DELIVERABLES: PHASE 2 —
GEOLOGICAL, GEOTECHNICAL AND YIELD EVALUATIONS FOR CEDAR RIDGE RESERVOIR

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DELIVERABLES

PHASE 2

GEOLOGICAL, GEOTECHNICAL AND YIELD EVALUATIONS

FOR

CEDAR RIDGE RESERVOIR

Prepared for:

TEXAS WATER DEVELOPMENT BOARD

Prepared by:

CITY OF ABILENE

eHT
Enprotec / Hibbs & Todd

HDR

June, 2010

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GEOLOGIC REPORT

FUGRO CONSULTANTS, INC.

REGIONAL GEOLOGIC STUDY
CEDAR RIDGE RESERVOIR ALTERNATIVE DAM SITES
HASKELL, SHACKELFORD AND THROCKMORTON COUNTIES

ENPROTEC/HIBBS & TODD, INC.

ABILENE, TEXAS

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Report No. 04.30091001
September 4, 2009

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Regional Geologic Study
Cedar Ridge Reservoir Alternative Dam Sites
Haskell, Shackelford and Throckmorton Counties, Texas

Submitted herewith is the Regional Geologic Study, presenting the results of the Cedar Ridge Alternative Dam Sites. In brief, the report includes the results of the literature search, oil and gas log review, helicopter flyover, field mapping and drilling investigation.

Fugro Consultants, Inc. appreciates the opportunity to be of continued service on this project and look forward to future phases of the project.

Sincerely,
FUGRO CONSULTANTS, INC
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REGIONAL GEOLOGIC STUDY
CEDAR RIDGE RESERVOIR ALTERNATIVE DAM SITES
HASKELL, SHACKELFORD AND THROCKMORTON COUNTIES, TEXAS

Report to:

ENPROTEC/HIBBS & TODD, INC.

Abilene, Texas

Submitted By:

FUGRO CONSULTANTS,INC.

September 2009

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INTRODUCTION

Project Overview

The Cedar Ridge Reservoir project is intended to significantly increase the water supply capacity for the City of Abilene, Texas. In February, 2009, Fugro Consultants, Inc. (Fugro) submitted a Phase I Geotechnical Investigation Report[1] for a proposed dam site located on the Clear Fork of the Brazos River about 5 miles upstream of the confluence with Paint Creek. That location, hereinafter referred to as the original dam site, is situated on the Lambshead Ranch about 40 miles northeast of Abilene. That investigation revealed the presence of significant layers of gypsum in the core borings drilled at the dam site and in an erosional outcrop in the river channel about ¼ mile upstream of the dam location. Gypsum, a highly soluble mineral, can adversely affect the long-term performance of dams and reservoirs. Gypsum was not identified in geologic literature and maps as being present in any of the geologic formations observed at the site. This unanticipated condition prompted an evaluation of the regional geology to determine if a more suitable dam site could be identified.

A Geotechnical Advisory Group (GAG) was formed to provide recommendations for proceeding with the project. The group consists of representatives of the owner and design team, as well as Dr. Kenneth Johnson, P.G., an independent geologist with particular expertise related to gypsum as it pertains to dam and reservoir projects. The group recommended that a regional geologic study be conducted to aid in the evaluation of alternative dam sites that may avoid or substantially reduce the adverse effects of gypsum in the dam foundation strata and reservoir impoundment. Although the original dam site is in Throckmorton County, the regional study and potential alternative dam sites encompass portions of Haskell, Shackelford and Throckmorton Counties. For brevity, the project location is listed as Throckmorton County on illustrations and boring logs contained in this report

Authorization

Mr. Scott Hibbs, P.E., president of Enprotec/Hibbs & Todd, Inc. (EHT), authorized the geologic study on January 9, 2009 with execution of Amendment No. 1 to a previous Subconsultant Agreement between EHT and Fugro for the investigation of the original dam site. Amendment No. 1 was based on Fugro Proposal No. 04.30091001. On April 14, 2009, Mr. Hibbs authorized additional borings in the streambed with execution of Amendment No. 2 to the previously referenced Subconsultant Agreement.

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[1] Phase 1 Geotechnical Investigation, Cedar Ridge Reservoir, Throckmorton County, Texas for Enprotec/Hibbs & Todd, Inc. by Fugro Consultants, Inc., Report No. 04.10013715, February 16, 2009.

Purpose and Scope

The purpose of this study was to aid in identifying alternative dam site(s) along the Clear Fork of the Brazos River by assessing the regional geology within a geographic area large enough to include the planned capacity for the proposed Cedar Ridge Reservoir. The geologic study included emphasis on the occurrence and structure of gypsum in the Jagger Bend/Valera Formations. The scope of this study includes the following six subtasks:

- Subtask 1.1 – Geologic Literature Review
- Subtask 1.2 – Geologic Structure Contour Map and Report
- Subtask 1.3 – Helicopter Flyover Reconnaissance
- Subtask 1.4 – Geologic Field Mapping and Report
- Subtask 1.5 – Geotechnical Core Borings for Geology Mapping
- Subtask 1.6 – Regional Geologic Study Report

Subtask 1.2 was conducted by Dr. Kenneth Johnson, P.G. Subtask 1.4 was primarily conducted by Mr. Jackson Harper, P.G., an independent consulting geologist. Their reports are contained in Appendix A and B, respectively.

There are numerous oil and gas producing and abandoned wells in the study area. Some of the wells are located within the area of the proposed Cedar Ridge Reservoir.

Location

The geologic study was conducted in an area approximately 20 miles in length along the Clear Fork of the Brazos River (Clear Fork) and neighboring uplands, starting from the town of Lueders on the south end and proceeding northeast to the confluence of the Clear Fork with Paint Creek. The location of the study area is presented on the Site Vicinity Map, Figure 1. During the course of the study, three potential dam site locations were identified and are designated Site A, B and C on Figures 2 through 8.

GEOLOGIC LITERATURE REVIEW

Identified Documents

A geologic literature review was conducted and based upon an online internet search and review of known sources of geologic information, such as the Bureau of Economic Geology. The identified documents are presented in the Data Sources section of the report.

Pertinent Findings

The geologic literature search resulted in the identification of a few pertinent publications in the study area. A summary of key findings is presented, as follow:

Geologic Atlas of Texas, Abilene Sheet, 1:250,000, 1972: There is no mention of the presence of gypsum in the Jagger Bend/Valera Formations, Bead Mountain Formation or Grape Creek Formation.

Geologic Atlas of Texas, Wichita Falls-Lawton Sheet, 1:250,000, 1987: The Waggoner Ranch Formation occurs stratigraphically between the Jagger Bend/Valera Formations and Bead Mountain Formation. The occurrence of selenite gypsum is described in the Waggoner Ranch Formation. The southern mapped occurrence of the Waggoner Ranch Formation occurs about 45 miles north of the original dam site. There is no mention of the presence of gypsum in the Jagger Bend/Valera Formations, Bead Mountain Formation or Grape Creek Formation.

Soil Survey of Shackelford County, Texas, 1990: The Leeray clay soils are described as containing up to 5 percent gypsum crystals. The presence of gypsum appears to be secondary and not a weathering product of a gypsum layer in the parent formation (Clear Fork Group). The Leeray soils occur west of the Clear Fork River in an area approximately six miles south of alternate dam site C.

Joseph Hornberger Ph.D. Thesis, 1932: Mr. Hornberger's thesis was on the Geology of Throckmorton County. The thesis includes a geologic map of the county. The southern part of his study area includes the original dam site, located a few miles north of the alternative dam sites. Mr. Hornberger did not identify the occurrence of gypsum as far south as the original dam site. He identified and mapped a belt of en echelon faults trending east-west in an area to the north of the original dam site. Mr. Hornberger stated that the vertical throw of the larger faults is 50 to 200 feet.

Stratigraphy of the Wichita Group in Part of the Brazos River Valley, North Texas, 1966: This paper discussed the en echelon fault trend referenced in the Hornberger thesis and stated that some of these faults were not field verified or identified on aerial photographs. Minor structures are present that cause local variation of strike and dip. The paper opined that many of the structures are a result of differential compaction over lenticular channel-fill sandstone structures present in the underlying formations of the Pennsylvanian. This paper did not discuss identifiable faults in the area to the south of the original dam site.

Area Geology

Based upon review of the geologic literature and the findings of the geotechnical investigation of the original dam site, the stratigraphy and structural geology present in the study area was evaluated. There are six geologic formations that outcrop along the length of the study area. The formations include from youngest to oldest, Quaternary-aged alluvium and terrace deposits, Permian-aged Lueders Formation, Talpa Formation, Grape Creek Formation, Bead Mountain Formation and Jagger Bend and Valera Formations (undivided). The location of the formations is presented on the Regional Geologic Map, Figure 2. The following is a general description of the formations. A more detailed discussion is presented in the Site Geology section of this report.

Quaternary-aged alluvial and terrace deposits were formed by the ancestral Clear Fork River within the Cedar Ridge Valley. The alluvial and terrace deposits consist of discontinuous beds of sand, gravel, silt and clay. Coarse-grained terrace deposits may include high permeability soils (e.g., > 10^{-3} cm/sec) that promote fluid migration.

The Lueders Formation is the uppermost rock unit that outcrops in the study area. The Lueders Formation consists of an alternating limestone and shale sequence with the upper part consisting of shale and 1 to 5 foot thick limestone beds and the lower part consisting of the Lueders quarry limestone. The Lueders Formation is 50 to 70 feet thick.

The Talpa Formation consists of fissile shale and limestone with shale beds up to 20 feet thick. Limestone beds range up to 10 feet in thickness and are more abundant in the lower part of the formation. The Talpa Formation is 90 to 120 feet thick.

The Grape Creek Formation consists of alternating beds of shale, limestone and siltstone. The upper part of the formation consists of mostly non-calcareous shale. Shale occurs mostly in the lower part of the formation with individual beds ranging up to 65 feet thick. The shale is tan, gray to maroon. The thickness of the Grape Creek Formation ranges between 100 to 150 feet.

The Bead Mountain Formation consists of alternating limestone and shale. The lower part of the formation is mostly limestone with interbedded shale. The thickness of the Bead Mountain Formation ranges between 150 to 180 feet.

The Jagger Bend and Valera Formations (undivided) is the gypsum bearing formation and consists of alternating shale, limestone and gypsum layers. The formation strikes approximately north-south and dips to the west. The Clear Fork flows in a general southwest to northeast direction. At the south end of the study area, the formation outcrops approximately 16-miles east of the Clear Fork. At the north end of the study area, the Clear Fork crosses the formation. Due to the north-south alignment of the outcrop and the southwest-northeast alignment of the Clear Fork, the gypsum-bearing sequence is deeper in the upstream direction to the southwest. Generally, calcareous shale occurs in the upper part and limestone occurs in the lower part. There was no mention of gypsum in the geologic literature, however, gypsum was identified in one outcrop and in the borings drilled during the geotechnical investigation at the original dam site. Gypsum is described on the published geologic map as occurring in the Waggoner Ranch Formation in an area about 45 miles north of the study area. The Waggoner Ranch Formation occurs stratigraphically between the Bead Mountain and Jagger Bend/Valera Formations but consists of varying lithologies due to changes in the depositional environment. The Jagger Bend/Valera Formations range between 150 to 210 feet.

The structural geology of the study area is a westward-dipping monocline controlled by the northeast-trending Woodson Arch. The axis of the Woodson Arch is approximately 22 miles in length and is superimposed on the much longer and regionally occurring Bend Arch. Strata located to the west of the arch dip to the west and strata located to the east of the arch dip to the east. The only known mapped faulting in the study area occurs near the original dam site. These faults were mapped by Hornberger in his 1932 thesis and comprise an east-west trending belt of en echelon faults that strike northwest-southeast with the downthrown side to the southwest. The faults occur along both flanks of the Woodson Arch.

The outcrop of the Permian formations strike nearly north-south with a regional dip to the west (35 feet per mile), as depicted on the Regional Geologic Map, Figure 2. The geologic map shows the intersection of the gypsum-bearing Jagger Bend/Valera Formations outcrop with the Clear Fork channel at the far north end of the study area. The gypsum-bearing outcrop trends due south from the north end while the river alignment and study area trend northeast-southwest. This relationship between the two alignments indicates that the gypsum-bearing zone gets deeper upstream along the Clear Fork channel and shallow to outcropping in the downstream direction in the area of the original dam site.

REGIONAL STRUCTURE MAP FROM OIL AND GAS WELL STUDY

Dr. Kenneth Johnson conducted a study of oil and gas well logs in the study area. The findings are presented in a report titled “Structure contour-mapping of gypsum beds in the Jagger Bend/Valera Formation along Clear Fork of Brazos River; Throckmorton, Haskell, and Shackelford Counties, Texas”, and is presented in Appendix A of this report. He selected about 100 well logs out of several thousand well locations for use in determining the occurrence, lateral continuity and structure of the gypsum layers. Individual gypsum layers greater than 2 feet in thickness were readily identifiable on the well logs. He concluded that several gypsum beds were laterally continuous throughout the study area. Structure contour maps were constructed on the top and base of the gypsum-bearing sequence. The gypsum beds dip uniformly to the west at approximately 35 feet per mile. There were local irregularities in strike and dip identified.

He discussed the adverse effects of gypsum in an area of a dam site. Solution activity from fluid migration may result in karst development and present a concern for the long term stability of a dam and water retention capabilities of a reservoir.

The structure contour map representing the top of the upper gypsum layer was overlain with the topographic map. There is an area along the stream channel located downstream of the proposed Dam Site A where he predicts the upper gypsum layer will intersect the stream channel. To the north of this point, gypsum is expected to outcrop along the valley wall and to the south, the gypsum-bearing sequence is expected to occur entirely in the subsurface and get deeper.

The results of Dr. Johnson's study were used to identify areas of potential alternate dam sites (A, B, C) and to delineate a more focused area within the broader study area to concentrate the geologic field mapping and drilling investigation subtasks of this report. This area is located near the common boundaries of Throckmorton, Shackelford and Haskell counties.

HELICOPTER FLYOVER RECONNAISSANCE

Brazos Helicopters in Waco, Texas provided a helicopter and pilot on March 18, 2009 for a flyover of the study area. In attendance were Cory Shockley, P.E.(HDR) and Mark Wilkerson, P.G. (Fugro). The overflight started at Lueders and proceeded to the north along the course of the river up to the original dam site. The flight path is presented on Figure 3a. Features such as sharp bends in the river channel, alluvial-bedrock contact and joint patterns in limestone beds were readily observable. The flight was documented photographically by video and still photos. Selected photographs are presented in Figure 3.

The outcrop of gypsum and soft slope of the encasing shale was observed in the area immediately upstream of the original dam site. The outcrop was not visible after a short distance south of the outcrop in part due to colluvial cover. On the flight back to the area of the alternative dam sites, the proposed drill sites were observed with regards to site access. The two narrow topographic ridges (shown on Figure 4 at B-1 and B-2) were observed from upstream and downstream perspectives.

GEOLOGIC FIELD MAPPING

Geologic field mapping was supervised by J. Jackson Harper, P.G. with the assistance of Kevin Mandeville, P.G. (Fugro). The field mapping occurred between March 14 through 24, 2009. The report presenting the findings of the geologic reconnaissance is presented in Appendix B. The geologic reconnaissance was concentrated along the river channel and adjacent uplands from the original dam site to the potential alternate sites. The purpose of the field mapping was to locate outcrops of gypsum and to assess geologic conditions such as lithology, strike, dip, fractures, and faulting. The findings are listed, as follows:

1. Gypsum was identified in an outcrop at one location upstream of the original dam site
2. Since alluvium and/or colluvial detritus covered the bedrock surface in other areas, it was not possible to determine the presence or absence of gypsum;
3. Lower and upper coarse-grained terrace deposits were identified; the alluvial materials are plentiful and expected to be good sources of construction materials for an earthen type dam;
4. Bedrock strata were highly fractured in outcrop that is most likely attributable to surficial weathering; the depth of fractures is unknown;
5. No major faults were observed, however, straight stream segments and sharp turns of the river channel are likely controlled by joints or small displacement faults;
6. Strike and dip measurements of the limestone beds were taken at 11 siteswith strike measurements ranging from 100 degrees to 248 degrees. Due to the low angle of dip, Mr. Harper attributed this variability in formational strike measurements to minor, localized undulations in the bedding.
7. No groundwater springs or seeps were observed.

GEOLOGIC RECONNAISSANCE DRILLING

Boring Locations and Surface Elevation

Core borings were located in the area of alternative dam sites as presented on the Plan of Borings, Figure 4. Subsurface conditions were explored by nine widely-spaced core borings advanced to depths ranging from 70 to 365 feet below existing grade, as presented on Table 1. Five of the borings (B-1, B-2, B-3, B-5, B-6) were drilled at truck accessible locations to a depth that penetrated the gypsum-bearing strata. The location for a proposed B-4 was deleted at the outset of the drilling program. Four of the borings (SB-1, SB-2, SB-3, SB-4) were drilled in the streambed channel to a depth penetrating the alluvium and into the gypsum-bearing strata. The borings were located with sufficient spacing to determine strike and dip, evaluate the gypsum sequence, explore narrow topographic ridges and assess the area proximal to the proposed alternative dam sites.

The borings were located in the field by representatives of Fugro using available aerial and topographic maps. Sheppard Surveying Company, Inc., Abilene, Texas, provided surveyed boring locations and elevation data. The Logs of Borings and Keys to Terms and Symbols used on the logs are contained in Appendix C of this report. The boring locations are referenced to the 1929 National Geodetic Vertical Datum in feet above mean sea level. The vertical accuracy of the survey was 0.01 feet. A summary of the boring location coordinates is presented on Table 1.

Table 1: Location, Elevation and Total Depth of Borings

Boring No.	Ground Elevation	Northing	Easting	Total Depth Ft, bgs*	Bottom Elevation, Ft, msl*
B-1	1532.68	7035922.157	1679491.387	365.0	1167.7
B-2	1529.20	7038859.200	1679052.600	350.0	1179.2
B-3	1497.24	7041633.472	1669072.635	350.0	1147.2
B-4	Deleted	-----	-----	-----	-----
B-5	1496.28	7031772.508	1666895.571	355.0	1141.3
B-6	1519.20	7032182.326	1676845.944	350.0	1169.2
SB-1	1370.83	7033133.565	1674237.720	85.0	1285.8
SB-2	1385.89	7036374.369	1676991.996	80.0	1305.9
SB-3	1366.72	7041210.565	1671015.683	85.0	1281.7
SB-4	1350.50	7036560.398	1680714.542	70.0	1280.5
*bgs: below ground surface *msl: mean sea level					

Drilling Procedures

The borings were drilled with two truck-mounted drill rigs equipped with: 1) continuous flight and/or hollow stem augers for advancing the holes dry and recovering disturbed samples of soil (ASTM D 1452), 2) seamless steel push-tubes for obtaining samples of cohesive soil strata (similar to ASTM D 1587, but thicker wall), 3) split-barrel samplers and drive-weight assembly for obtaining representative samples and measuring penetration resistance (N-values) of non-cohesive soil strata (ASTM D 1586), and 4) double-tube wireline core barrels equipped with diamond and/or carbide bits for obtaining 2-inch (NQ) and 2.5-inch (HQ) diameter rock and rock-like cores (ASTM D 2113). It should be noted that two different hammer weights were used for the Standard Penetration Tests. A 170-pound drop hammer was used in performing the Standard Penetration Tests in borings B-1, B-2, SB-1and SB-3. This hammer weight is in accordance with TxDOT specifications for Texas Cone Penetration tests, but not in accordance with the ASTM specified 140-pound hammer for the Standard Penetration Tests (which was used for all the other borings). The hammer weight is noted at the bottom of each boring log. Caution and judgment should be exercised when evaluating and utilizing the standard penetration test data.

During rock coring, water was used as drilling circulation fluid (wet rotary). Additives such as bentonite to create slurry were not used in any of the borings. Water losses into the formation were estimated at the occurrence depth, i.e., *20% drilling fluid loss from 73.0 to 76.0 feet.* In some instances, the water loss was either reduced or ceased as the boring was advanced. In that case, an estimate was made of the percent return of the original loss rate, i.e., *100% drilling fluid return at 80 feet.* These observations are noted in brackets on the boring logs contained in Appendix C.

Log of Borings

Detailed descriptions of subsurface materials encountered are presented on the Log of Borings. The descriptions include lithology, soil type, fractures, pocket penetrometer values in tons per square foot, standard penetration test N-values in blows per foot, core recovery and Rock Quality Designation (RQD, ASTM D 6032) values in percent. The borings were logged in the field by Kevin Mandeville, P.G. and Andrew Johnson, P.E. (Fugro) and again in the laboratory for quality control and consistency. The Log of Borings and Key to Terms and Symbols are presented in Appendix C.

SITE GEOLOGY

Physiography and Topography

The proposed Cedar Ridge Reservoir is located on the Limestone Belt physiographic province in north central Texas. The Limestone Belt was formed on late Paleozoic-aged carbonates and shales with a resultant valley and upland ridge topography due to erosion.

The topography in the study area is more pronounced to the north due to erosion than to the south near Lueders. The topography in the area of the alternative dam sites consists of valley and upland hills and ridges with elevations ranging from about EL 1320 along the river channel to about EL 1600 on the top of the upland hills, as presented on Figure 4.

Stratigraphy

Four of the stratigraphic units discussed in the Area Geology section earlier were encountered during the drilling investigation. The formations include, from youngest to oldest, Alluvium, Grape Creek Formation, Bead Mountain Formation, and Jagger Bend/Valera Formations. Detailed descriptions and depths of the formations are presented on the Log of Borings, Appendix C.

A stratigraphic cross section was constructed using the deep boring logs, as presented on Figure 5. The cross section is vertically oriented on the contact of the Bead Mountain Formation and Jagger Bend/Valera Formations, thereby removing structural dip and facilitating correlation of formation contacts and individual beds. A description of the formations and key beds is described below.

Quaternary Alluvium: discontinuous beds of clay, silt, sand and gravel; fat clay, gray to reddish-brown (CH); lean clay, reddish-brown (CL); silty sand (SM), reddish-brown; poorly graded sand, tan, (SP); well graded gravel with clay and sand (GW-GC); thickness of alluvium encountered in the boreholes ranged from 5.6 feet at SB-2 to 39.5 feet at boring SB-3. The shallower streambed borings are not shown on Figure 5, but are included on the boring profiles on Plates 6 and 7.

Grape Creek Formation: alternating beds of limestone and shale; limestone, tan, fossiliferous, vuggy; shale, red, brown and bluish-gray; the Grape Creek Formation was partially penetrated by the borings and the thickness ranged from 67.9 feet to 103.1 feet. Anomolous gypsum seams (1/4 inch thick) were observed in B-1 at a depth of about 40 feet below grade.

Bead Mountain Formation: alternating beds of limestone with some shale interbeds; limestone, gray, hard, slightly fractured, fossiliferous and shale, bluish-gray with interbedded dolomitic limestone; the Bead Mountain was fully penetrated during the drilling investigation and the thickness ranged from 100.3 feet to 113.0 feet.

