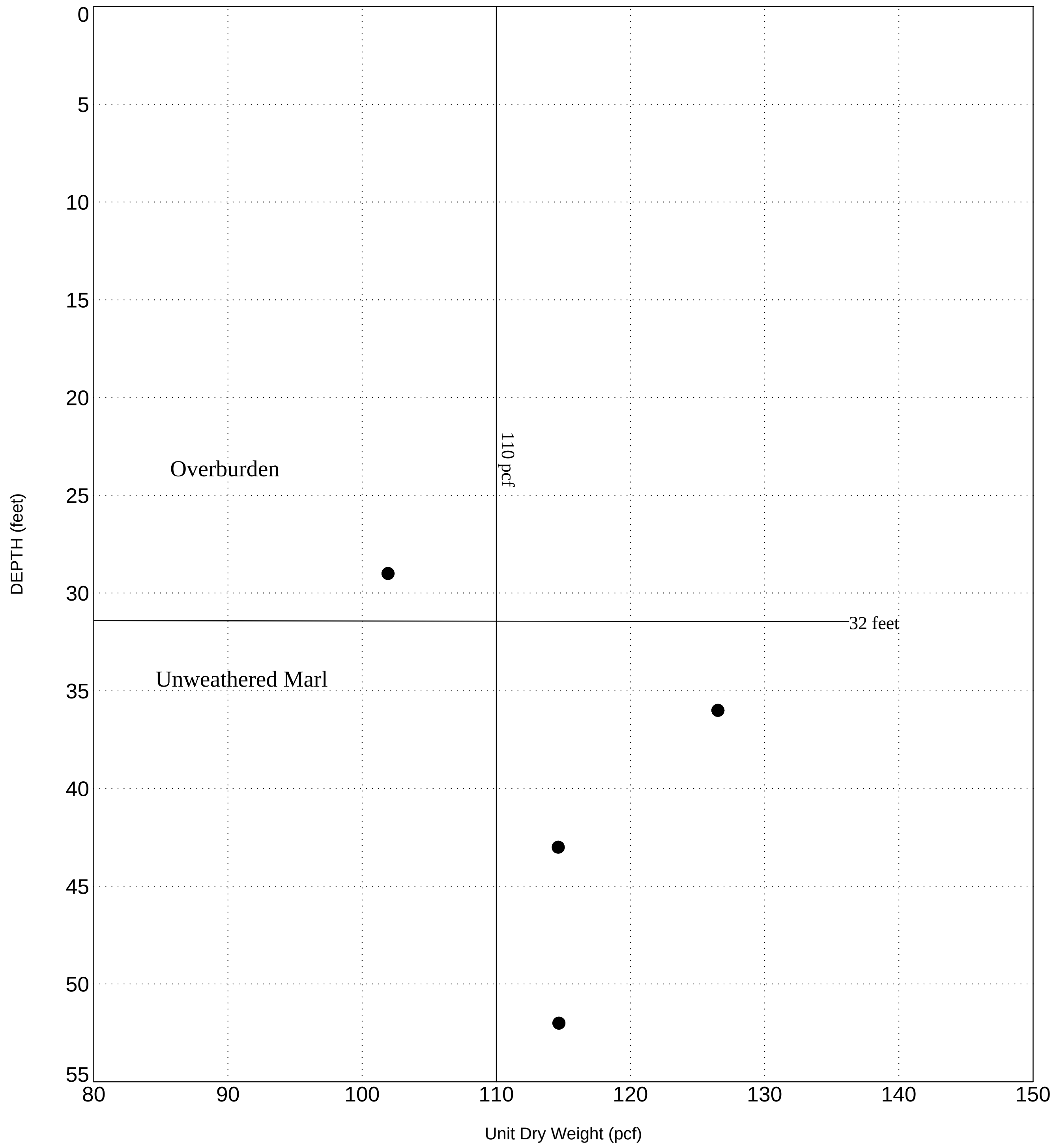
UNIT DRY WEIGHT VERSUS DEPTH

Project: Ralph Hall Dam Preliminary - Ladonia, Texas

Number: 53882

Boring B-02

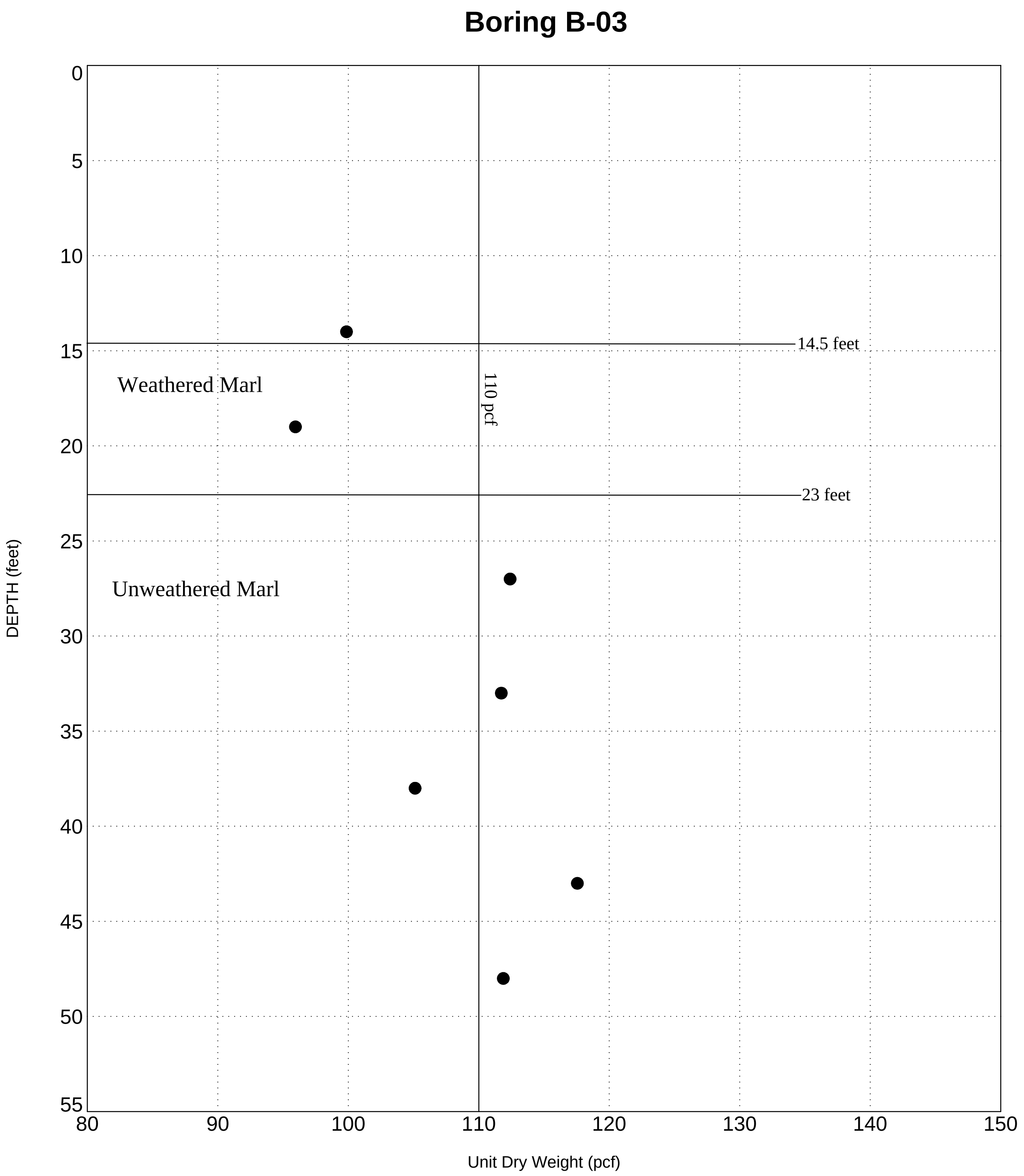


UNIT DRY WEIGHT VERSUS DEPTH

KLEINFELDER

Project: Ralph Hall Dam Preliminary - Ladonia, Texas

Number: 53882



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UNIT DRY WEIGHT VERSUS DEPTH

Project: Ralph Hall Dam Preliminary - Ladonia, Texas

Number: 53882