Jagger Bend/Valera Formations: alternating beds of limestone, shale and gypsum; limestone, gray, dolomitic in places, shale, red, brown and bluish-gray and gypsum, white to light gray to pink, no evidence of dissolution. For correlation purposes, the laterally continuous gypsum, shale and limestone beds were identified and include one limestone bed, eight gypsum layers and two shale beds. The laterally continuous beds include the basal limestone unit, Layer A through Layer H gypsum beds, Red-Brown Shale unit separating Gypsum Layer C and Layer D and Upper Shale unit at the top of the formation. The Jagger Bend/Valera Formations were partially penetrated during the drilling investigation.

The thickness of the continuous beds in the Jagger Bend/Valera Formations is presented in Table 2 on the following page and also on Figure 5.

Table 2: Thickness of Continuous Marker Beds in the Jagger Bend/Valera Formations

	B-1	B-2	B-3	B-5	B-6
Upper Shale	20.1	20.0	18.0	17.1	17.0
Gypsum Layer H	3.7	4.3	2.8	2.0	2.1
Gypsum Layer G	2.9	3.8	3.7	3.8	3.0
Gypsum Layer F	2.5	2.8	3.7	2.9	3.1
Gypsum Layer E	3.3	2.6	2.0	1.9	3.5
Gypsum Layer D	4.1	3.5	4.7	3.6	4.2
Red Brown Shale	21.4	20.0	18.9	18.0	21.5
Gypsum Layer C	0.5	1.0	0.9	0.4	0.3
Gypsum Layer B	5.3	5.2	6.2	4.5	5.3
Gypsum Layer A	10.9	9.6	10.6	9.8	12
Basal Limestone Bed	18.1	18.4	15.9	9+	14.2
Net Thickness of Gypsum	33.2	32.8	34.6	28.9	33.5
Thickness of Gypsum Bearing Zone*	130.2	121.9	114.3	113.2	128.0

*As measured from base of upper shale to top of basal limestone bed

The gypsum-bearing sequence is capped by the Upper Shale unit that occurs near the top of the Jagger Bend/Valera Formations. The Upper Shale ranges between 17.0 to 20.1 feet thick and consists of a dark bluish-gray non calcareous shale, with gypsum and limestone seams. It is expected that the vertical permeability of the Upper Shale unit is low and thus would restrict vertical fluid movement in the absence of vertical or near-vertical fractures extending through the unit. Beneath the Upper Shale is the gypsum-bearing sequence comprised of eight laterally continuous gypsum layers and a few discontinuous gypsum layers and seams. The gypsum layers are named from oldest to youngest, Layer A through Layer H. The thickest continuous gypsum layer is Layer A that ranges in thickness between 9.6 feet to 12.0 feet. The thinnest continuous gypsum layer is Layer C that ranges in thickness between 0.3 feet to 1.0 feet. Gypsum Layer C is readily identifiable by its' pink coloration. The net thickness of gypsum in the formation ranges between 28.9 feet to 34.6 feet. The Red-Brown Shale unit is situated near the middle of the gypsum-bearing sequence between Layer C and Layer D. The Red-Brown Shale ranges in thickness between 18.0 feet to 21.5 feet. There are a few thin, discontinuous gypsum seams present in the lower part of the unit. The Red-Brown Shale was readily identifiable in Dr. Johnson's study and was laterally continuous throughout the study area. It is expected that the vertical permeability of the Red-Brown Shale is low and thus would restrict vertical fluid movement in the absence of vertical or near-vertical fractures extending through the unit. A Basal Limestone bed underlies the gypsum-bearing sequence and occurs near the base of the Jagger Bend/Valera Formations. The Basal Limestone bed consists of a hard, slightly fractured limestone with shale seams and layers and gypsum seams. The Basal Limestone bed ranged in thickness from 14.2 feet to 18.4 feet.

Boring and Geologic Profiles

A Generalized Boring Profile with all nine borings is presented on Figure 6 to illustrate the overall geologic sequence in the area of the alternative dams sites. Six Geologic Profiles were constructed using selected boring logs and topographic surface elevation interpolated from USGS maps. For purposes of this report, the term buffer refers to the thickness of shale and limestone above the uppermost Gypsum Layer H. This layer is interpolated between borings and projected on the geologic profiles as the upper dashed line. It should also be noted that the river channel bottom shown on the geologic profiles is estimated from USGS topographic maps and the actual elevations could vary considerably. A description of each profile is presented, as follows:

Geologic Profile A-A' (Figure 7a)

A-A' is a dip profile that trends east-west across the narrow topographic ridge located about midway between proposed dam sites A and B and includes borings SB-2, B-1 and SB-4. The profile shows a west dip of the formations. The buffer at SB-2 is 59 feet, and the projected buffer at the river channel bottom between SB-2 and B-1 is about 20 feet. The distance across the thin ridge at B-1 between the upstream and downstream river channel is approximately 2,000 feet. The projection across the thin topographic ridge shows that the top of Gypsum Layer H should outcrop about 20 feet above the river channel on the east side of the ridge. Based on the projected gypsum layers and observation of the core recovered from SB-4, it is our opinion that Layer H is completely eroded in the river channel, Layers E, F and G are dissolved with remnants of gypsum nodules, and Layer D is partially dissolved.

Geologic Profile B-B' (Figure 7a)

B-B' is a dip profile that trends east-west on the Shackelford County line in the vicinity of Dam Site B and includes borings B-5, SB-1 and B-6. The profile illustrates the westward dip of the formations. The buffer at SB-1 is 60 feet, and the projected buffer at the river channel bottom between SB-1 and B-6 is about 50 feet. SB-1 is located approximately 2,000 feet downstream of the proposed Dam Site B.

Geologic Profile C-C' (Figure 7b)

C-C' is a strike profile that trends north-south across the narrow topographic ridge located upstream of proposed Dam Site A and includes borings B-6, SB-2 and B-2. The buffer at SB-2 is 59 feet, and the projected buffer at the bottom of the two river channels between B-6 and B-2 is about 25 feet at both locations. The distance across the narrow topographic ridge at B-2 between the upstream and downstream river channel is approximately 1,200 feet. There is 21 feet of the Upper Shale unit separating the upstream channel from the top of Gypsum Layer H.

Geologic Profile D-D' (Figure 7c)

D-D' is a strike profile that trends north-south along the west side of the proposed reservoir just upstream of Dam Site A and includes borings B-5 and B-3. The projected buffer at the bottom of the two river channels between B-5 and B-3 is about 50 to 60 feet.

Geologic Profile E-E' (Figure 7d)

E-E' is a dip profile that trends northeast-southwest between proposed dam sites A and B and includes borings B-5, SB-1, B-6, SB-2, B-1 and SB-4. The buffer at SB-1 and SB-2 is 60 feet and 59 feet, respectively. The projected buffer at the bottom of the two river channels between B-5 and B-1 is about 55 feet at both locations. The projection across the thin ridge at B-1 shows that the top of Gypsum Layer H should outcrop 20 feet above the river channel. As discussed in the previous description of A-A', Gypsum Layers E,F,G and H have apparently been eroded or dissolved in the river channel near SB-4 downstream of Dam Site A.

Geologic Profile F-F' (Figure 7e)

F-F' is a dip profile that trends northwest-southeast downstream of proposed Dam Site A and includes borings B-3, SB-3, B-2, SB-2, B-1 and SB-4. The buffer at SB-3 and SB-2 is 18 feet and 59 feet, respectively. The projected buffer along F-F' at the bottom of the river channel is 20 feet between B-2 and B-1. On the downstream side of the topographic ridge at B-1, Gypsum Layer H is projected to outcrop along the river channel. As discussed in the previous description of A-A', Gypsum Layers E, F,G and H have apparently been eroded or dissolved in the river channel near SB-4 downstream of Dam Site A.

Geologic Profile G-G' (Figure 7f)

G-G' is a profile that trends northwest-southeast between Dam Sites A and B and includes borings B-3, SB-3, SB-1and B-6. The buffer at SB-3 and SB-1 is 18 feet and 60 feet, respectively. The projected buffer at the bottom of the three river channel crossings between B-3 and B-6 ranges from approximately 40 to 60 feet.

Structural Geology

A structure contour map was constructed for the top of the upper gypsum Layer (H) using elevations determined from the five deep boring logs, as presented on Figure 8. The structure of the upper gypsum layer is a gently dipping monocline with a strike of N 12° W and SW dip of 35 feet per mile. This is consistent with the regional strike and dip determined by Dr. Johnson in the study of oil and gas well logs.

CONCLUSIONS

1. Based upon the findings of this geologic investigation, it is now known that the multiple gypsum layers encountered in the borings at the original dam site are not isolated in occurrence but are an integral part of the Jagger Bend/Valera formation stratigraphy that extends regionally to the study area, in spite of the absence of discussion of gypsum in the geologic literature.
2. Gypsum was encountered in the borings and eight laterally continuous gypsum layers were identified. Individual gypsum layers ranged between 0.4 feet to 12 feet in thickness. Numerous gypsum seams less than 3 inches in thickness were encountered in all the borings. Dissolution of gypsum is suspected in SB-4 downstream of Dam Site A based on the absence of the upper Gypsum Layers E, F, G and H. There were no visual indications of dissolution in the gypsum seams or layers in any of the other borings.
3. The distance between the top of the uppermost Gypsum Layer H and the top of the borings drilled through the alluvium in the streambed at SB-1, SB-2, and SB-3 is 71, 65 and 56 feet, respectively. The buffer thickness based on estimated streamed elevations along selected geologic profiles ranges from 20 to 60 feet.

4. The Upper Shale unit overlies the gypsum-bearing sequence and is expected to have low vertical permeability that would restrict vertical fluid movement in the absence of vertical or near-vertical fractures through the unit.
5. There was only one gypsum outcrop observed during the geologic field mapping part of this study. This is the same outcrop observed for the previous investigation of the original dam site. Gypsum outcrops, which we believe are present in the study area, are likely obscured by alluvium and colluvial detritus. As projected on the geologic profiles A-A', C-C', E-E' and F-F', it is expected that gypsum outcrops along the river channel downstream of Dam Site A between B-2 and SB-4.
6. The alignment of the Clear Fork of the Brazos River trends southwest to northeast and the strike of the gypsum beds trends N 12° W and dip to the west at 35 feet per mile., The gypsum becomes deeper in the upstream direction to the southwest.
7. The structural geology appears to be favorable for the siting of a reservoir. A gently dipping monocline dips approximately 35 feet per mile to the west/southwest. There were no faults observed.
8. There are two narrow topographic ridges identified in the reservoir that would be created by proposed Dam Site A. The distance across topographic ridge B-2 is 1,200 feet and neck B-1 is 2,000 feet. These two narrow topographic ridges could adversely affect the water retention capability of a reservoir created at Dam Site A given the possibility of highly permeable vertical and horizontal discontinuities in the bedrock strata.
9. From a geological and geotechnical perspective, the alternative dam sites have two distinct advantages over the original site; namely, (1) the gypsum-bearing stratum is deeper and, (2) the gypsum-bearing stratum does not outcrop within the reservoir impoundment. Dam Site A has a potential disadvantage in that two relatively narrow topographic ridges are present in the impoundment which could result in excessive seepage from the reservoir to the river channel downstream of the dam. Proposed Dam Site B (and C by extrapolation) has the geologic advantage of a thicker buffer (greater than 50 feet) between the base of the river channel to the top of Gypsum Layer H.
10. There are numerous oil and gas producing and abandoned wells in the study area. These wells will have to be located and either moved or plugged and abandoned in accordance with the procedures of the Texas Railroad Commission. If not properly decommissioned, these wells could provide direct access of reservoir water into the underlying gypsum beds and oil/gas producing formation.

DATA SOURCES

- USGS, 7½ minute topographic maps
- Aerial Photography, Orthophotography
- Geologic Atlas of Texas, Abilene Sheet, Bureau of Economic Geology, 1972, The University of Texas at Austin, 1:250,000
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- Hornberger, Joseph Jr., M.S., 1932, The Geology of Throckmorton County, Texas, Ph.D. Thesis, The University of Texas at Austin
- Preston, R. D., 1969, Occurrence and quality of groundwater in Shackelford County, Texas, Report No. 100, Texas Water Development Board, Austin, Texas
- Preston, R. D., 1969, Occurrence and quality of groundwater in Throckmorton County, Texas, Report No. 113, Texas Water Development Board, Austin, Texas
- Fugro Consultants, Inc., September 2008, Geologic Reconnaissance Report, Cedar Ridge Reservoir (original dam location), Throckmorton County, Texas, Project No. 04.10013715

CONDITIONS

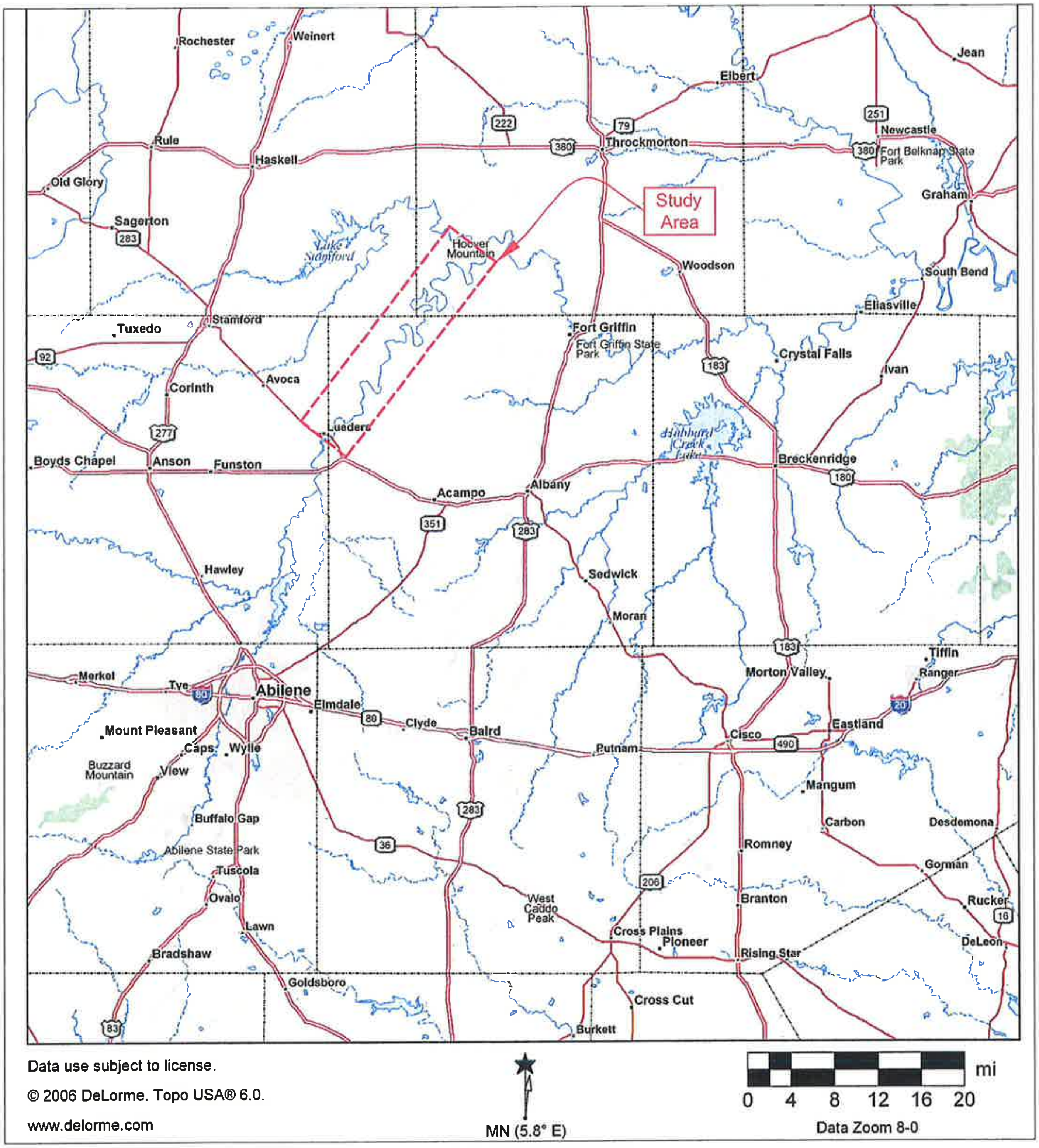
Since some variation was found in subsurface conditions at boring locations, all parties involved should take notice that even more variation may be encountered between boring locations. Statements in the report as to subsurface variation over given areas are intended only as estimations from the data obtained at specific boring locations.

The professional services that form the basis for this report have been performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical engineers practicing in the same locality. No warranty, expressed or implied, is made as the professional advice set forth. Fugro's scope of work does not include the investigation, detection, or design related to the presence of any biological pollutants. The term 'biological pollutants' includes, but is not limited to, mold, fungi, spores, bacteria, and viruses, and the byproducts of any such biological organisms.

The results and conclusions contained in this report are directed at, and intended to be utilized within, the scope of work contained in the agreement executed by Fugro Consultants, Inc. and client. This report is not intended to be used for any other purposes. Fugro Consultants, Inc. makes no claim or representation concerning any activity or condition falling outside the specified purposes to which this report is directed, said purposes being specifically limited to the scope of work as defined in said agreement. Inquiries as to said scope of work or concerning any activity or condition not specifically contained therein should be directed to Fugro Consultants, Inc. for a determination and, if necessary, further investigation.

PLATES

ILLUSTRATIONS

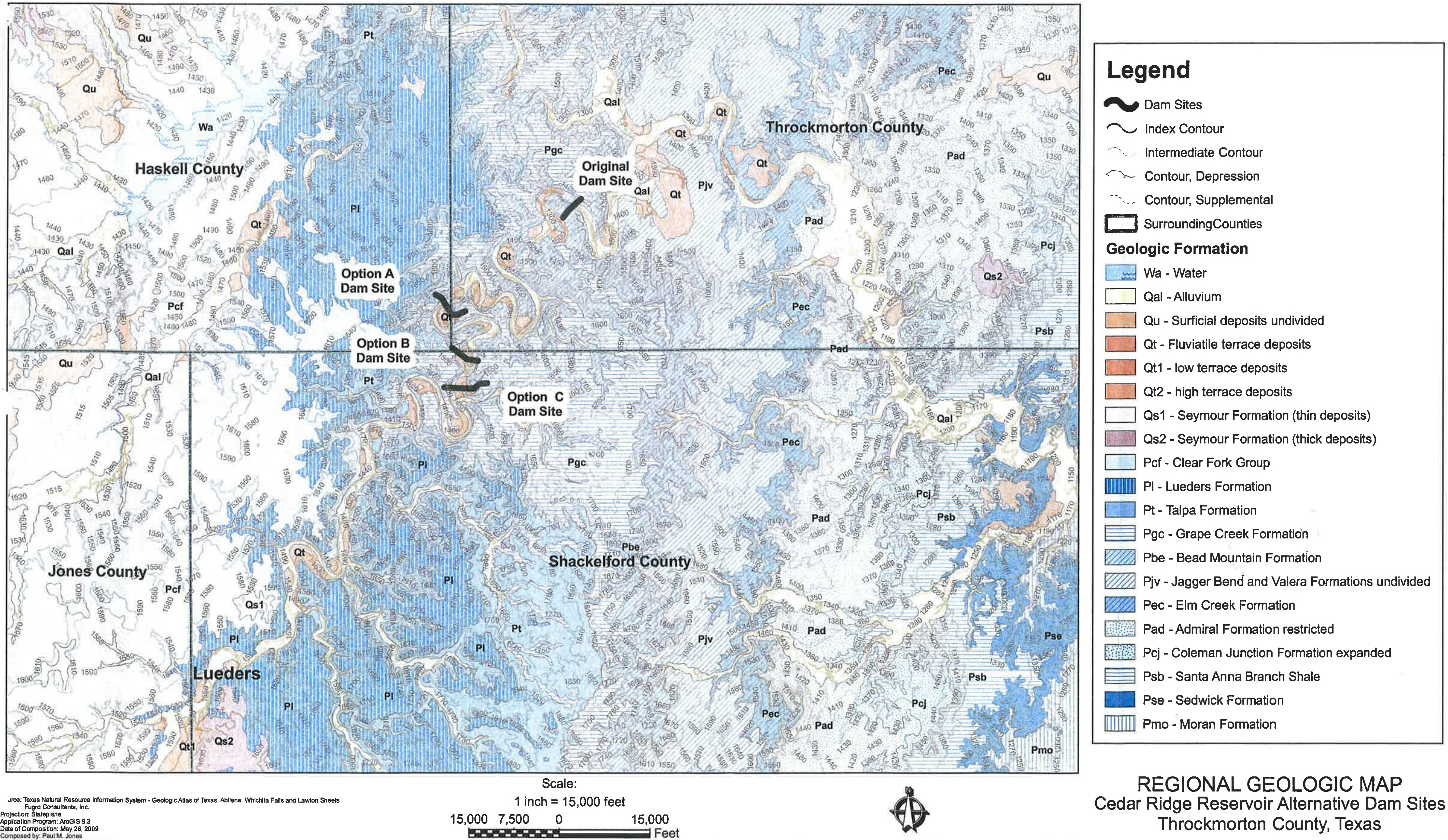


VICINITY MAP

Cedar Ridge Reservoir Alternative Dam Sites

Throckmorton County, Texas

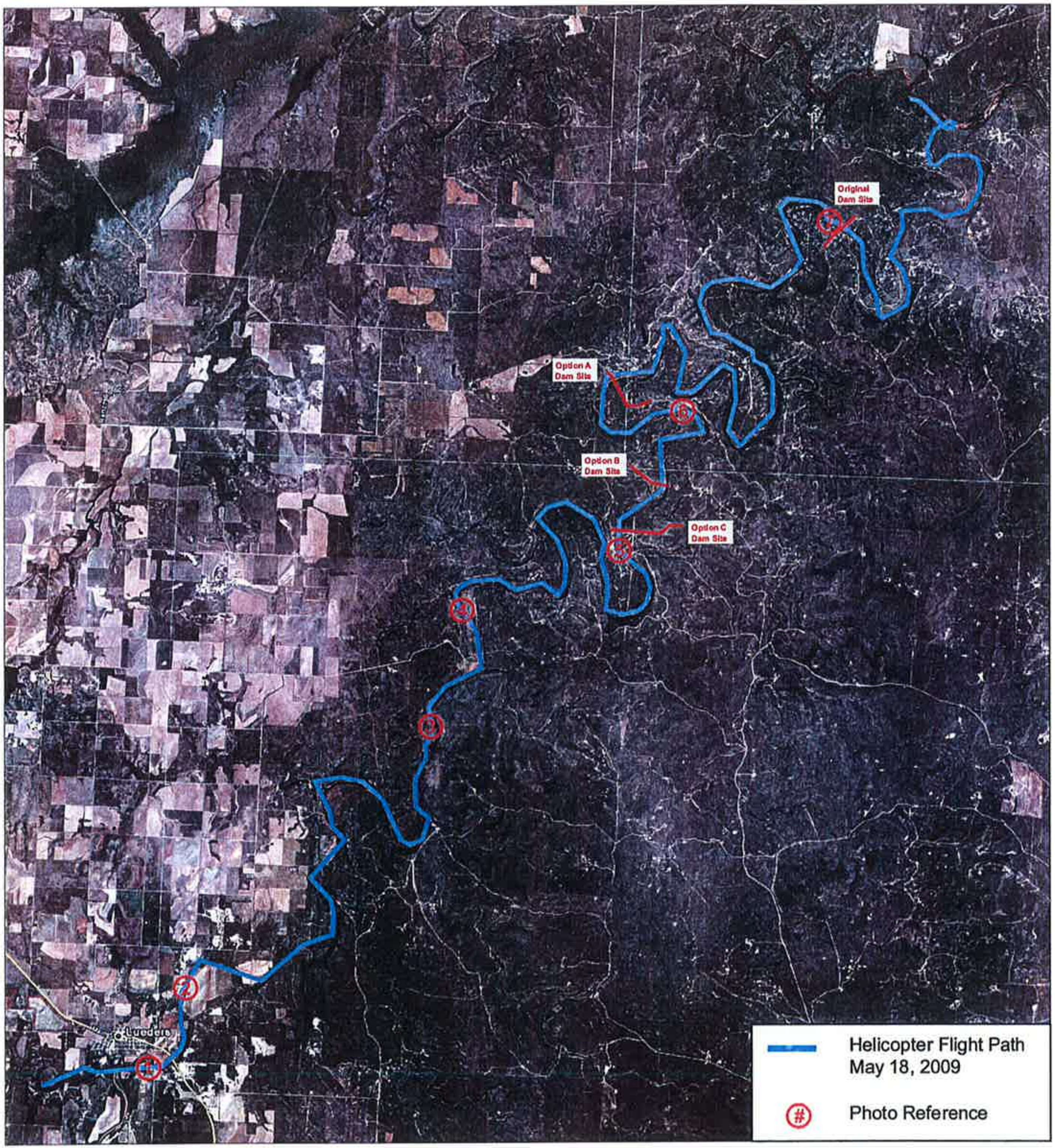
FIGURE 1



urce: Texas Natural Resource Information System - Geologic Atlas of Texas, Abilene, Whichita Falls and Lawton Sheets
Fugro Consultants, Inc.
Projection: Stateplane
Application Program: ArcGIS 9.3
Date of Composition: May 26, 2009
Composed by: Paul M. Jones

REGIONAL GEOLOGIC MAP
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 2



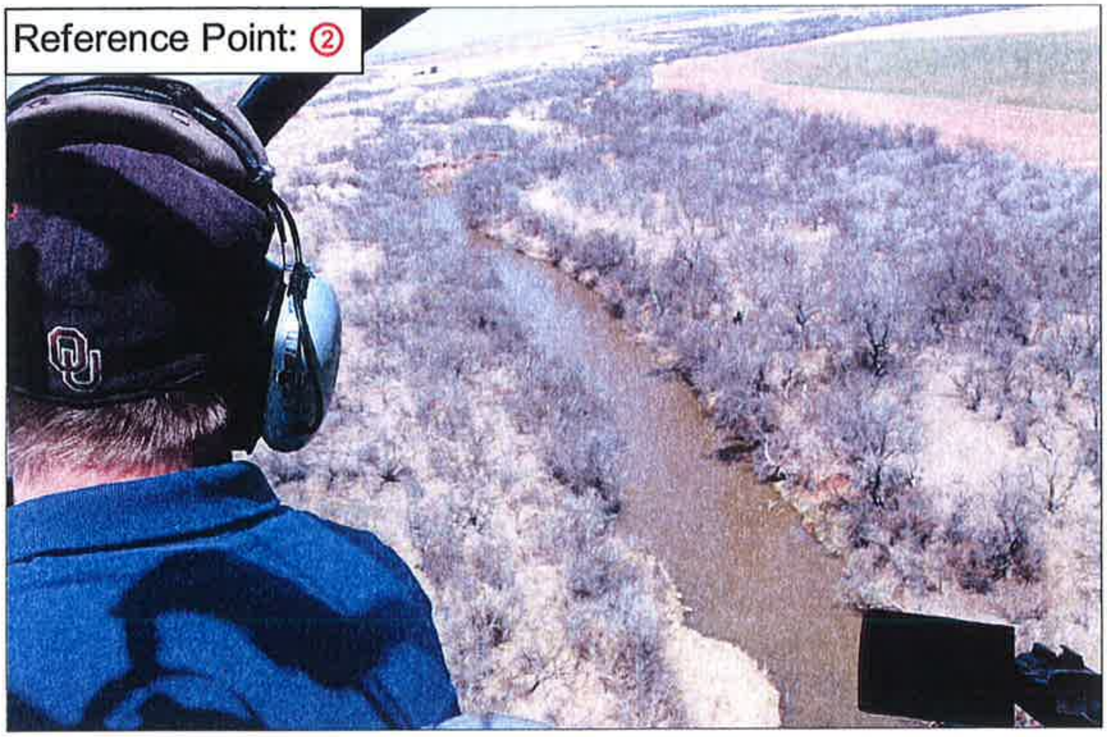
Source: Aerial Image from Google Earth Professional.

HELICOPTER FLYOVER PHOTOGRAPHS

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 3a

Lueders Spillway - Clear Fork of the Brazos River spilling over resistant limestone beds.



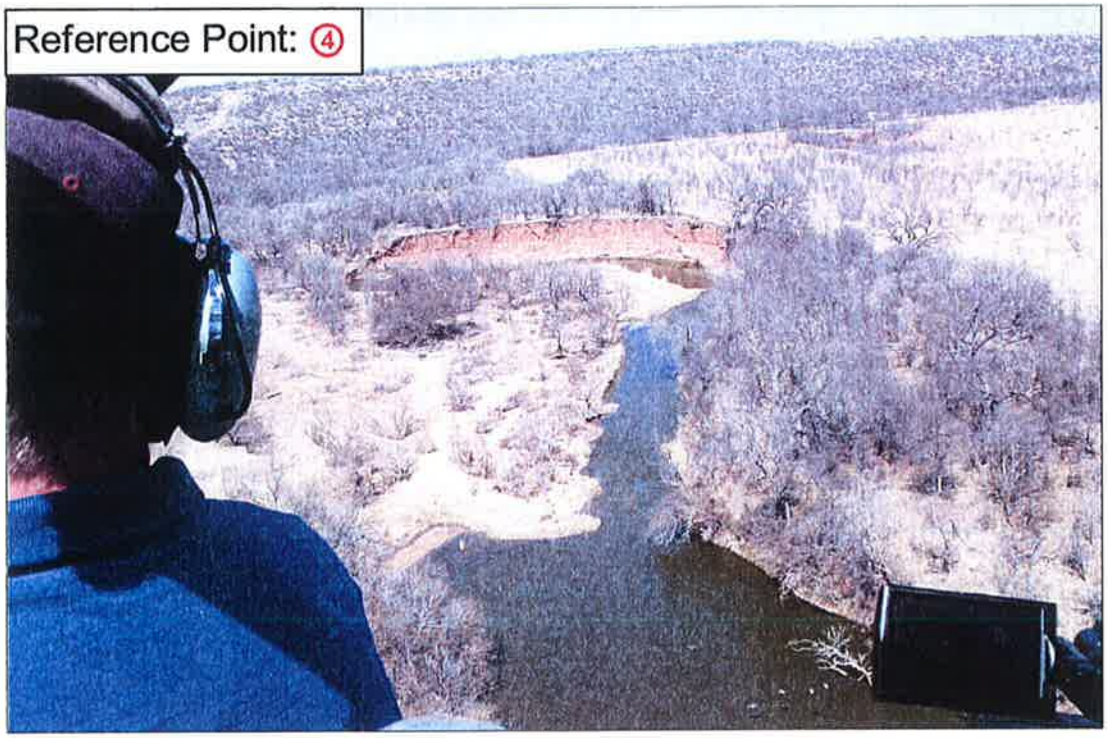
Alluvial Deposits Downstream on Clear Fork of the Brazos River.

HELICOPTER FLYOVER PHOTOGRAPHS

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 3b

Oxbow lake on Clear Fork of the Brazos River.



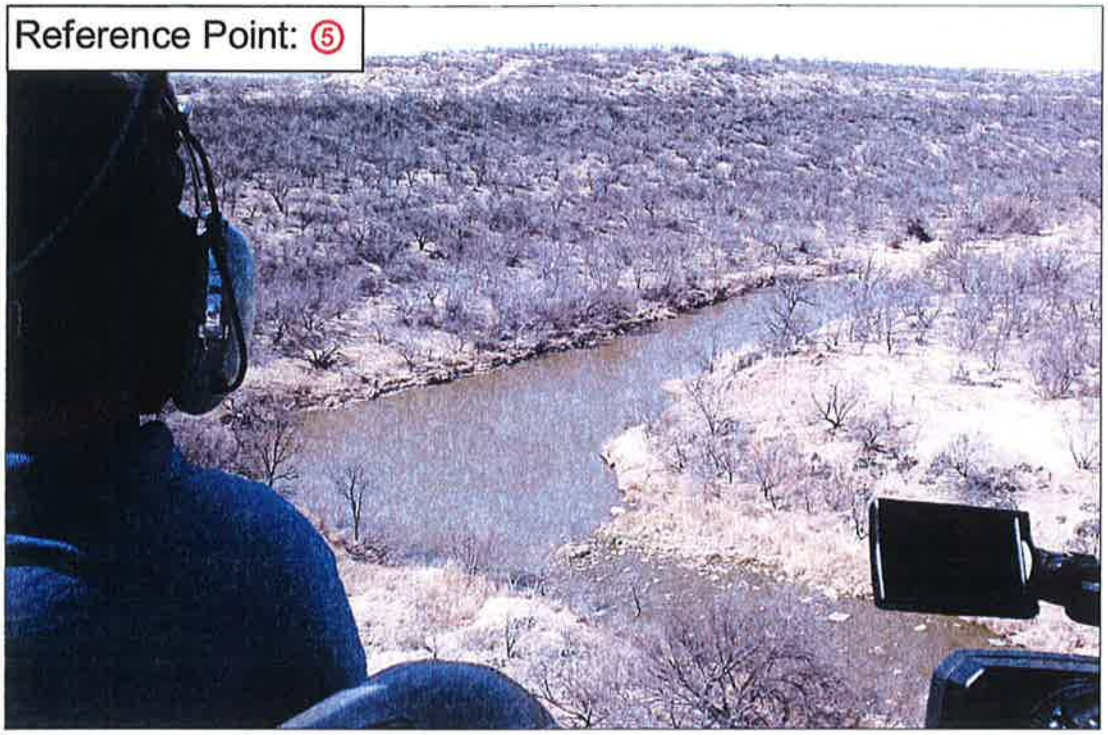
Alluvial Deposits Downstream of Hendrick Boy's Home Crossing.

HELICOPTER FLYOVER PHOTOGRAPHS

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 3c

Reference Point: ⑤



Bend in Clear Fork of the Brazos River south of Dam Site C.

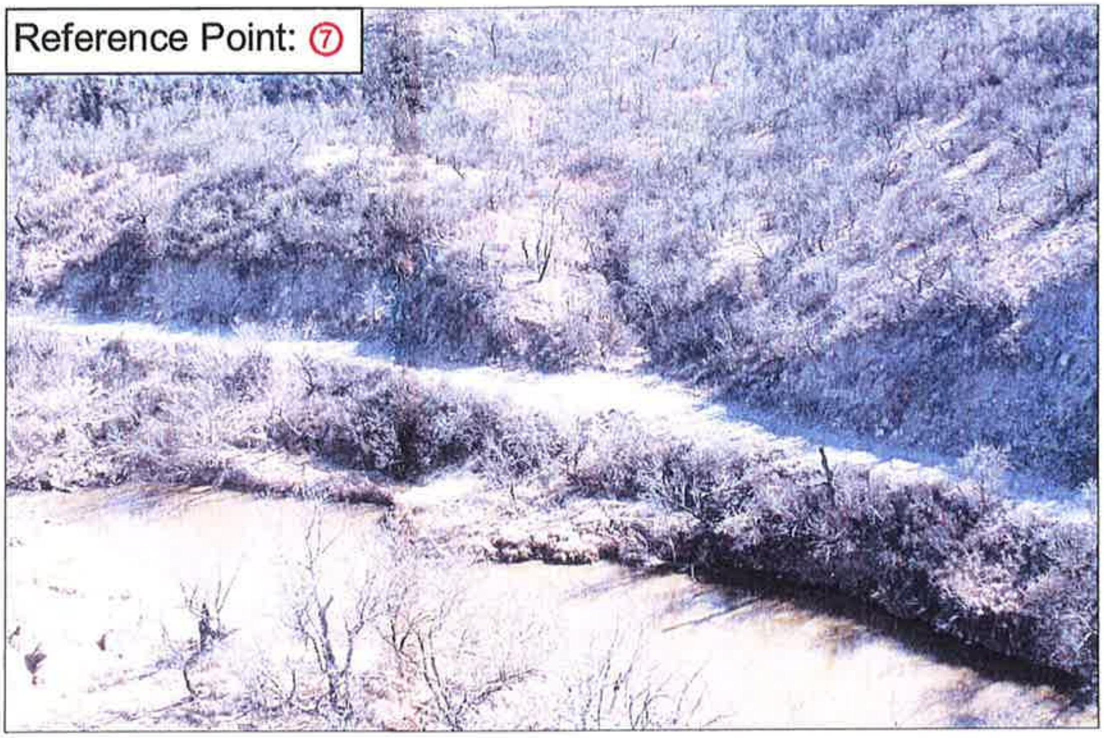
Reference Point: ⑥

B-2 Narrow topographic ridge (right).

HELICOPTER FLYOVER PHOTOGRAPHS

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 3d

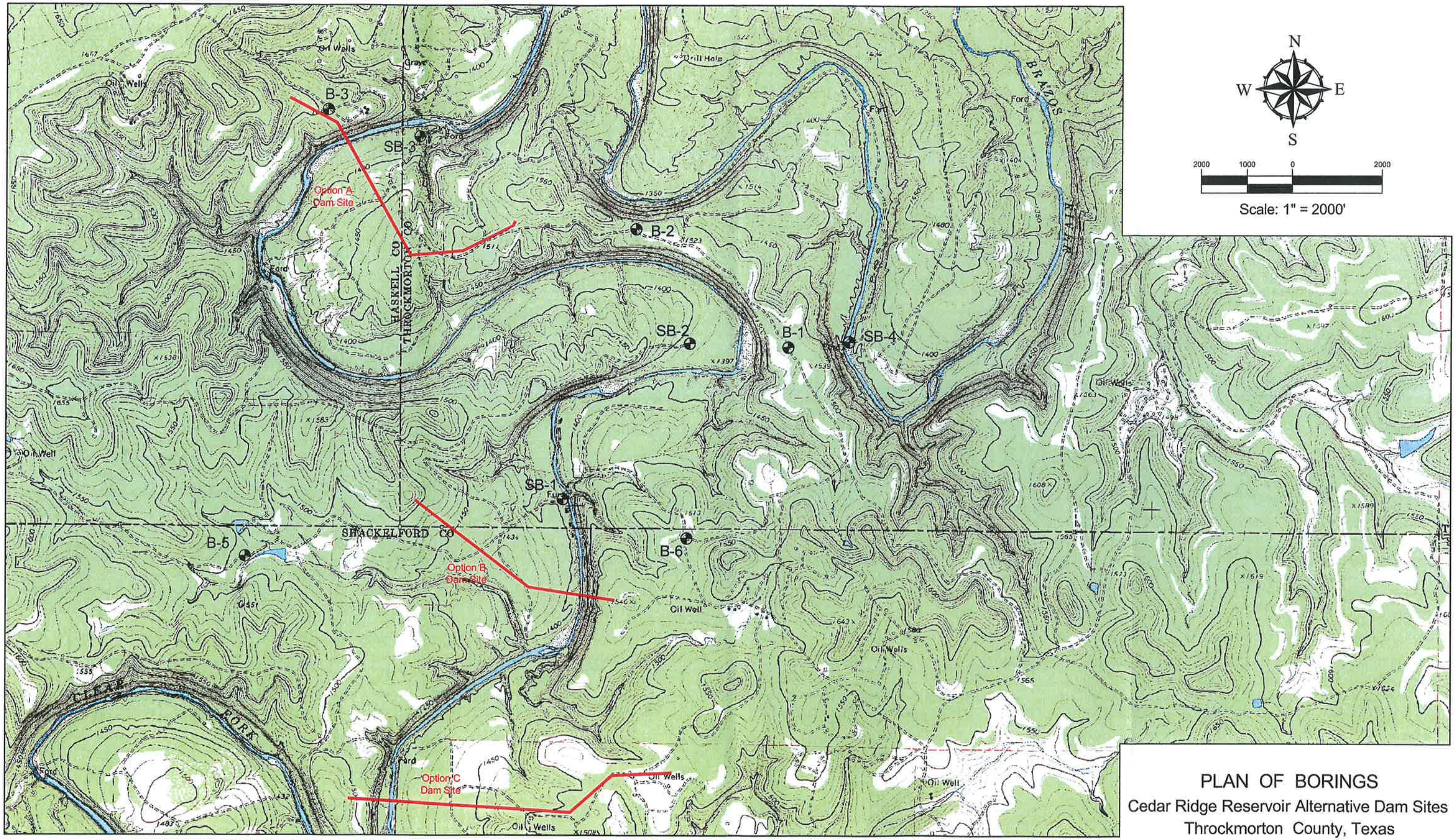


Gypsum outcrop at Original Dam Site.

HELICOPTER FLYOVER PHOTOGRAPHS

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

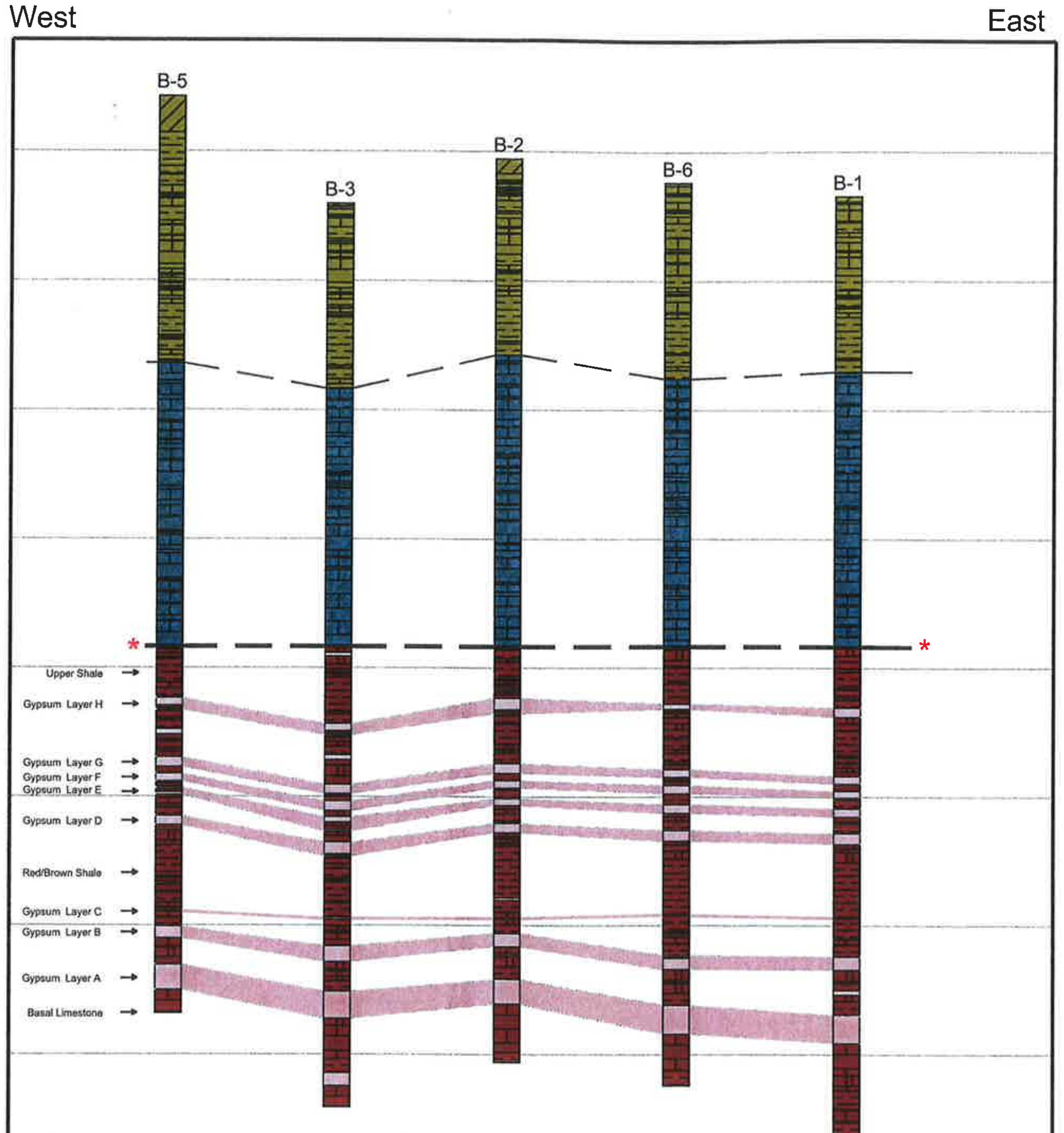
FIGURE 3e



PLAN OF BORINGS

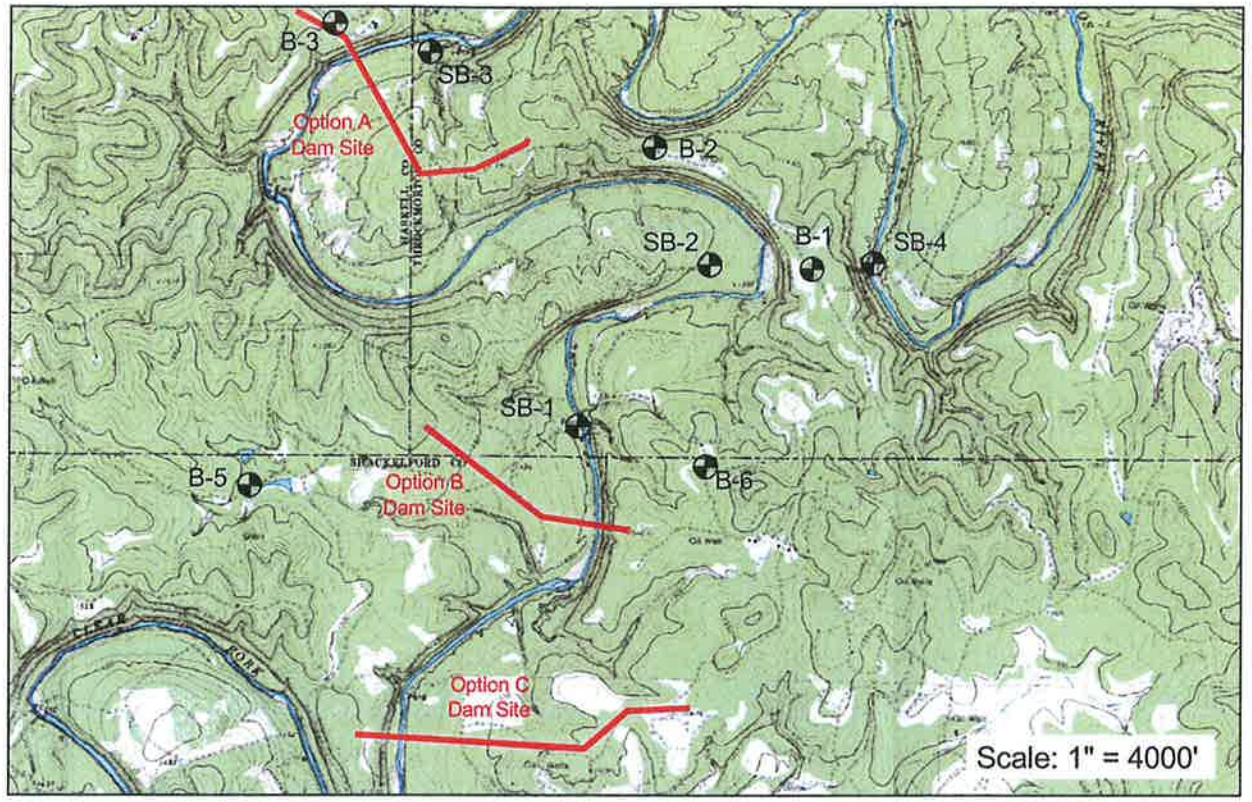
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 4



* Note: Borings are vertically oriented on the Bead Mountain (P_{be}) Jagger Bend/Valera Formation (P_{jv}) contact for illustration purposes and do not represent actual ground surface elevations at top of borings.

Vertical Scale: 1" = 60'
Horizontal Scale: NONE



LEGEND

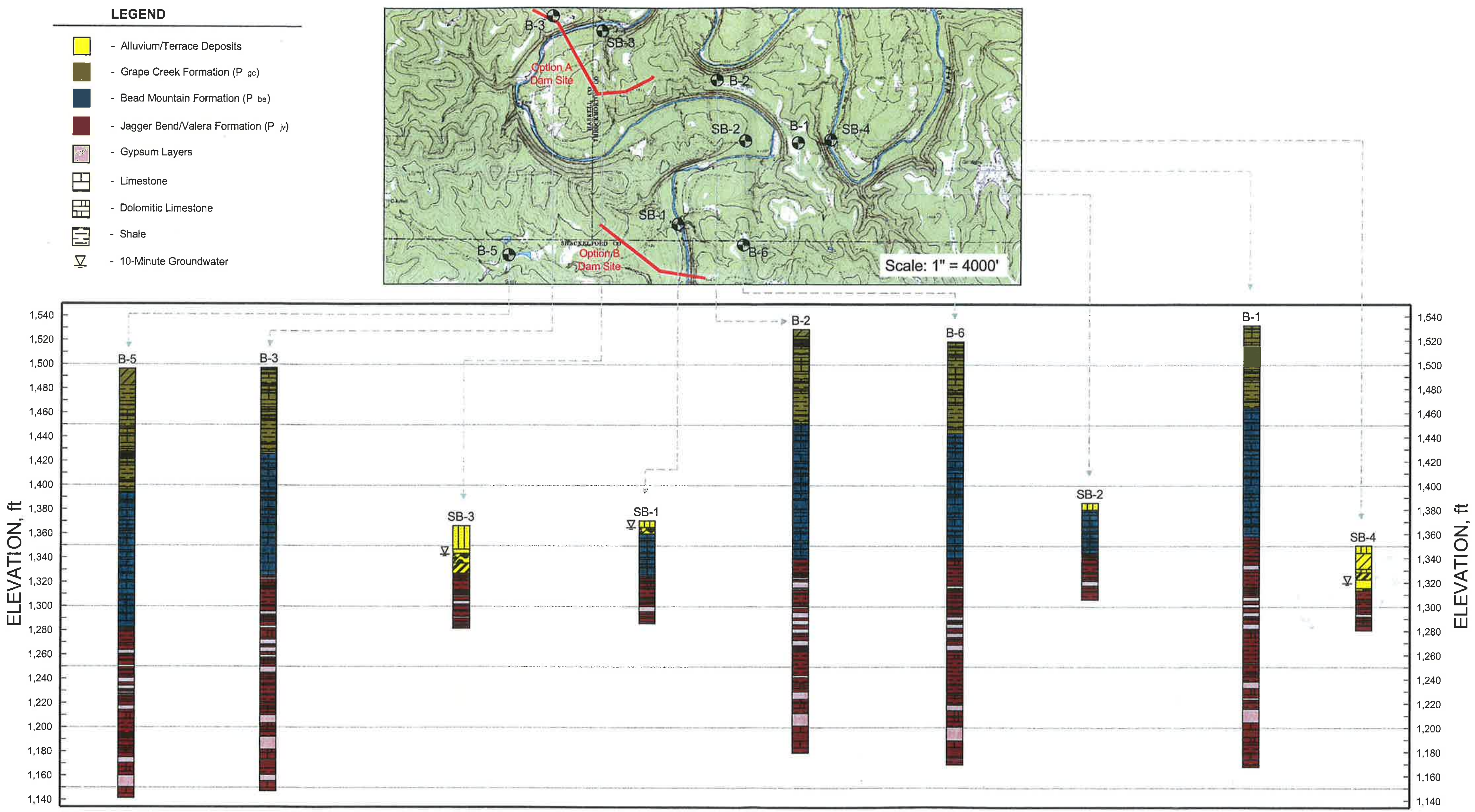
- 🟩 - Grape Creek Formation (P_{gc})
- 🟦 - Bead Mountain Formation (P_{be})
- 🟥 - Jagger Bend/Valera Formation (P_{jv})
- ▨ - Gypsum Layers
- ⊞ - Limestone
- ▦ - Dolomitic Limestone
- ☰ - Shale

STRATIGRAPHIC CROSS SECTION

(Hung on Top of Jagger Bend/Valera)
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

*Revision Date: August 7, 2009

FIGURE 5



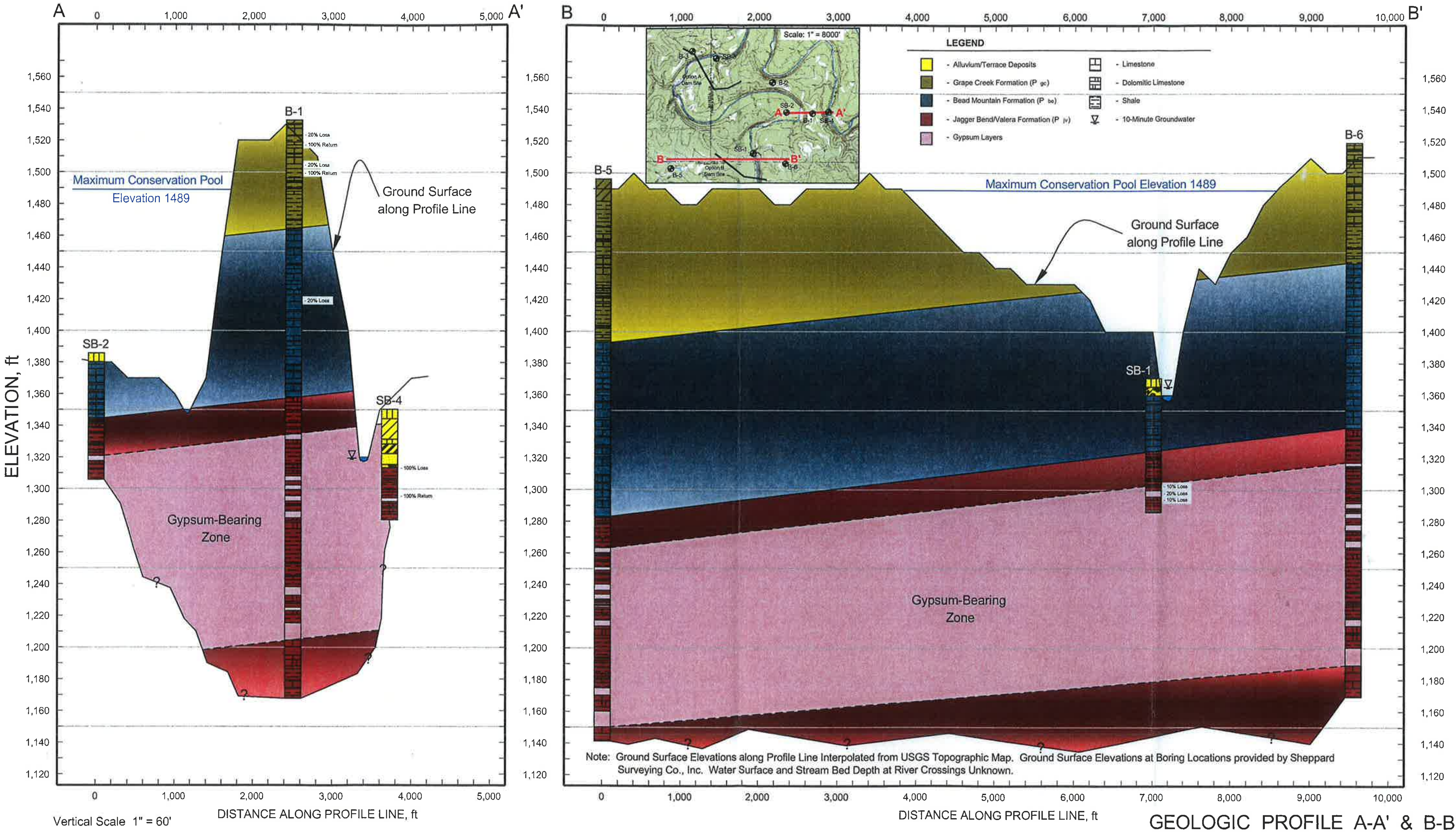
Vertical Scale: 1" = 80'
Horizontal Scale: NONE

*Revision Date: May 20, 2009

GENERALIZED BORING PROFILE

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 6



Note: Ground Surface Elevations along Profile Line Interpolated from USGS Topographic Map. Ground Surface Elevations at Boring Locations provided by Sheppard Surveying Co., Inc. Water Surface and Stream Bed Depth at River Crossings Unknown.

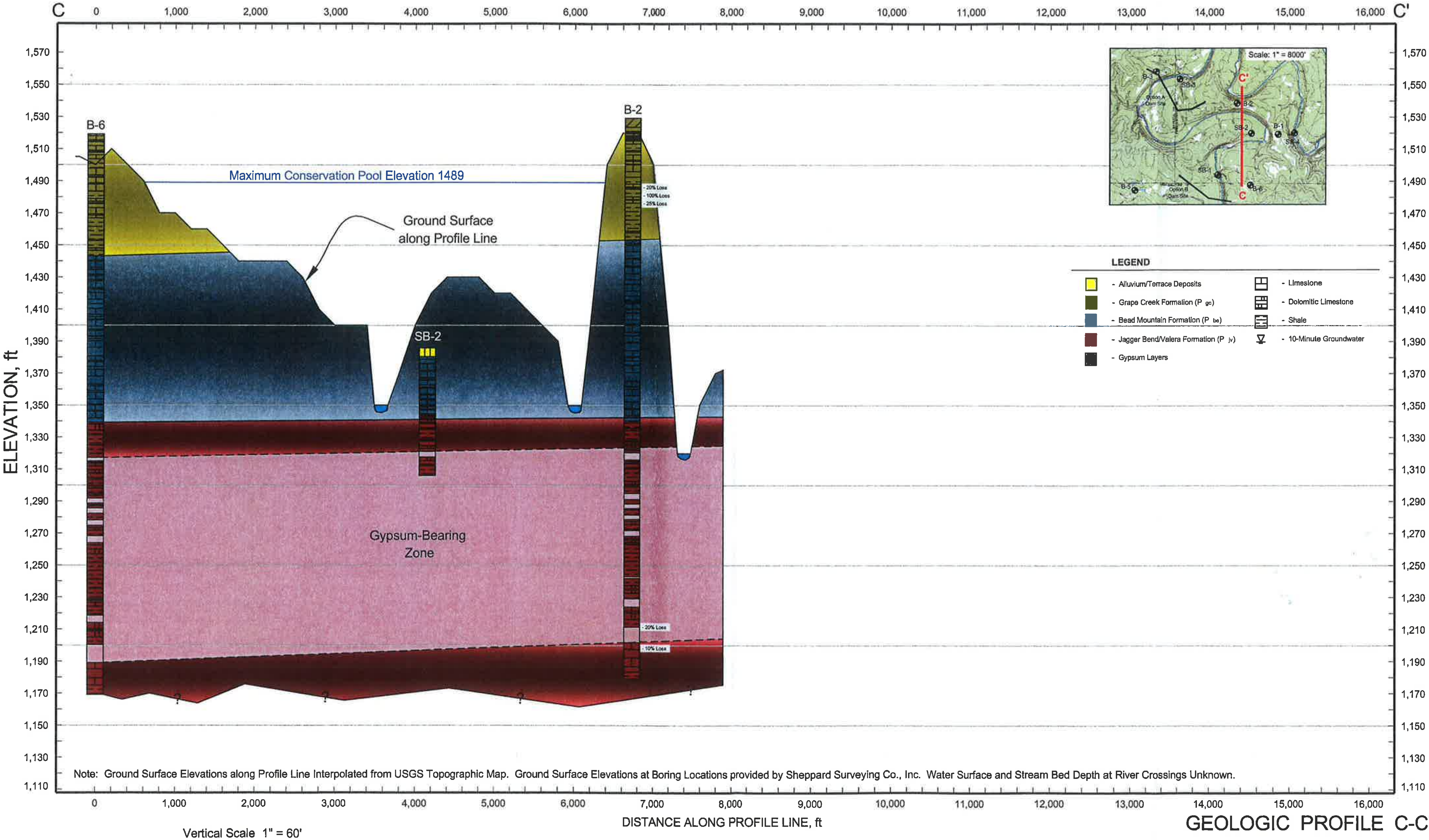
Vertical Scale 1" = 60'
Horizontal Scale 1" = 1200'

*Revision Date: August 7, 2009

GEOLOGIC PROFILE A-A' & B-B'

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 7a



Note: Ground Surface Elevations along Profile Line Interpolated from USGS Topographic Map. Ground Surface Elevations at Boring Locations provided by Sheppard Surveying Co., Inc. Water Surface and Stream Bed Depth at River Crossings Unknown.

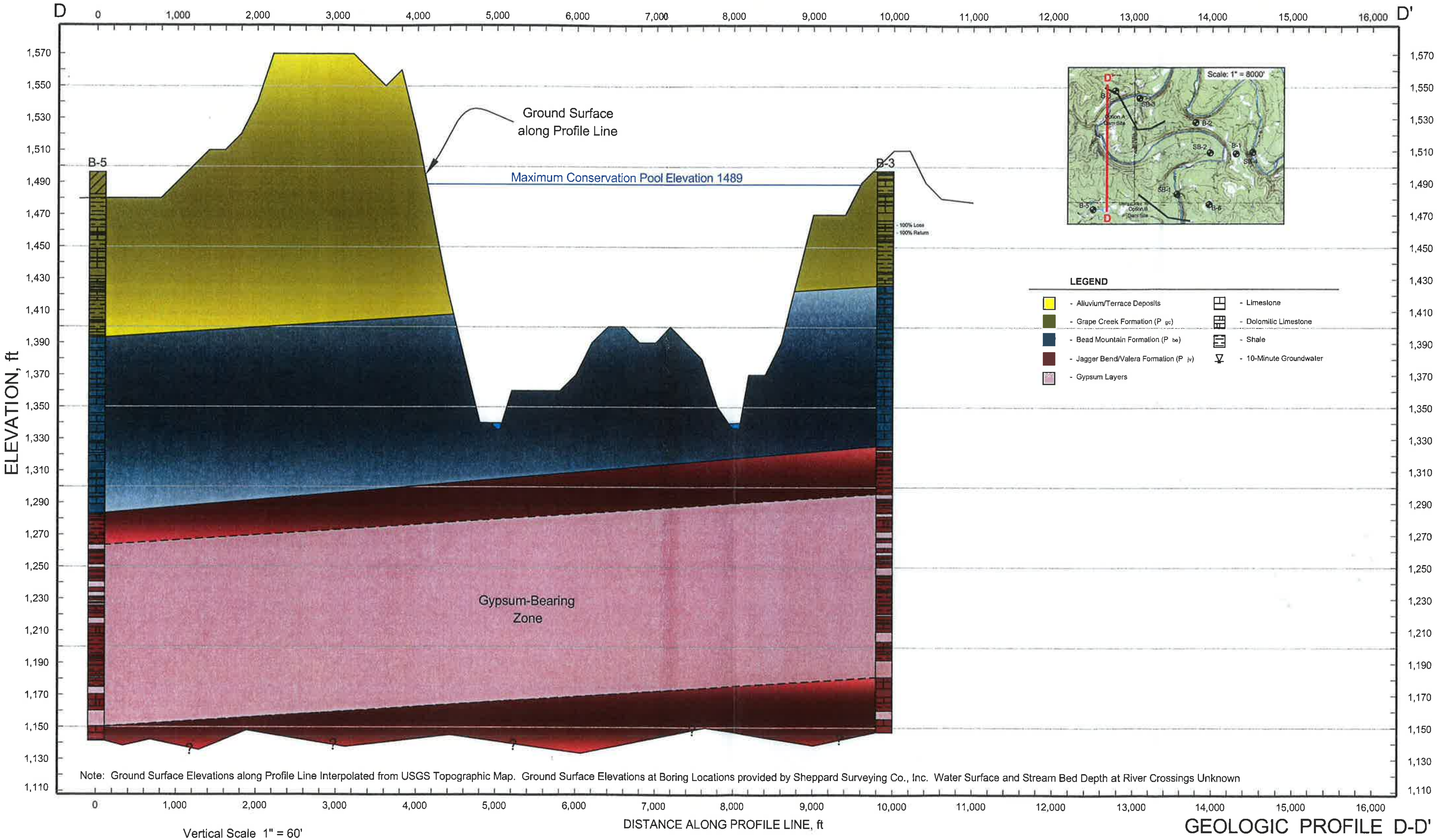
Vertical Scale 1" = 60'
Horizontal Scale 1" = 1200'

*Revision Date: August 7, 2009

GEOLOGIC PROFILE C-C'

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 7b



Note: Ground Surface Elevations along Profile Line Interpolated from USGS Topographic Map. Ground Surface Elevations at Boring Locations provided by Sheppard Surveying Co., Inc. Water Surface and Stream Bed Depth at River Crossings Unknown

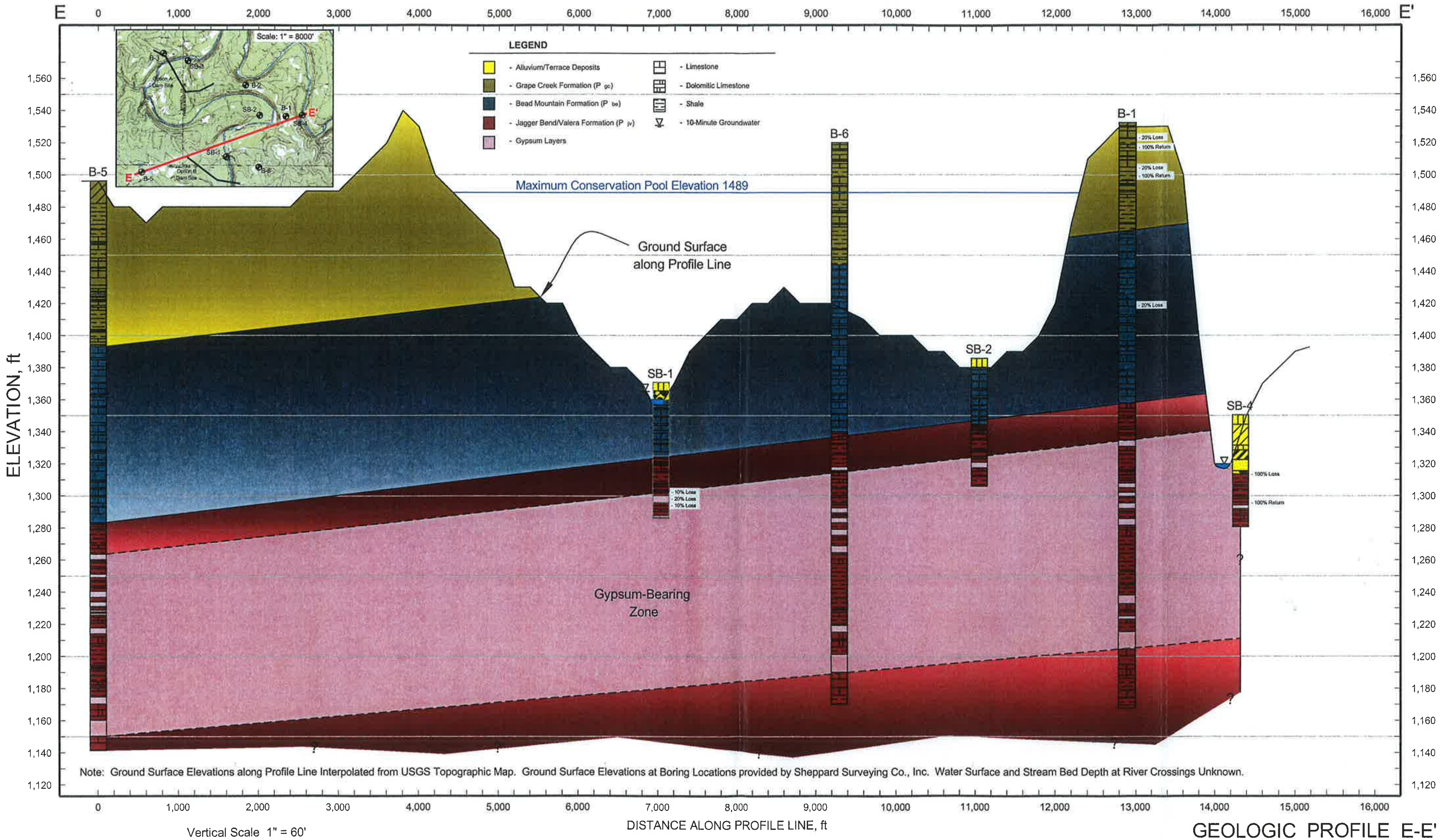
Vertical Scale 1" = 60'
Horizontal Scale 1" = 1200'

*Revision Date: August 7, 2009

GEOLOGIC PROFILE D-D'

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 7c



Note: Ground Surface Elevations along Profile Line Interpolated from USGS Topographic Map. Ground Surface Elevations at Boring Locations provided by Sheppard Surveying Co., Inc. Water Surface and Stream Bed Depth at River Crossings Unknown.

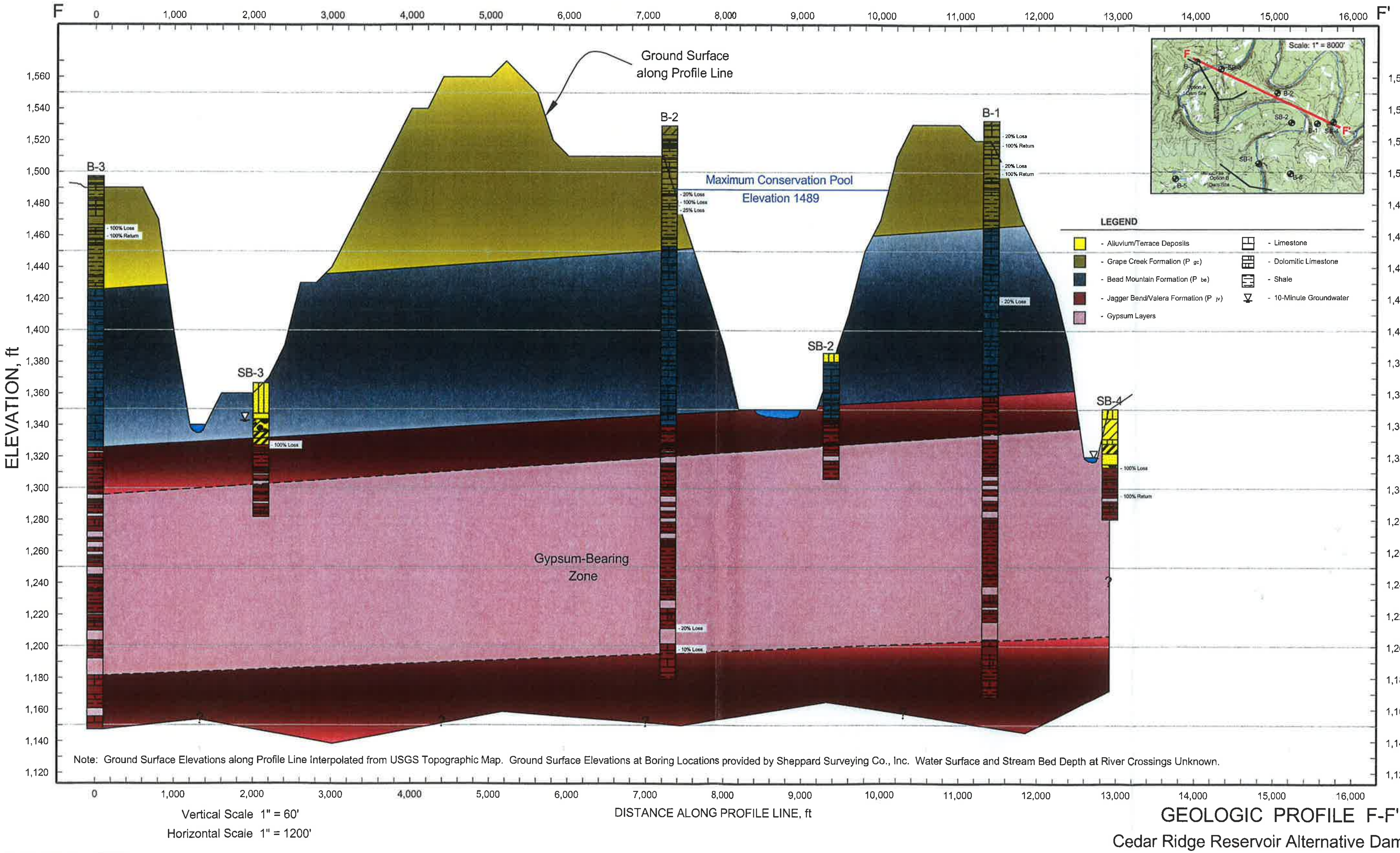
Vertical Scale 1" = 60'
Horizontal Scale 1" = 1200'

*Revision Date: August 7, 2009

GEOLOGIC PROFILE E-E'

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 7d



Note: Ground Surface Elevations along Profile Line Interpolated from USGS Topographic Map. Ground Surface Elevations at Boring Locations provided by Sheppard Surveying Co., Inc. Water Surface and Stream Bed Depth at River Crossings Unknown.

Vertical Scale 1" = 60'

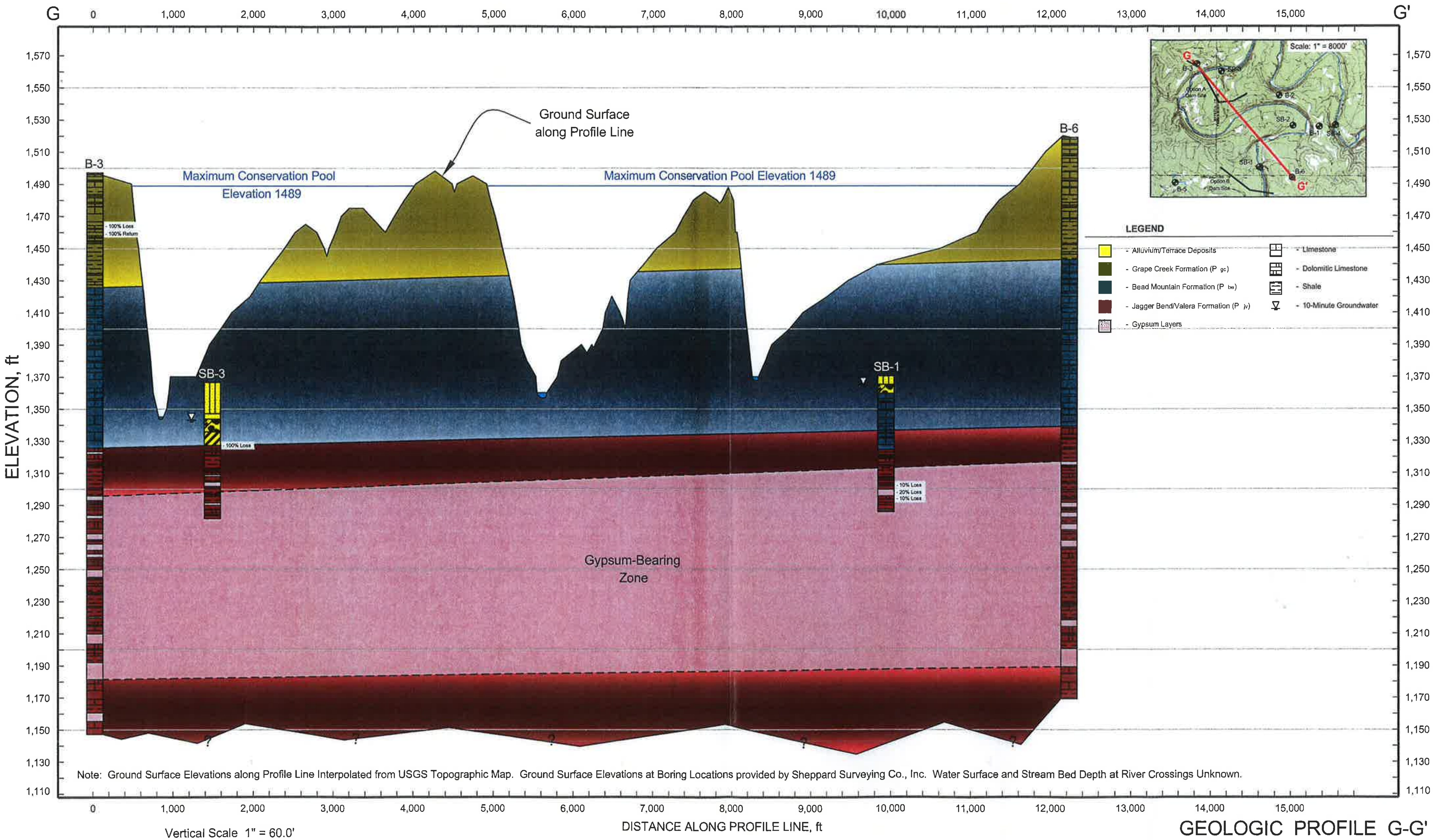
Horizontal Scale 1" = 1200'

*Revision Date: August 7, 2009

GEOLOGIC PROFILE F-F'

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 7e



Note: Ground Surface Elevations along Profile Line Interpolated from USGS Topographic Map. Ground Surface Elevations at Boring Locations provided by Sheppard Surveying Co., Inc. Water Surface and Stream Bed Depth at River Crossings Unknown.

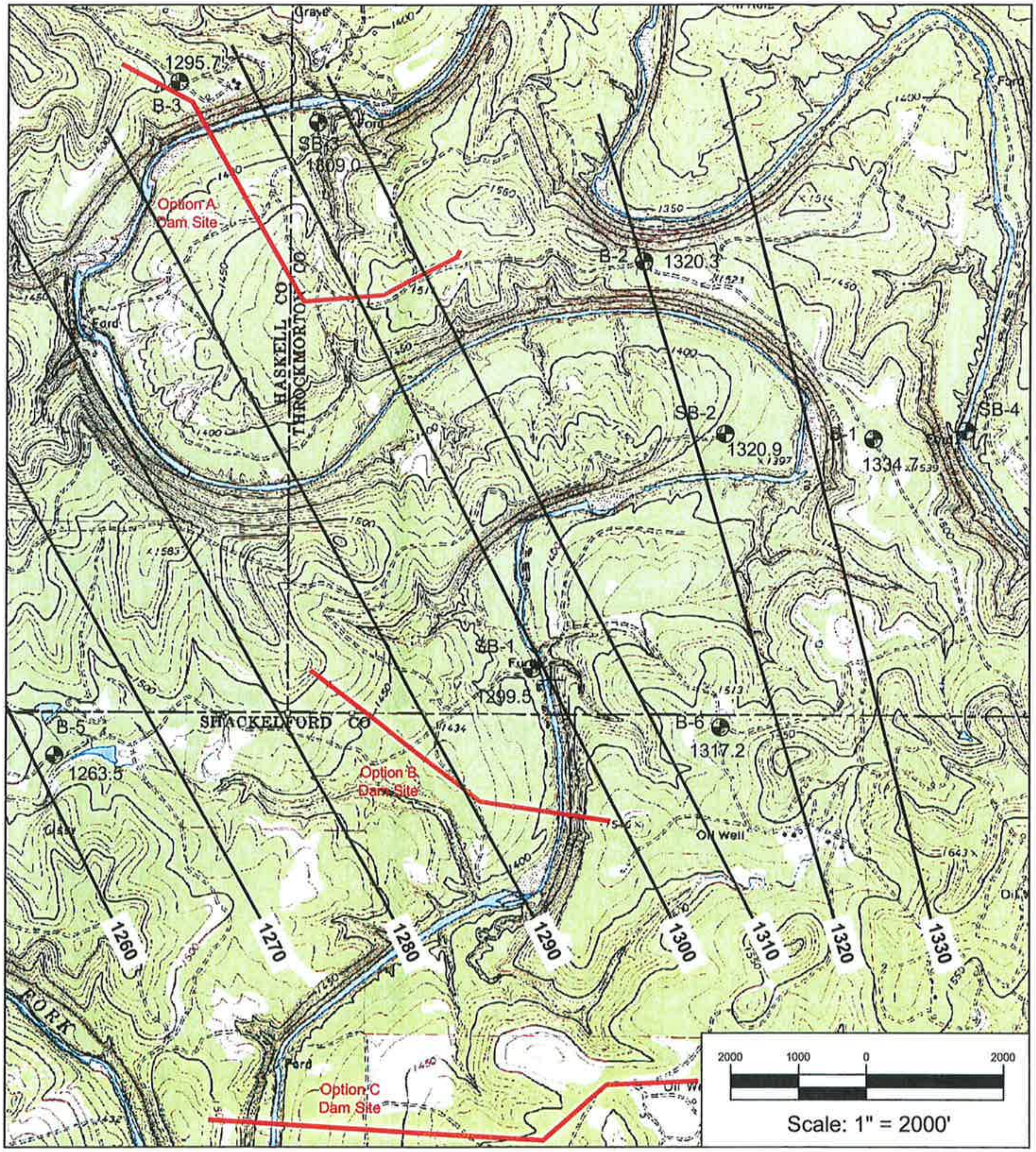
Vertical Scale 1" = 60.0'
Horizontal Scale 1" = 1200.0'

*Revision Date: August 7, 2009

GEOLOGIC PROFILE G-G'

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

FIGURE 7f



STRUCTURE CONTOUR MAP (Top of Gypsum H Layer)

Cedar Ridge Reservoir Alternative Dam Sites

Throckmorton County, Texas

FIGURE 8

APPENDICES

APPENDICES

APPENDIX A

APPENDIX A

STRUCTURE CONTOUR MAPPING OF GYPSUM IN THE JAGGER BEND/VALERA FORMATION ALONG CLEAR FORK OF BRAZOS RIVER; THROCKMORTON, HASKELL, AND SHAKELFORD COUNTIES, TEXAS

BY KENNETH S. JOHNSON, Ph.D., P.G.

Structure contour-mapping of gypsum beds in the Jagger Bend/Valera Formation along Clear Fork of Brazos River; Throckmorton, Haskell, and Shackelford Counties, Texas

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Submitted to:
EMPROTEC/Hibbs & Todd, Inc.
Abilene, Texas

August 31, 2009

CONTENTS

LIST OF ILLUSTRATIONS AND TABLE (in back of report)

INTRODUCTION

This study examines aspects of the subsurface geology of an area embracing about 8 miles by 20 miles along the Clear Fork of Brazos River (Clear Fork) in parts of Throckmorton, Haskell, and Shackelford Counties, Texas (Plates 1, 2, 3). The study area extends from the town of Leuders in the southwest to Paint Creek in the northeast: it includes the originally proposed Cedar Ridge Reservoir damsite (CR), along with two other prospective damsites (A and B) farther upstream (to the southwest). The study focuses on the distribution, thickness, and structure of a series of gypsum beds or layers that are present in the Jagger Bend/Valera Formation.

Gypsum is a relatively soluble rock. Generally, it is susceptible to being partially or totally dissolved by ground water, and to developing karst features such as caves, sinkholes, and underground water courses (Johnson 2003a, 2008a). Gypsum beds underlie all parts of the study area, and also crop out near the original Cedar Ridge damsite and along the river for several miles farther upstream on Clear Fork. Because of the potential for gypsum karst along parts of the river, the distribution and depth of the various gypsum beds is important in considering the eventual siting of a dam along the Clear Fork.

Gypsum karst is an important consideration in dam location and construction because at several sites in the United States it has had an adverse impact on holding water behind a dam. Dams built upon gypsum karst generally are not able to retain water, and can even result in collapse and failure of the dam (Johnson, 2008a, 2008b). Where gypsum karst is within the proposed impoundment area of a reservoir, water can penetrate the karst features and may escape from the reservoir. Several articles have been published on properties of dam foundations built upon gypsum deposits (James and Lupton, 1978; Chen and Wu, 1983; Milanović, 2000).

Several examples of gypsum-karst problems and dams in the United States are: Quail Creek Dike (Utah), Upper Mangum Dam (Oklahoma), Anchor Dam (Wyoming), and Horsetooth and Carter Lake Dams (Colorado) (Johnson, 2008b). Quail Creek Dike failed in 1989 due, in part, to flow of water through an undetected gypsum-karst unit beneath an earth-fill embankment (James and others, 1989; O'Neill and Gourley, 1991; Payton and Hansen, 2003). The long-studied Upper Mangum Dam was abandoned before construction, because of extensive gypsum karst in the abutments and impoundment area (Johnson, 2003b). Anchor Dam, built in 1960, has significant drainage of water from the reservoir because of earth fissures, sinkholes, and gypsum karst that underlie the impoundment area (Jarvis, 2003). Horsetooth and Carter Lake Reservoirs, built upon gypsum-bearing strata in the 1940s, experienced development of sinkholes and seepage-loss of water in the 1980s and 1990s (Pearson, 2002).

This report is part of a larger geologic investigation of potential damsites in the study area that is being carried out by Fugro Consultants, Inc.

METHODS OF STUDY

Study of the subsurface distribution, thickness, and structure of gypsum beds in the area required examining the electric logs (also known as "geophysical logs") of 100 oil and gas tests drilled within the 8- x 20-mile area that extends about 4 miles on each side of the Clear Fork (Plates 1, 2, 3). The logs were ordered from A2D Logs (Tobin), and the locations of the wells on the accompanying maps are provided by Tobin Map Data. Several thousand oil and gas tests have been drilled within the study area (Plate 1), but it is not necessary to examine all the well logs to determine the general distribution, depth, and character of the gypsum beds; furthermore, electric logs are available for only a small percentage of the wells.

Recognition of gypsum beds and associated rock types on electric logs is well established (Alger and Crain, 1966), and I have carried out many studies using various well logs to identify, correlate, and map gypsum beds in the subsurface—some of the studies are in public documents (Johnson, 1967, 1985), and many others are in consulting reports.

In each well log examined in the study area, individual gypsum beds (and interbedded shale units) that are at least 2 feet thick can be readily identified (Figs. 1, 2, 3). Recognition and identification of gypsum beds on the electric logs is confirmed by comparison and correlation with continuous cores that were drilled near several of the oil wells. Figure 1 shows Core B-3, which was drilled May 21, 2008, at the original Cedar Ridge damsite; the core contains gypsum beds that are readily correlated with gypsum beds that I interpret to be present on electric logs for two wells (#69 and #66) drilled 400 feet and 2 miles, respectively, away from the core. There is almost a bed-for-bed correlation of the gypsums from Core B–3 with those in Well 69, and also a good correlation with those in Well 66, located 2 miles away. Well 66 contains several thin gypsums at the top of the sequence that are not present in Core B–3.

Farther to the southwest, in the vicinity of potential damsites A and B, gypsum beds in Core B–5 (drilled March 31, 2009) are readily correlated with those in the electric log of Well 2–5, located about 3,000 feet away (Fig. 2). The gypsum beds have been "named" A through H (ascending order) in the accompanying geologic report by Fugro Consultants, Inc., and I show those names on the left side of Core B–5 (Fig. 2). Also showing up very clearly in Well 2–5 are several other rock units that have been identified in the core and have been named elsewhere in the geologic report prepared by Fugro Consultants, Inc.: the "Upper Shale" is a 20- to 30-foot-thick shale that immediately overlies Gypsum H throughout the study area; the "Red-Brown Shale" is a 25- to 40-foot-thick, predominantly shale unit between Gypsums C and D; and the "Basal Limestone" is a conspicuous limestone at the base of Gypsum A.

RESULTS OF STUDY

With recognition of gypsum and shale beds on these electric logs, it is then possible to confidently identify and correlate individual gypsum and shale units of the Jagger Bend/Valera Formation on other electric logs throughout the study area. An example of how these units can be correlated across the study area is presented in Figure 3. This is a structural cross section showing that the gypsum beds are at a higher elevation in the east (Well–66), and that they dip down to a lower elevation in the west (Well–27). It also shows that some of the gypsum beds present in the west become thinner towards the east, and some of them disappear and grade laterally into shale to the east.

Upon establishing the recognition of gypsum and shale units in electric logs, all 100 of the well logs ordered within the study area were examined and the gypsum and shale units were identified and correlated. The depths to the base of the lowest gypsum in the gypsum sequence (Gypsum–A in most wells), and to the top of the uppermost gypsum in the sequence (Gypsum–H in most wells), were identified (Table 1) and plotted on maps (Plates 2 and 3). In some areas, mainly in the west, additional gypsum beds are present above Gypsum–H and below Gypsum–A, and they have been considered part of the Jagger Bend/Valera gypsum sequence in those areas. Similarly, towards the east, the upper and lower gypsum beds disappear and grade laterally into shale, and the Jagger Bend/Valera gypsum sequence becomes thinner.

It is noteworthy that there are two fairly thick shale sequences within the Jagger Bend/Valera Formation. Both the Upper Shale (above Gypsum H) and the Red-Brown Shale (between Gypsums C and D) are persistent throughout the study area. The Upper Shale typically is 20 to 30 feet thick, and the Red-Brown Shale typically is 25 to 40 feet thick.

Plates 2 and 3 are structure-contour maps on gypsum beds at the base and the top, respectively, of the gypsum sequence in the Jagger Bend/Valera Formation. They show, regionally, that the gypsum units dip fairly uniformly towards the west, at about 35 feet/mile. Local irregularities do exist, where the dip is slightly higher or lower, and the direction of dip varies slightly. For example, the dip is about 30 feet/mile towards the west-southwest in the vicinity of prospective damsites A and B, near the common corner of Throckmorton, Haskell, and Shackelford Counties. This is based upon data in Cores B–1, B–2, B–3, B–5, B–6, SB–1, SB–2, and SB–3 that were drilled in March and April, 2009, and described in the Geologic Report by Fugro Consultants, Inc.

Plate 3 is very significant because it shows the elevation (above sea level) of the top of the highest gypsum bed throughout the area. By comparing this map with topographic maps it is possible to determine how deep the gypsum is below the land surface; and whether gypsum beds do, or should, crop out and be exposed in the valley walls of Clear Fork. The uppermost gypsum beds are exposed, or should be exposed, in the valley of Clear Fork at and near the originally proposed Cedar Ridge Reservoir damsite (CR). Gypsum crops out near CR; but at other places where it should crop out, the gypsum either is partly dissolved, or is covered by alluvium, colluvium, or soil.

If soluble gypsum does, or should, crop out in a particular part of Clear Fork Valley, it could be a problem if a dam is constructed in that part of the valley, or if water is impounded too closely over the gypsum beds. Possible karst development in the gypsum could provide pathways for impounded water to escape from the reservoir and be discharged downstream of the dam. Also, if such a pathway is established, the gypsum would undoubtedly be dissolved further, and the pathway could be enlarged. Therefore, it is important to know where gypsum does, or should, crop out in the valley of the Clear Fork.

The top of the gypsum sequence is about 55 feet above stream level of the Clear Fork at the original Cedar Ridge damsite, and thus the upper part of the gypsum sequence is, or should be, exposed in the valley walls (Fig. 4). The top of the gypsum is then at successively lower heights above stream level in the valley upstream from CR because of: 1) westward dip of the gypsum sequence (Plate 3); and 2) the rise of stream-level elevation upstream from CR (Fig. 4). The uppermost gypsum finally dips beneath stream level in the vicinity of borehole SB–4. Therefore, gypsum is present, or should be present, in all parts of Clear Fork Valley from CR up to the vicinity of borehole SB–4 (Fig. 4). The top-most gypsum (Gypsum–H) is about 50 feet below stream level at Dam A, and about 75 feet below stream level at Dam B.

Another result of this subsurface study is recognition that a large number of oil and gas wells have been drilled along and near Clear Fork in the study area (Plate 1). These wells are beneficial for the current study, because they provide many electric logs that can be used to evaluate the gypsum beds. However, it also means that there would be a number of wells in the future reservoir's impoundment area, and these could impact the reservoir and its water quality. These boreholes are potential pathways for oil, gas, or associated salt-water brines to seep to the surface and mix with reservoir water. They also are potential pathways for reservoir water to flow down into the gypsum beds. Producing oil and gas wells in or near the reservoir must be properly plugged and sealed; and even dry or abandoned wells must be found, and it must be verified that they have been properly plugged and sealed.

SUMMARY

Gypsum is a relatively soluble rock that typically contains cavities, sinkholes, and caves ("karst" features), and its presence in a dam foundation or in an impoundment area could allow water to escape from the reservoir. The presence of gypsum at the original Cedar Ridge damsite on the Clear Fork of Brazos River was confirmed in core holes, and a decision was made to look at potential sites farther upstream where any gypsum problem would be minimized or eliminated.

The current study focused on examination of 100 oil- and gas-well electric logs to identify, correlate, and map the gypsum and associated rock layers of the Jagger Bend/Valera Formation within an 8- x 20-mile area embracing the Clear Fork. Gypsum beds can be identified readily on the logs, and this is affirmed by comparing several cores (B–3 and B–5) with nearby electric logs (Figs. 1 and 2). Gypsum beds dip fairly uniformly to the west at about 35 feet/mile, and at 30 feet/mile in the vicinity of prospective damsites A and B. Gypsum beds in the area are thinner to the east; they grade laterally into shale and disappear in that direction.

Gypsum beds crop out, or should be exposed, in the Clear Fork Valley upstream from the original Cedar Ridge damsite, all the way to the vicinity of borehole SB–4 (Fig. 4). The presence of gypsum beds in this portion of the valley means that there may be karst pathways whereby impounded water could escape a reservoir built downstream of SB–4. Therefore, the best location for a dam on the Clear Fork would be at a site located some distance upstream from SB–4, at a site where a sufficient thickness of the Upper Shale is present above the gypsum sequence.

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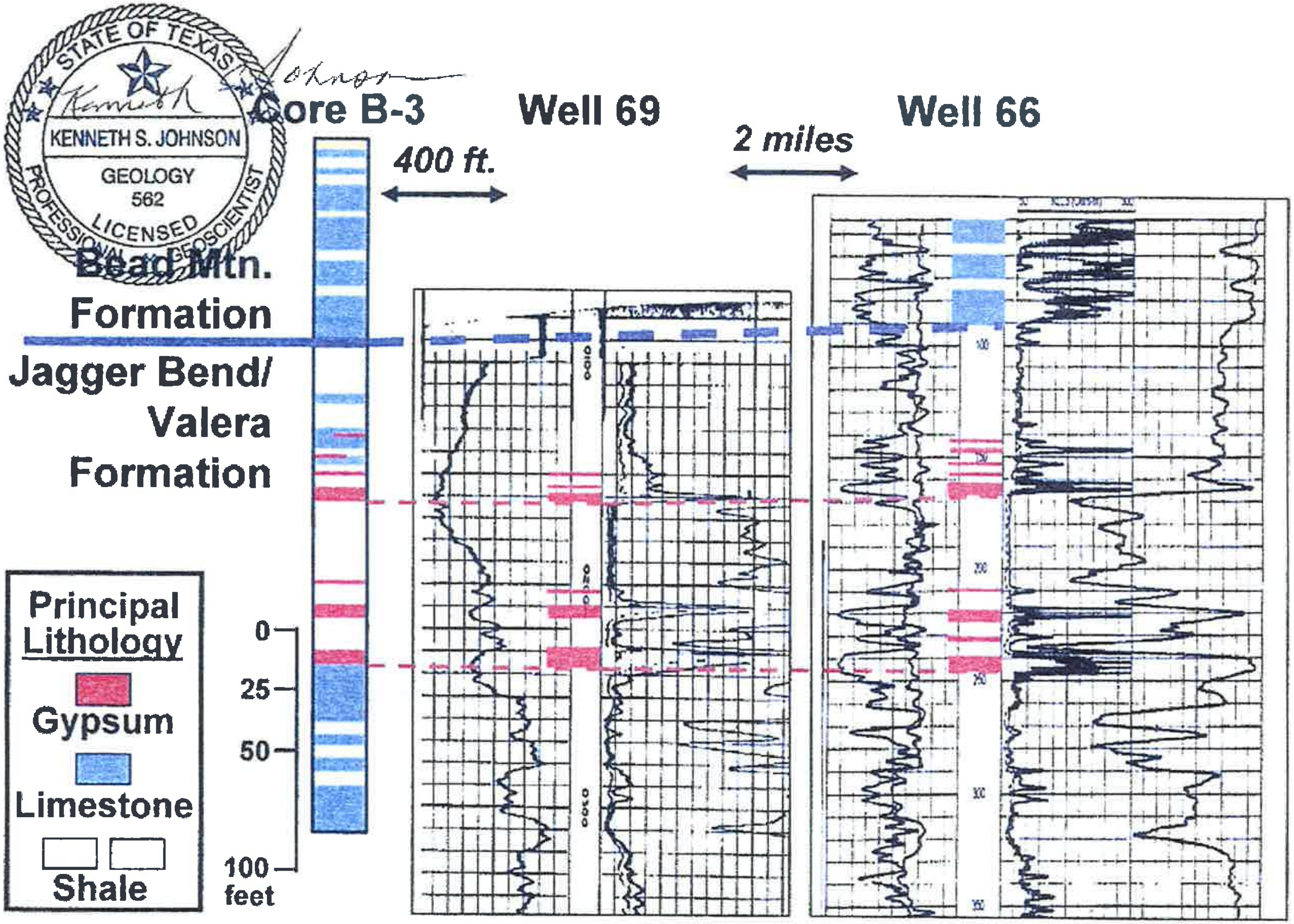

Figure 1. Gypsum beds in Core B–3 are correlated with electric logs of oil wells #69 and #66. Core B–3 was drilled at the originally proposed Cedar Ridge (CR) damsite.

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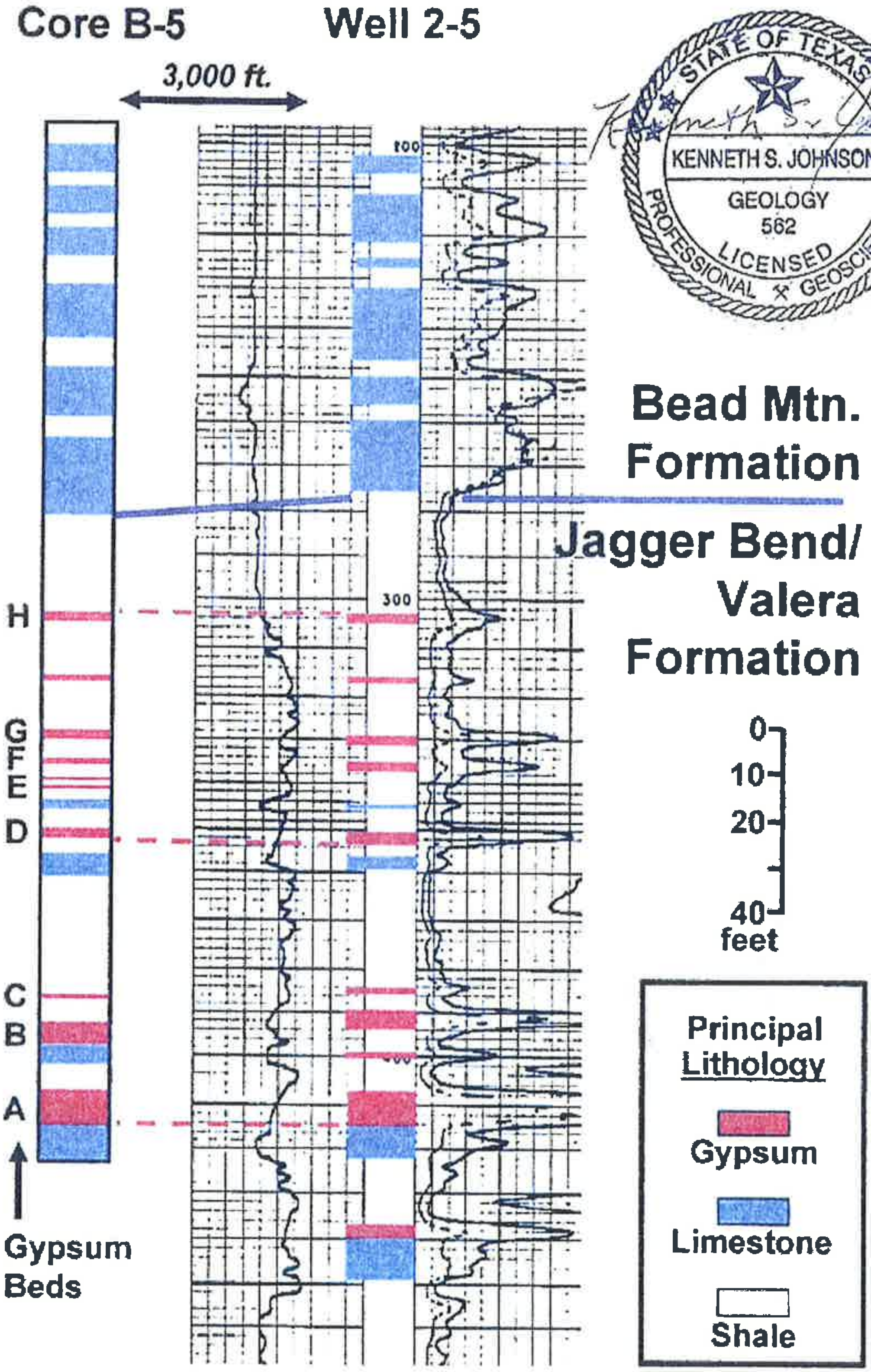

Figure 2. Gypsum beds in Core B–5 are correlated with electric log of oil well #2–5. Core B–5 was drilled in the vicinity of proposed damsites A and B.

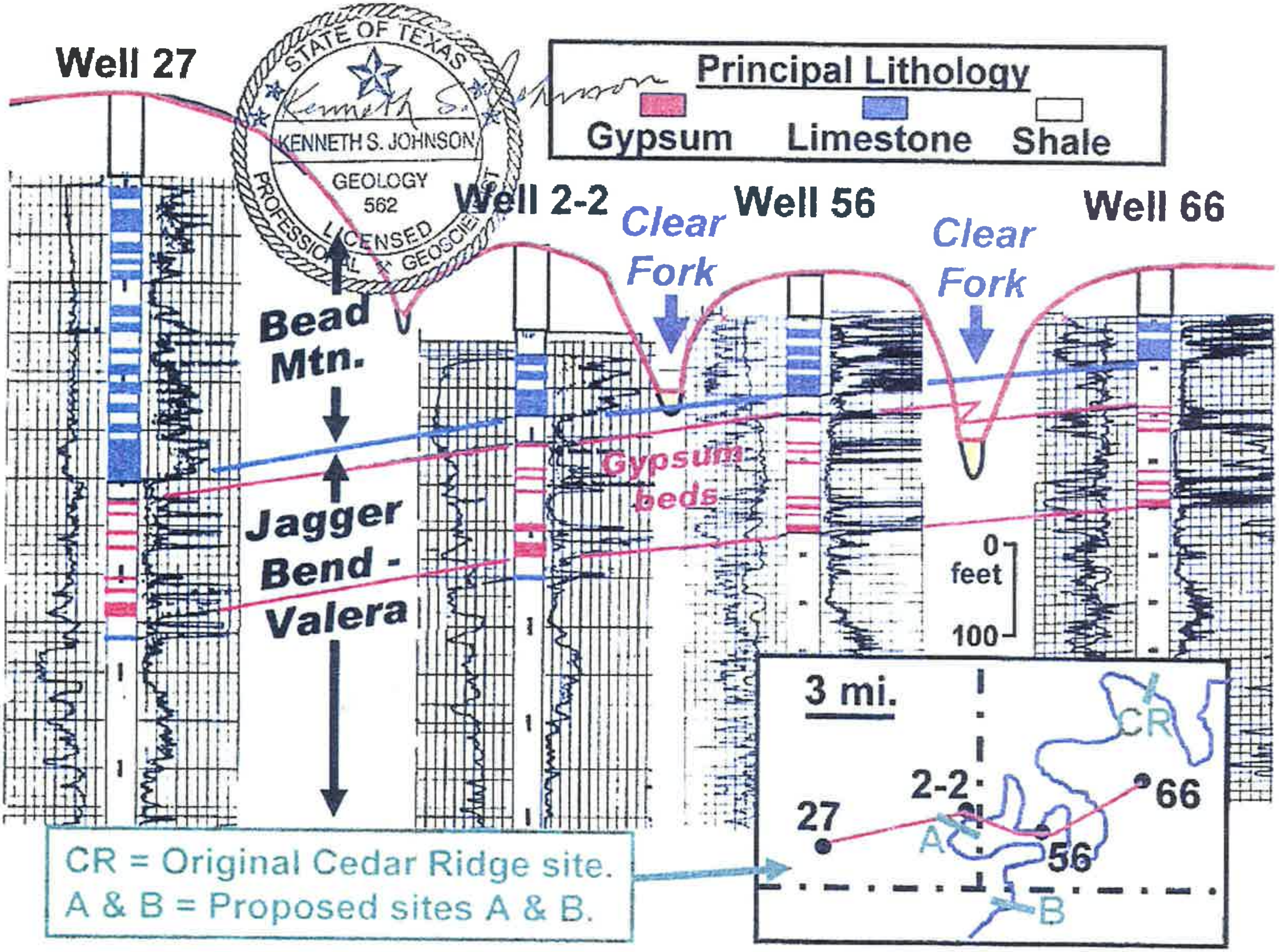

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Figure 3. Structural cross section showing that gypsum beds of the JaggerBend/Valera Formation dip down to the west, and that they thin and disappear by grading laterally into shale towards the east.

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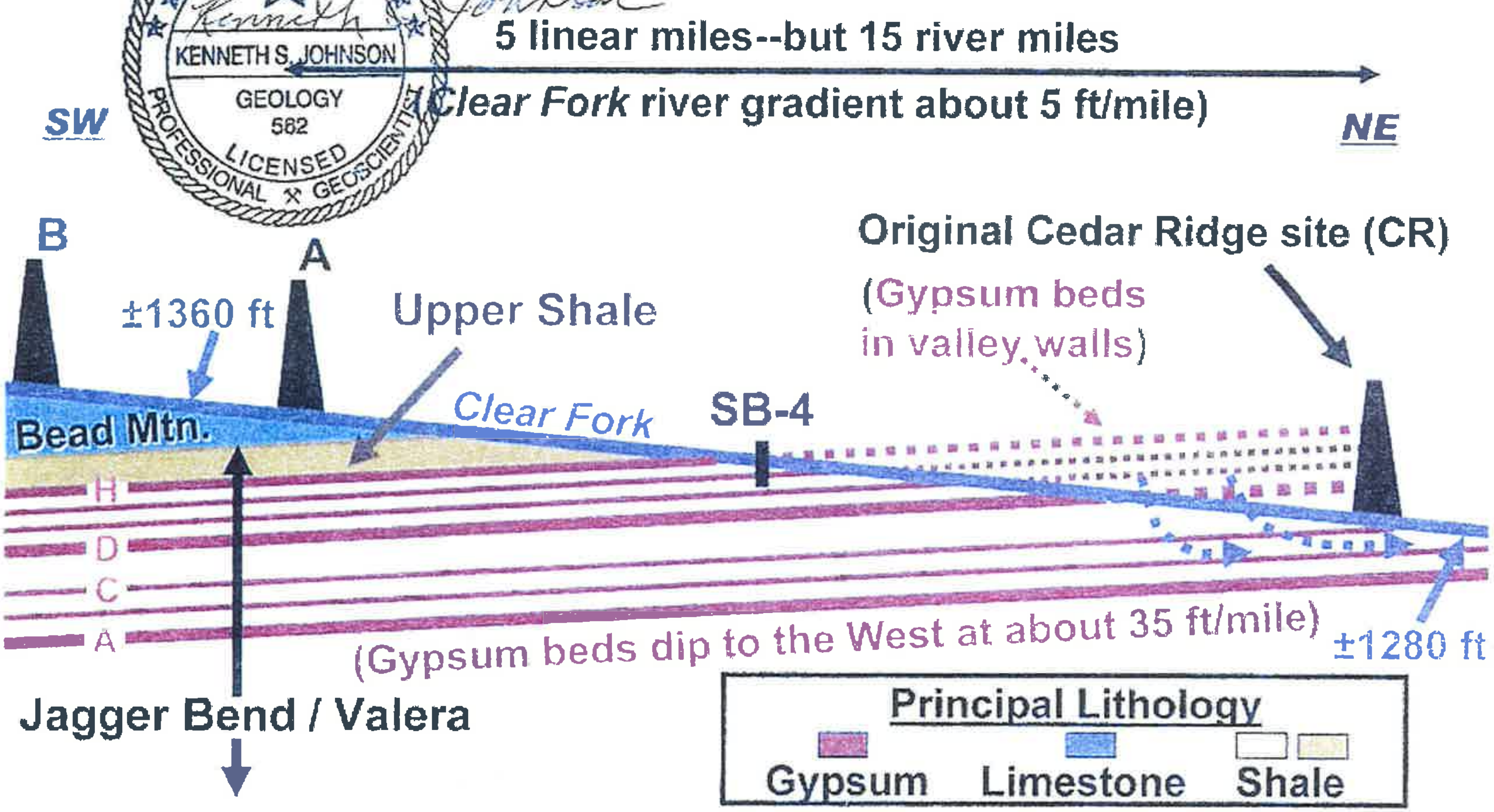


Figure 4. Schematic cross section showing west dip of gypsum beds beneath the Clear Fork of Brazos River and damsites CR, A, and B. Top of gypsum sequence is above stream level at Dam CR, and is about 50 feet below stream level at Dam A and 75 feet below stream level at Dam B. Dashed blue lines in NE show flow lines for potential loss of water beneath or around Dam CR.

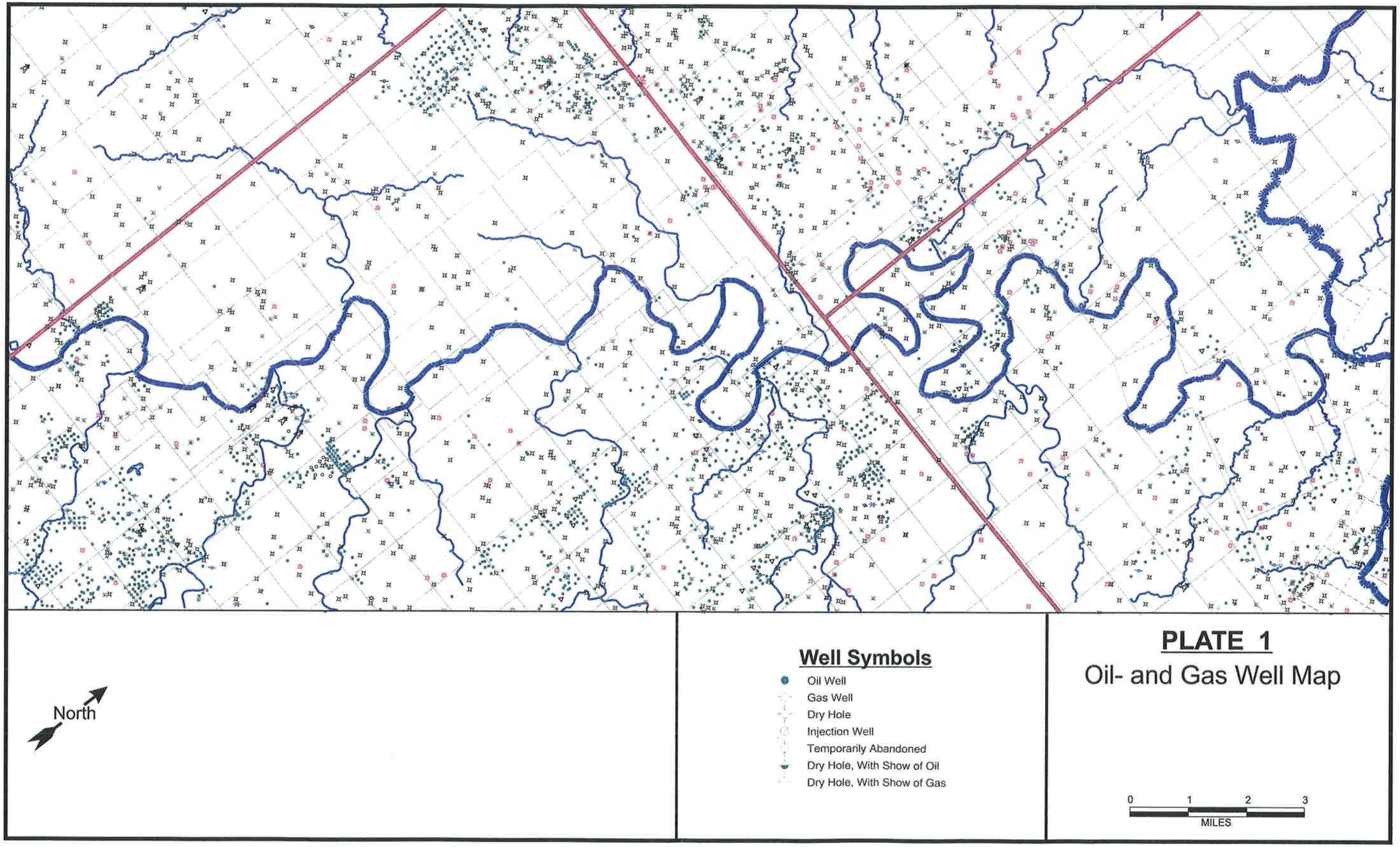
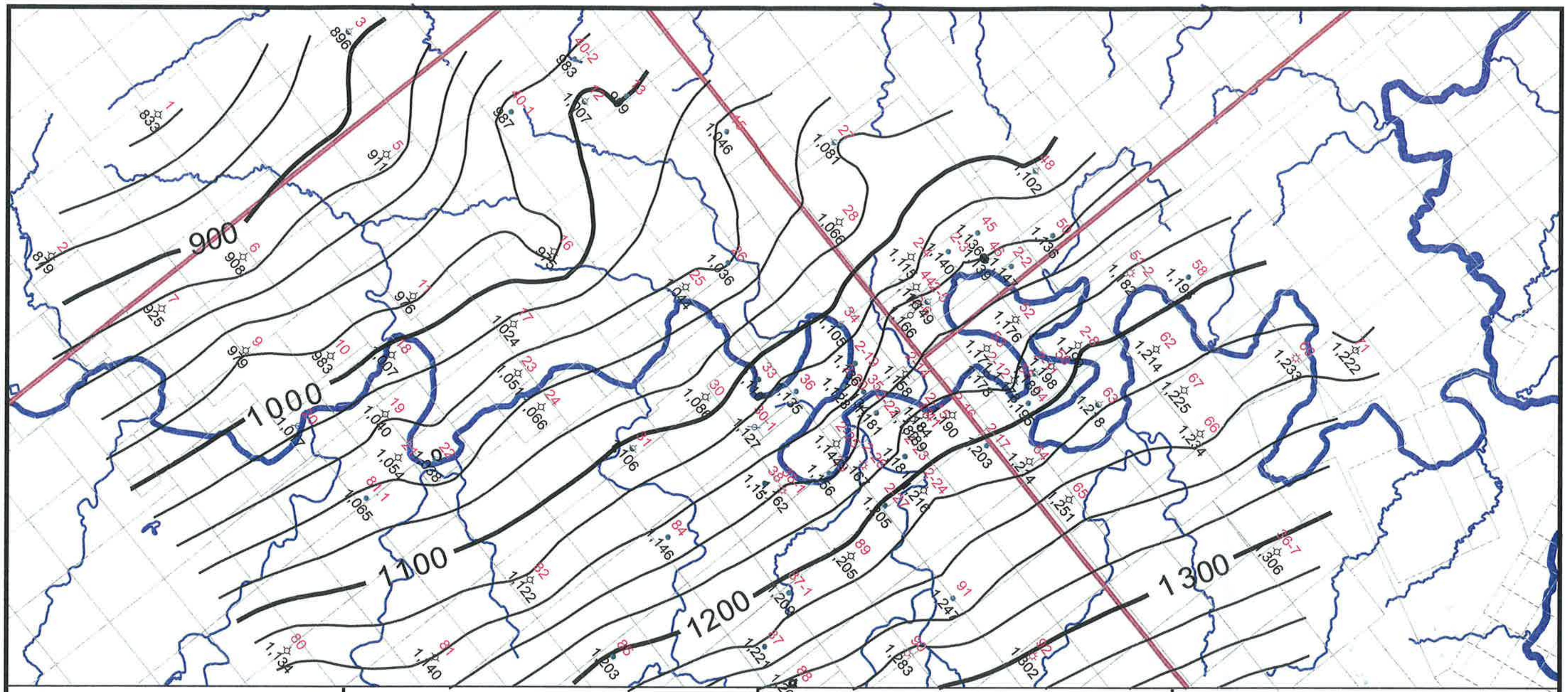


PLATE 1

Oil- and Gas Well Map



North

Well Symbols

- ● Oil Well
- Gas Well
- Dry Hole
- Injection Well
- Temporarily Abandoned
- Dry Hole, With Show of Oil
- Dry Hole, With Show of Gas

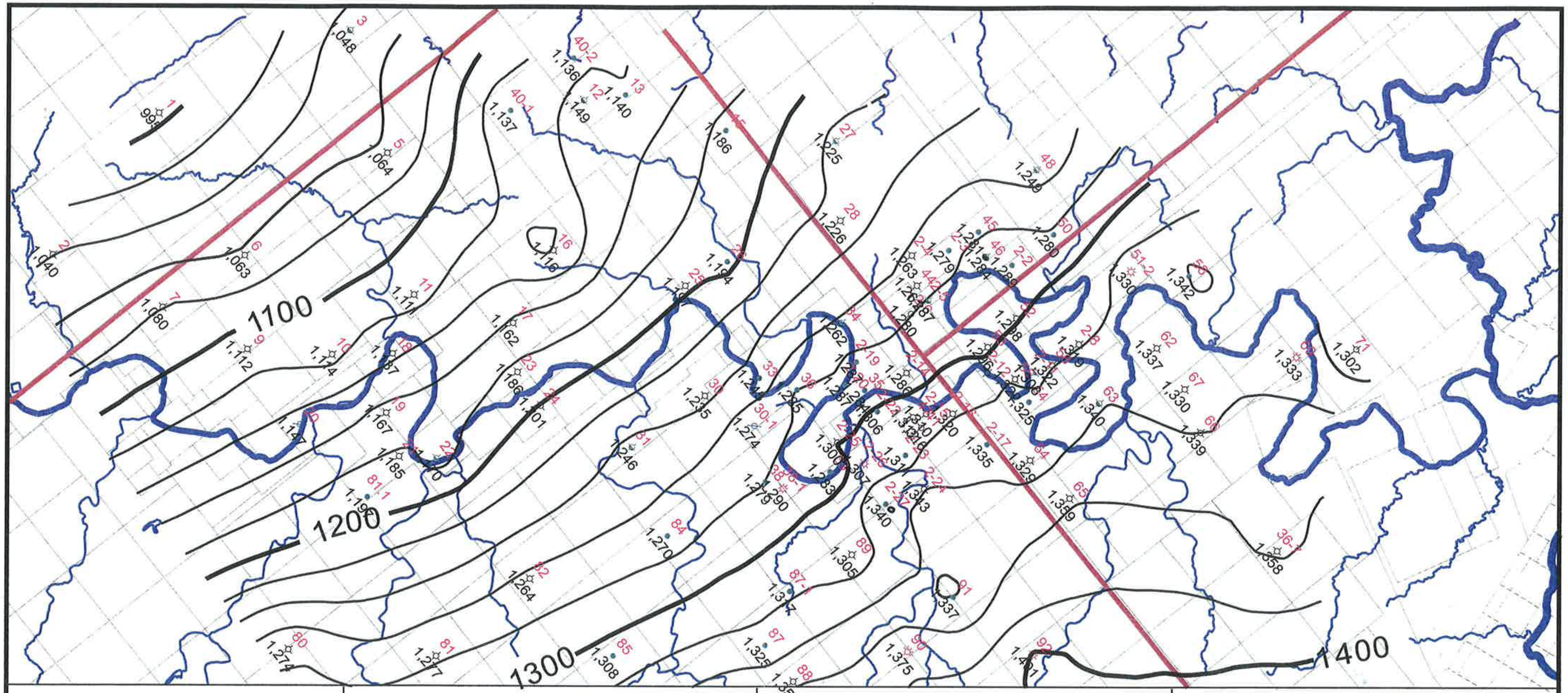
Posted Well Data

91 = Well number
●
1247 = Elevation at base of lowest gypsum bed

PLATE 2

Structure - contour map at base of lowest gypsum in the Jagger Bend / Valera Formation

0 1 2 3
MILES



North

Well Symbols

- ● Oil Well
- Gas Well
- Dry Hole
- Injection Well
- Temporarily Abandoned
- Dry Hole, With Show of Oil
- Dry Hole, With Show of Gas

Posted Well Data

91 = Well number

1,337 = Elevation at top of highest gypsum bed

PLATE 3

Structure - contour map at top of highest gypsum bed in the Jagger Bend / Valera Formation

0 1 2 3
MILES

Table 1. Oil and gas wells used in study, with depths and elevations of gypsum beds.

WELL NO	API NUMBER	ELEVATION OF KB	DEPTH TO TOP GYP	DEPTH TO BASE GYP	GYP THICKNESS	ELEVATION TOP OF GYP	ELEVATION OF BASE GYP
1	42253201680000	1581	586	748	162	995	833
2	42253007060000	1569	529	690	161	1040	879
3	42253319490000	1546	498	650	152	1048	896
5	42417002090000	1574	510	663	153	1064	911
6	42417068030000	1588	525	680	155	1063	908
7	42417381920000	1535	455	610	155	1080	925
8	42417119190000	1826	443	470	27	1383	1356
9	42417300660000	1602	490	623	133	1112	979
10	42417115660000	1574	460	591	131	1114	983
11	42417374760000	1566	455	590	135	1111	976
12	42417075760000	1607	458	600	142	1149	1007
13	42417353620000	1605	465	606	141	1140	999
15	42417359960000	1601	415	555	140	1186	1046
16	42417003570000	1588	472	613	141	1116	975
17	42417376660000	1618	456	594	138	1162	1024
18	42417051550000	1489	352	482	130	1137	1007
19	42417313270000	1600	433	560	127	1167	1040
20	42417342670000	1497	350	480	130	1147	1017
21	42417376980000	1636	451	582	131	1185	1054
22	42417109830000	1533	363	495	132	1170	1038
23	42417341700000	1506	320	455	135	1186	1051
24	42417120680000	1517	316	451	135	1201	1066
25	42417050160000	1512	315	468	153	1197	1044
26	42417378310000	1604	410	568	158	1194	1036
27	42207020410000	1646	421	565	144	1225	1081
28	42207200180000	1596	370	530	160	1226	1066
30	42417383600000	1575	340	489	149	1235	1086
31	42417003410000	1551	305	445	140	1246	1106
33	42417073240000	1470	225	360	135	1245	1110
34	42417312140000	1501	180	337	157	1262	1105
35	42417313840000	1501	217	367	150	1284	1134
36	42417018270000	1492	207	357	150	1285	1135
38	42417318290000	1629	350	478	128	1279	1151
39	42417076990000	1416	133	260	127	1283	1156
41	42417368460000	1461	145	272	127	1316	1189
44	42207324430000	1595	334	479	145	1261	1116
45	42207036010000	1536	255	400	145	1281	1136
46	42207000920000	1594	310	455	145	1284	1139
47	42417069270000	1437	125	255	130	1312	1187
48	42207010130000	1637	388	535	147	1249	1102
50	42207021750000	1518	238	382	144	1280	1136
52	42447022330000	1518	220	342	122	1298	1176
53	42447356370000	1481	185	310	125	1296	1171
54	42447044390000	1525	200	330	130	1325	1195
55	42447052460000	1548	255	375	120	1322	1173
56	42447361490000	1474	152	276	124	1322	1198
58	42447360710000	1541	199	346	147	1342	1195
62	42447052570000	1532	195	318	123	1337	1214
63	42447052750000	1476	136	258	122	1340	1218
64	42447052450000	1404	75	190	115	1329	1214

Table 1. Oil and gas wells (continued).

WELL NO	API NUMBER	ELEVATION OF KB	DEPTH TO TOP GYP	DEPTH TO BASE GYP	GYP THICKNESS	ELEVATION TOP OF GYP	ELEVATION OF BASE GYP
65	42447308230000	1559	200	308	108	1359	1251
66	42447360620000	1481	142	247	105	1339	1234
67	42447052550000	1505	175	280	105	1330	1225
69	42447022720000	1473	140	240	100	1333	1233
71	42447354230000	1500	198	278	80	1302	1222
80	42417373220000	1714	440	580	140	1274	1134
81	42417312470000	1700	423	560	137	1277	1140
82	42417205240000	1602	338	480	142	1264	1122
84	42417325780000	1706	436	560	124	1270	1146
85	42417363460000	1728	420	525	105	1308	1203
86	42417327880000	1721	356	463	107	1365	1258
87	42417354460000	1753	428	532	104	1325	1221
88	42417370090000	1663	305	398	93	1358	1265
89	42417121290000	1570	265	365	100	1305	1205
90	42417051170000	1615	240	332	92	1375	1283
91	42417366830000	1537	200	290	90	1337	1247
92	42417377400000	1646	245	344	99	1401	1302
93	42417379240000	1633	246	273	27	1387	1360
95	42417385880000	1620	195	200	5	1425	1420
96	42417358420000	1771	208	241	33	1563	1530
2-11	42447204430000	1510	202	321	119	1308	1189
2-12	42447046090000	1390		217			1173
2-14	42417306810000	1488	202	330	128	1286	1158
2-15	42417069250000	1517	207	333	126	1310	1184
2-16	42417339680000	1550	230	360	130	1320	1190
2-17	42417065850000	1593	258	390	132	1335	1203
2-19	42417314740000	1452	165	316	151	1287	1136
2-2	42207023190000	1497	208	350	142	1289	1147
2-20	42417304660000	1429	142	301	159	1287	1128
2-22	42417325740000	1449	143	268	125	1306	1181
2-23	42417113910000	1503	192	322	130	1311	1181
2-24	42417362710000	1453	110	237	127	1343	1216
2-25	42417365800000	1450	150	306	156	1300	1144
2-26	42417363410000	1497	190	330	140	1307	1167
2-27	42417368450000	1545	205	340	135	1340	1205
2-3	42207028840000	1584	305	444	139	1279	1140
2-4	42207314520000	1563	300	448	148	1263	1115
2-5	42207201080000	1589	302	440	138	1287	1149
2-6	42207027220000	1498	218	332	114	1280	1166
2-8	42447052690000	1419	100	220	120	1319	1199
30-1	42417358400000	1527	253	400	147	1274	1127
36-7	42447361770000	1496	138	190	52	1358	1306
36-8	42447361800000	1514	167	199	32	1347	1315
38-1	42417373250000	1619	329	457	128	1290	1162
40-1	42417383170000	1617	480	630	150	1137	987
40-2	42417348970000	1581	445	598	153	1136	983
51-2	42447333310000	1527	197	345	148	1330	1182
81-1	42417359440000	1645	448	580	132	1197	1065
87-1	42417333690000	1642	325	433	108	1317	1209
88-1	42417053570000	1724	346	442	96	1378	1282

APPENDIX B

APPENDIX B

GEOLOGIC FIELD MAPPING REPORT, CEDAR RIDGE RESERVOIR

BY J. JACKSON HARPER, P.G.

J. Jackson Harper, P.G.
Geological & Hydrogeological Consulting

GEOLOGIC FIELD MAPPING REPORT,
CEDAR RIDGE RESERVOIR

Prepared for:

Enprotec/Hibbs & Todd, Inc.
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Project No. 09001
7 August 2009

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1.0 Introduction

Geologic field mapping was conducted as part of ongoing geologic evaluations for the proposed Cedar Ridge Reservoir. The work was conducted from March 14-24, 2009 along a 20-mile reach of the river valley upstream of an initially preferred dam site. This report is a compilation of the collected data and observations made during field mapping.

2.0 Purpose and Scope

A preliminary geotechnical investigation by Fugro Consultants, Inc. (Fugro, 2009) revealed the presence of several gypsum layers that could compromise the long-term stability of a dam at an initial dam site located five miles upstream of the Clear Fork's confluence with Paint Creek. As a result, several tasks were undertaken to further delineate the extent of the gypsum beds and to assess geological conditions at three alternate dam sites selected upstream of the initial site.

2.1 Gypsum Identification

Borings and outcrops at the initial dam site indicated that the gypsum occurred within the undifferentiated Jagger Bend-Valera formations, beginning approximately 40 feet below the overlying Bead Mountain Formation. Individual gypsum layers up to 6 feet in thickness were encountered in the borings, and the layers appeared to be laterally continuous in the area of the initial investigation.

Kenneth S. Johnson Co. examined geophysical logs for more than 50 oil wells in the project area and prepared structural contour maps of the gypsum zones identified near the initial dam site. The beds were found to be laterally persistent and correlatable throughout the project area. Consequently a major focus of the field mapping tasks was to confirm the presence of the gypsum zones by visiting points where the zones were predicted to outcrop. In addition, field mapping would look for gypsum outcrops in areas where they were not expected to occur.

2.2 Mapping of Principal Geologic Units

Available geologic maps of the project area were either at scales that were too small (e.g., 1:250,000) to show the geologic units in practical detail for the project or presented on Texas land survey base map that had few ground reference points and no vertical control (i.e., topographic contours). Consequently, the field mapping task sought to locate, identify, and document the major stratigraphic units and geologic features that could influence siting of a dam and emergency spillway. The geologic mapping included describing, measuring, and photographing rock outcrops with respect to lithology, formational boundaries, bedrock strikes and dips, and fracture geometry and characteristics.

In addition to visiting points of geologic interest across the project area, the tentative alignments for dam alternatives A and B were walked to obtain more detailed information for each dam site. Similarly, the hillsides on both sides of the narrow ridge (i.e., gooseneck) upstream of dam site A were walked to gather information about this critically located feature.

2.3 Methods

The field mapping was conducted by Kevin Mandeville (Fugro project geologist) and J. Jackson Harper. The mapping focused on the Clear Fork stream valley between the initially preferred dam site and alternate dam site C and between the stream channel and a valley sidewall elevation of about 1,500 ft above mean sea level (msl). Practically all of the roads within these boundaries were traversed by four-wheel, all-terrain vehicle. In addition, numerous reaches of Clear Fork stream bank, tributary drainages, and hillsides were traversed on foot. Figure 1 shows the locations of discrete points, transects, and dam alignments where geologic data were collected. Figure 1 also serves as an index to figures 2 through 9, which present the same information at a larger scale.

During the course of field work, the mapping team had the opportunity to participate in a helicopter flight along the Clear Fork stream valley between the town of Leuders and the Clear Fork's confluence with Paint Creek downstream of the initial dam site. The flight provided an excellent opportunity to develop an overall perspective on study area geology, and it helped identify several outcrops that were subsequently visited on the ground.

Notes on formational contacts, formation lithology, stratigraphic strike and dip, and joint patterns were recorded and are included as Appendix A to this report. Strike and dip measurements are presented in the notes in the form 'strike/dip'. Strike (i.e., directional bearing of a horizontal line across a planar surface) is reported in degrees relative to true north. Dip (i.e., tilt of the planar surface) is reported in degrees (0°-90°) below horizontal. By the 'right-hand' convention, the directional bearing of dip is 90° to the right (i.e. clockwise) of the strike direction. The jointing patterns measures at four sites are included in the notes and are shown on Figure 10. The strike and dip measurements made at nine sites are shown on Figure 11.

Many of the geologic and topographic features of interest were documented with photographs. These are presented in Appendix B with descriptive captions.

Geographic positions for points of geologic and/or topographic interest were measured using a GPS receiver. In most instances, a Trimble ProXH receiver was used and the field readings were later differentially corrected using GPS data from four Texas Department of Transportation base stations. This resulted in positions having a horizontal accuracy that was commonly less than one-half meter (1.7 ft). The corresponding vertical accuracy is approximately two to three times the horizontal accuracy. A few positions were measured using a Garmin GPSMAP 76CSx receiver, which uses real time WAAS differential correction and typically has a horizontal accuracy of 15 ft. Vertical accuracy of the Garmin measurements is unpredictable.

3.0 Geological Observations

Published information about the physiography and geology of the project area has been summarized in a geological reconnaissance report by Fugro (2009). Briefly, the bedrock units that outcrop within the study area consist of Permian age formations of the Wichita-Albany Group. From oldest to youngest, they are the Jagger Bend and Valera formations undivided (Pjv), the Bead Mountain Formation (Pbe), and the Grape Creek Formation (Pgc). These formations consist predominantly of alternating layers of limestone and shale. Along the Clear Fork channel, the bedrock units have been eroded and are overlain, in most places, by recent Quaternary age alluvium (Qal) and, in some areas, by slightly older and topographically higher fluviatile terrace deposits (Qt). These stream deposits consist primarily of gravel, sand, silt, and clay.

3.1 Alluvium

Fluvially deposited Quaternary alluvium occurs almost continuously along the Clear Fork of the Brazos River between alternate dam site C and the initially preferred dam site. The alluvium occurs primarily as low, 5 to 15 ft high terraces that border either side of the active channel. The alluvium deposits are generally narrow along straight reaches of the Clear Fork and on the outsides of stream bends (photos A01c and B11c). On the insides of most stream bends, the alluvium is noticeably wider and frequently occurs as point bars (photos A15a and N2-02). There are few instances where steep exposures of bedrock (either shale or limestone) crop out along the stream bank. Two examples are shown in photos Z03 and Z07.

Sediments comprising the point bars are mostly limestone gravels and cobbles and sand. Otherwise, the alluvium on either side of the active stream channel is mostly pale yellowish brown silty to clayey sand with varying amounts of colluvium from the adjacent hillsides. Beneath the active stream channel, the alluvium appears no more than a few feet thick and consists mostly of limestone gravels and cobbles; similar to the point bars. The active channel is floored occasionally by resistant limestone.

Approximately 7,000 ft east-southeast of alternative dam site A, a narrow ridge (i.e., gooseneck) separates segments of the Clear Fork channel that are upstream and downstream of dam site A. On the south (i.e., upstream) side of the ridge the alluvial terrace is approximately three feet high at the stream's edge and rises steadily to a height of 13 ft above stream level at a distance of 35 ft from the channel. On the north side of the ridge, the alluvium is approximately 100 ft wide and rises to a height of 17 to 22 ft above stream level. However, in this instance, the sediments farthest from the stream may be older Quaternary terrace deposits (Section 3.2).

3.2 Terrace Deposits

Quaternary terrace deposits that predate the more recent alluvium discussed in Section 3.1 occur throughout the study at heights as much as 30 ft above the current day stream level. Two types of occurrences seem to predominate.

In the first case, areally extensive deposits mantle the gentle slopes and low ridges found on the insides of large bends of the Clear Fork, such as Shinnery Bend, the bend southeast of dam site A, and the bend west of dam site B. The terrace deposits in these areas seem to form a thin veneer over the underlying shale and bedrock strata. The deposits presumably become thinner with increasing distance from the river. Their thickness is uncertain, but there are areas where the underlying bedrock is exposed and areas where the terrace deposits may be up to 10 ft thick.

In the second case, the terrace deposits occur as 15-20 ft high vertical exposures on 'cut banks' (i.e., outside bends) of the Clear Fork. In these instances, the stream channel appears to have migrated and eroded the older, thick terrace deposits to form the distinctive vertical exposures (Photo Z32).

The older terrace deposits are typically light red to red and consist of clayey silt with varying amounts of sand and gravel. The clay content of the material is, presumably, what enables the material to stand vertically. Gravelly zones appear to be distributed irregularly both laterally and vertically within the terrace deposits, even within localized exposures. The irregular distribution of particle size is probably attributable to variable energy levels associated with depositional events. That gravels are present at all levels within the terraces indicates they were deposited fluvially for the most part. But, local absences of coarse sediment suggest some deposits could have an aeolian origin.

The Quaternary terrace deposits also are found in association with the semi-circular landform known as Round Valley in the northern part of the study area. As previously stated (Fugro, 2009), this features is probably an oxbow cutoff that was eroded by the Clear Fork at a time when the river was at a higher elevation.

3.3 Jagger Bend and Valera Formations

The Permian age Jagger Bend and Valera formations (undivided) make up the lowest stratigraphic unit of interest in the project area. In geotechnical borings drilled at the initially preferred dam site (Fugro, 2009) the Jagger Bend-Valera consisted of alternating beds of limestone, shale and gypsum. The limestone was described as gray and slightly fractured, and locally dolomitic. The shale was described as dark bluish gray, non-calcareous, and low to moderately hard. Multiple gypsum beds were found to occur mainly within two zones (i.e., upper zone "A" and lower zone "B") between approximately 40 ft and 135 ft below the top of the Jagger Bend-Valera.

Due to gypsum's solubility, the occurrence of gypsum layers would be a significant factor in the selection of a dam and reservoir site. Kenneth S. Johnson Co. subsequently examined geophysical logs for more than 50 oil wells in the project area and prepared structural contour maps of the gypsum zones identified near the initial dam site. The contours of the top of the upper gypsum zone are reproduced on Figure 11.

One focus of geologic field mapping was to confirm the presence of the gypsum zones by visiting points where they were projected to intersect the land surface. In parts of the study area north of Shinnery Bend, such outcrops were expected to be between river level and the lower slopes of the Clear Fork stream valley. Over the six-mile reach of river valley south of Shinnery Bend, gypsum outcrops were likely to occur near river level only. Despite extensive searching, no projected gypsum outcrops were found. This is attributed to the outcrops being extensively covered by alluvium, higher terrace deposits, or colluvium. However, a few outcrops of Jagger Bend-Valera were found and are summarized below.

- <u>Point Z07</u> – This is a 20-ft high vertical exposure of interbedded shale and limestone at stream level on the east bank of the Clear Fork channel (Photo Z07). Quaternary terrace deposits that contain gravel occur at the top of the outcrop.

- Point Z08 – This 6-ft high predominantly shale outcrop on the east bank of the Clear Fork was notable for the occurrence of mineral precipitate on the surface of the exposure. The mineral is suspected to be disseminated, microcrystalline gypsum.

- Point Z11 – This site included a 20-ft vertical section of weathered shale in a road cut and an adjacent gully (Photo Z11a). No gypsum was evident, but an interesting sample of calcite boxwork (Photo Z11b) was found in the weathered shale. It is suspected that drying and rehydration of gypsum created a network of veins in the weathered shale, and that calcite formed in the veins after the original gypsum had dissolved (Palmer and Palmer, 2000).

- Point Z12 – This as an approximately 15-ft vertical section of shale exposed on a low ridge just above alluvium. No gypsum was observed.

3.4 Bead Mountain Formation

The Bead Mountain Formation overlies the Jagger Bend-Valera and consists primarily of thin- to thick-bedded, hard, fossiliferous limestone, with some interbedded gray to bluish gray shale. The Bead Mountain is approximately 100 ft thick, and its full section crops out along the stream valley within the study area. It forms steeper slopes than the underlying Jagger Bend-Valera and the lowermost part of the overlying Grape Creek Formation.

One of the immediately obvious characteristics of the Bead Mountain (as well as the overlying and underlying bedrock formations), is that the limestone beds are extensively jointed and fractured in outcrop. Fracturing may result when softer shale beds are eroded and the limestone beds lose support. In addition, cyclic shrinkage and expansion of weathered shale due to moisture content changes may promote jointing and fracturing. Regardless of the cause, the stream valley slopes are blanketed extensively by colluvium that consists of small to large limestone blocks intermixed with weathered shale (photos A06, A11, B08, and B20). The colluvium mostly obscures the underlying bedrock, and it was one reason why expected gypsum exposures were covered.

Nonetheless, some good exposures of Bead Mountain were found, primarily along tributaries of the Clear Fork. Examples include Buffalo Draw (photos Z09 and Z10), Wolf Creek (photos Z27a, b, c and Z29a), and an unnamed drainage at Shinnery Bend (photos Z13a, b, and c). These exposures were the primary source of bedrock joint and strike/dip measurements discussed in Section 3.6.

3.5 Grape Creek Formation

The Grape Creek Formation overlies the Bead Mountain and consists of alternating beds of limestone and shale with an overall thickness ranging between 100 to 120 feet. The limestone is pale yellow to light gray, fine to coarse-grained, nodular, argillaceous, and very fossiliferous, with individual beds from 1 to 2 ft thick. The weathered shale is pale yellow to greenish-gray and clayey.

The descriptive logs for the geotechnical borings drilled at the initially preferred dam site (Fugro, 2009) place the contact between the Bead Mountain and Grape Creek formations at the base of a 30-ft thick, predominantly shale interval above 100-ft thick predominantly limestone interval. This contact is not readily observed in outcrop due to the amount of colluvium that mantles the hillsides in the project area. However, in most cases, there is a visibly discernable change in slope at the contact, with the Grape Creek Formation having a slightly gentler slope. Also, there is a prominent, 11-12 ft thick, resistant section of Grape Creek limestone approximately 30 feet above the base of the formation (photos B10, B20, and N1-16).

3.6 Structural Geology

The occurrence of northeast- and northwest-trending, straight channel segments along the Clear Fork of the Brazos strongly suggests that bedrock jointing and/or faults influenced the stream course. The horizontal directions of joints in limestone bedrock were measured at four sites in the project area, and the data are tabulated below and shown on Figure10. Based on simple visual inspection, most of the straight, northeast- and northwest-trending stream segments correlate well with the joint patterns measured at points Z10, A29, and N3-03.

Joint Measurements

Point	Location	Description	Joint Directions
A29	Dam A alignment	Pgc boulder field	52°, 157°
N3-03	Neck 3	Pbe bedrock in drainage channel	46°, 161°
Z10	Buffalo Draw	Pbe bedrock in drainage channel	20°, 145°
Z27	Wolf Creek	Pbe bedrock in drainage channel	29°, 123°

Strike and dip measurements of limestone beds were made wherever possible. However, the number of readings was limited due to difficulty finding outcrops where the beds were intact and not slumped downslope. The data are tabulated below and are shown on Figure 11 together with structural contours of the top of the upper gypsum zone in the project area. The correlation between the contours and the strike and dip measurements is poor, except in a gross sense. This may reflect the inclusion of some strike/dip readings from bedrock that was not intact and/or inaccuracies in contouring. Lastly, no faults were observed in the project area during field mapping, and the structural contours depicted on Figure 11 are inconclusive with respect to the occurrence of faults.

Strike and Dip Measurements

Point	Location	Description	Strike / Dip
A02	Dam A alignment	Pbe just above river level	205° / 1°
B11	Dam B alignment	Pgc bluff	180° / 6°
C03	Dam C alignment	Pgc bluff	215° / 2.5°
N1-13	Gooseneck transect	Pgc bluff	120° / 1.5°
N3-02	Gooseneck transect	Pbe bedrock in drainage channel	162° / 3.5°
Z03	Clear Fork stream bank	Pbe bedrock at stream level	210° / 1°
Z09	Buffalo Draw	Pbe bedrock in drainage channel	129° / 1.5°
Z10	Buffalo Draw	Pbe bedrock in drainage channel	100° / 1°
Z13	Steep drainage	Pbe bedrock in drainage channel	248° / 0.5°
Z31	Clear Fork stream bank	Pbe bedrock at stream level	200° / 1.5°
Z08	Clear Fork stream bank	Pjv	129° / 1.5°

4.0 Ground Water Observations

A review of the current regional water plan covering the study area indicates there are no major or minor aquifers used for water supply in Shackelford, Throckmorton, and eastern Haskell counties. Published ground water reports for Shackelford and Throckmorton counties (Preston; 1969 and 1970) state the Jagger Bend, Valera, and Bead Mountain formations are capable of producing only small amounts of water from erratically-distributed, low-permeability zones on or near the formations' outcrops. The Grape Creek Formation is not known to yield ground water in these counties. The only wells mentioned in these reports were hand dug domestic and livestock wells located outside of the Clear Fork stream valley.

The Texas Water Development computerized ground water database contained records of a few water wells east and south of alternate dam site C, which are used in conjunction with petroleum production. The wells appear to produce saline water that is reinjected as part of secondary oil recovery. The wells vary from approximately 1,200 to 1,800 ft deep.

No evidence of ground water springs or seeps was observed in the Clear Fork stream valley, including the contributing drainages to the main stream. However, following periods of rain, runoff may be expected to infiltrate the alluvium, terrace deposits, and small fractures in weathered bedrock and produce temporary seeps on some hillsides or near stream level.

5.0 Conclusions

Based on the observations made of the surface geology during field mapping and the information made available on subsurface geology at the time of this report, the following conclusions have been made concerning geologic conditions in the project area.

1. The lithology of the Jagger Bend-Valera, Bead Mountain, and Grape Creek formations is remarkably consistent within the project area.

2. There is no indication of major faults in the project area. Straight stream segments and sharp turns of the river channel are most likely controlled by joints or by faults with offsets of a few feet.

3. The structural geology of the bedrock units appears to be relatively simple and will be best refined using borings with accurate horizontal and vertical control.

4. Formational strike measurements varied from 100° to 248°. Given the small dip angle of the bedrock strata (i.e., generally 0.5° to 1.5°), this variability may only be due to minor, localized undulations in the bedding.

5. Subsurface borings will be the only reliable means for identifying the presence or absence of gypsum layers in areas of concern.

6. The bedrock strata in the project are highly fractured in outcrop throughout the project area. Unless subsurface cores of the rock suggest otherwise, this fracturing is most likely attributable to surficial weathering.

7. The depth extent of this surficial fracturing is unknown and needs to be considered for all structures that will need to have their foundations in competent bedrock.

8. The Quaternary terrace deposits and alluvial deposits are plentiful in the project area and are expected to be good sources of material for a variety of construction purposes.

6.0 References

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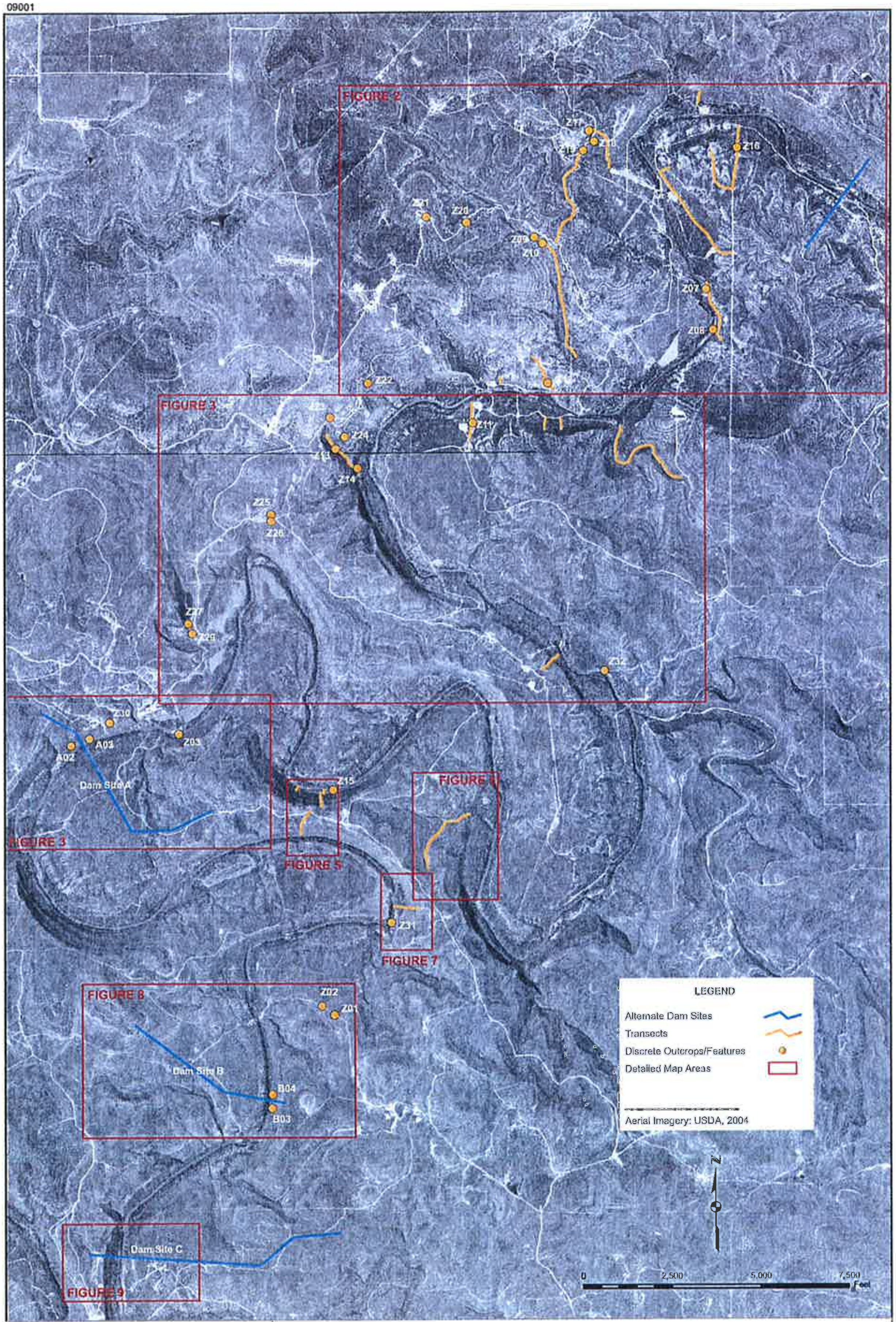

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FIGURE 1

GEOLOGIC FIELD MAPPING AREA
(MARCH 14-24, 2009)

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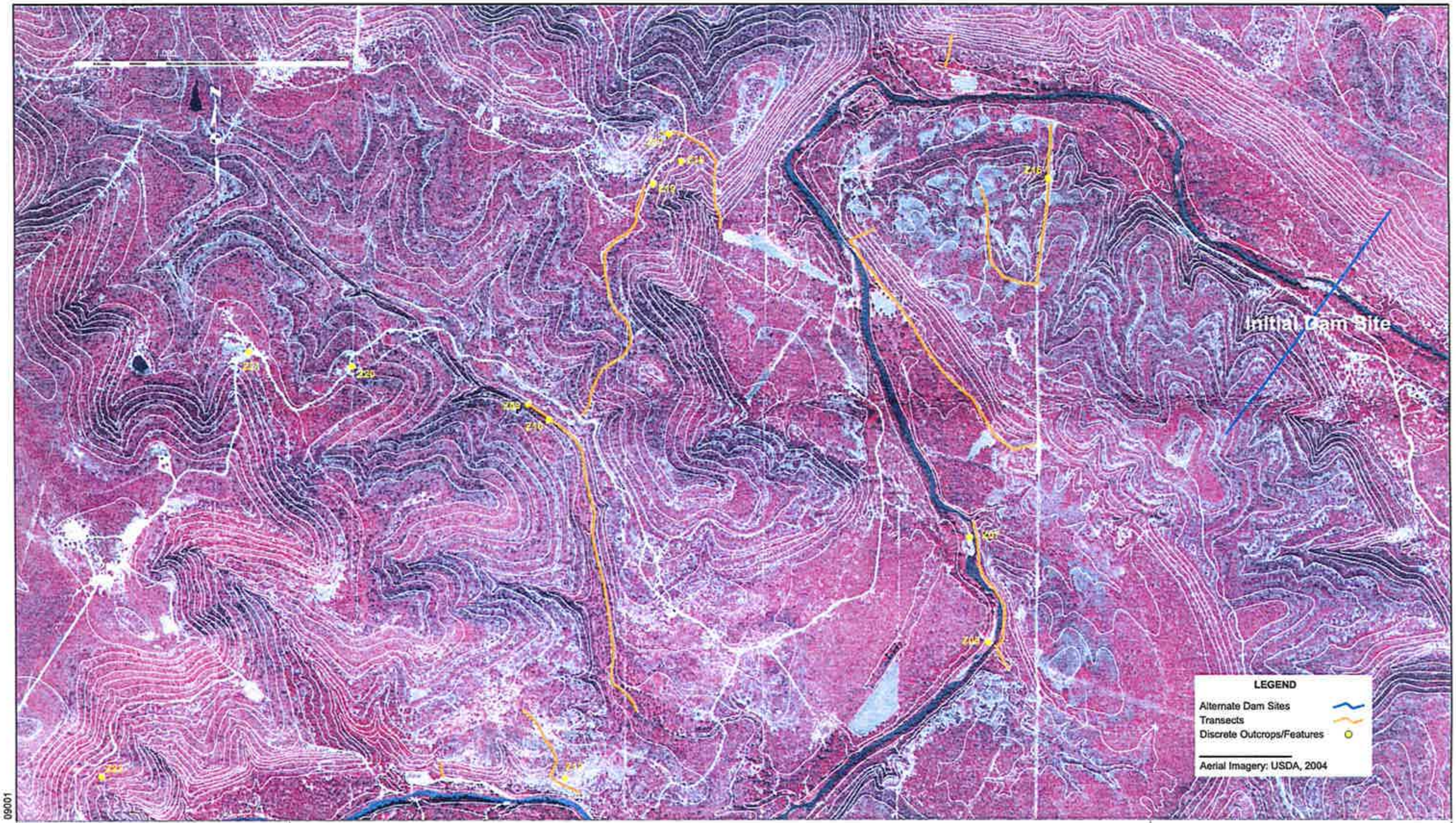

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FIGURE 2

GEOLOGIC TRANSECTS AND OUTCROPS
SHINNERY BEND TO CEDAR RIDGE

Cedar Ridge Reservoir Project

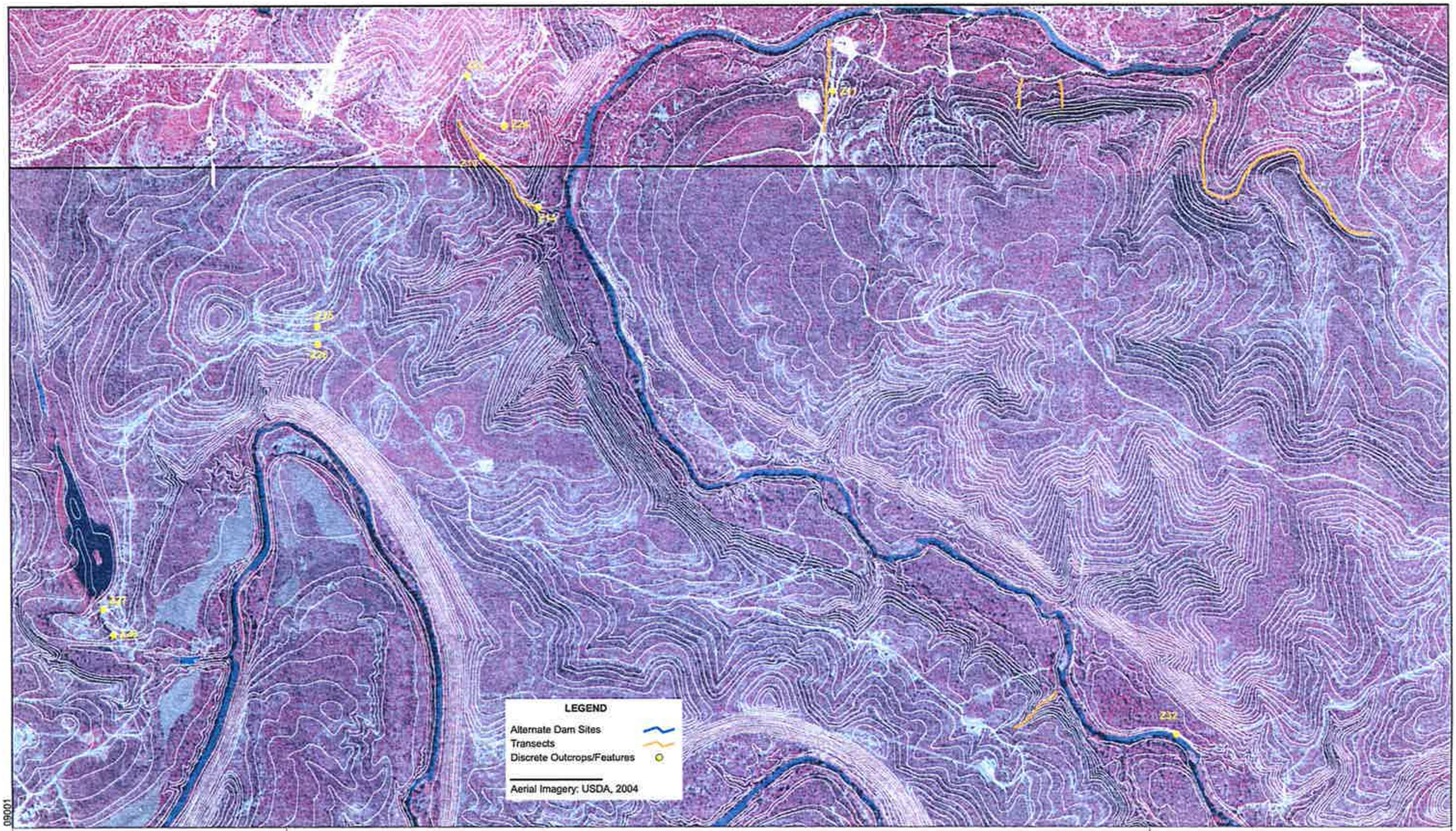

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FIGURE 3

GEOLOGIC TRANSECTS AND OUTCROPS
WOLF CREEK TO SHINNERY BEND

Cedar Ridge Reservoir Project

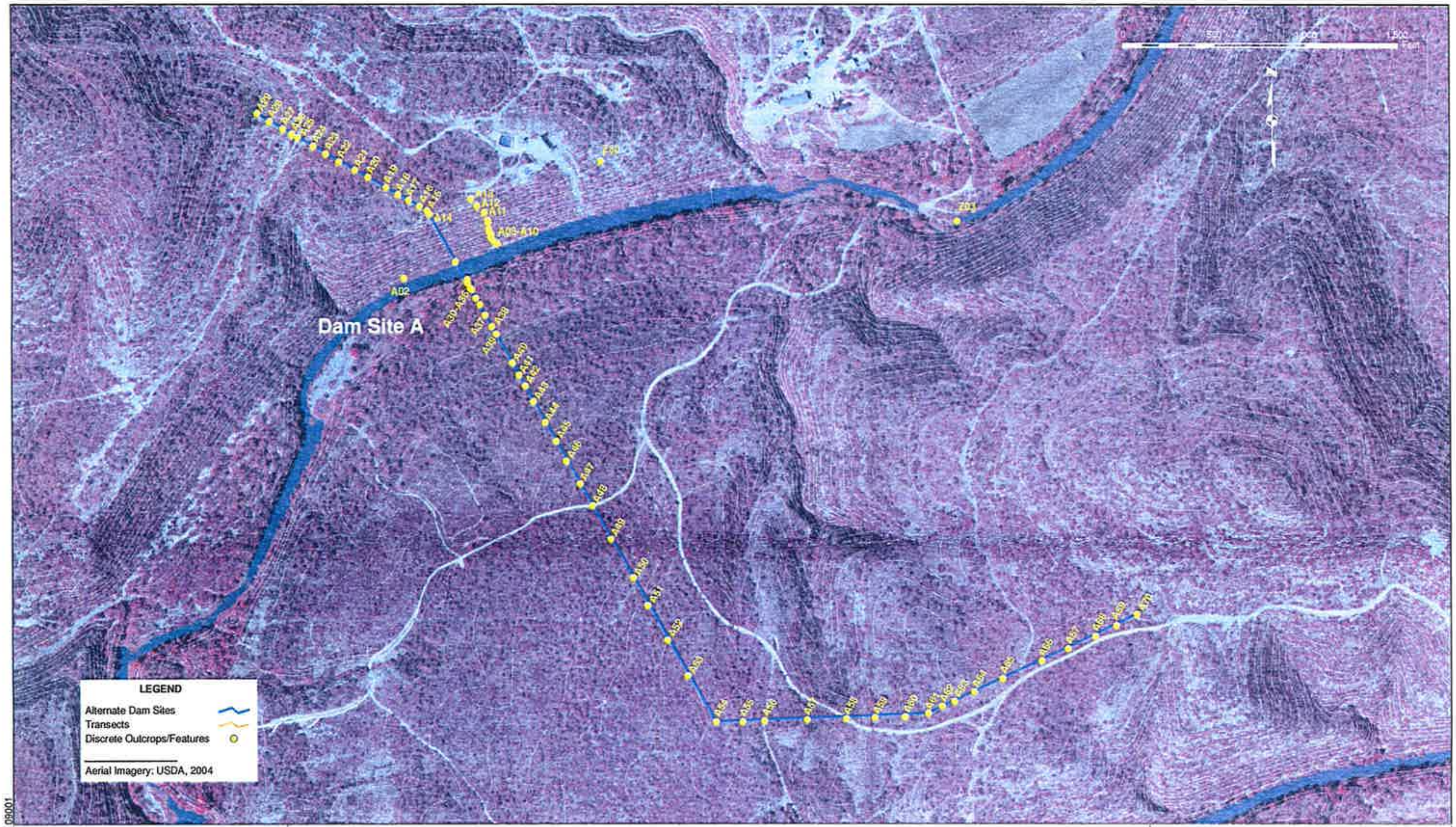

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FIGURE 4

GEOLOGIC TRANSECTS AND OUTCROPS
DAM SITE A

Cedar Ridge Reservoir Project

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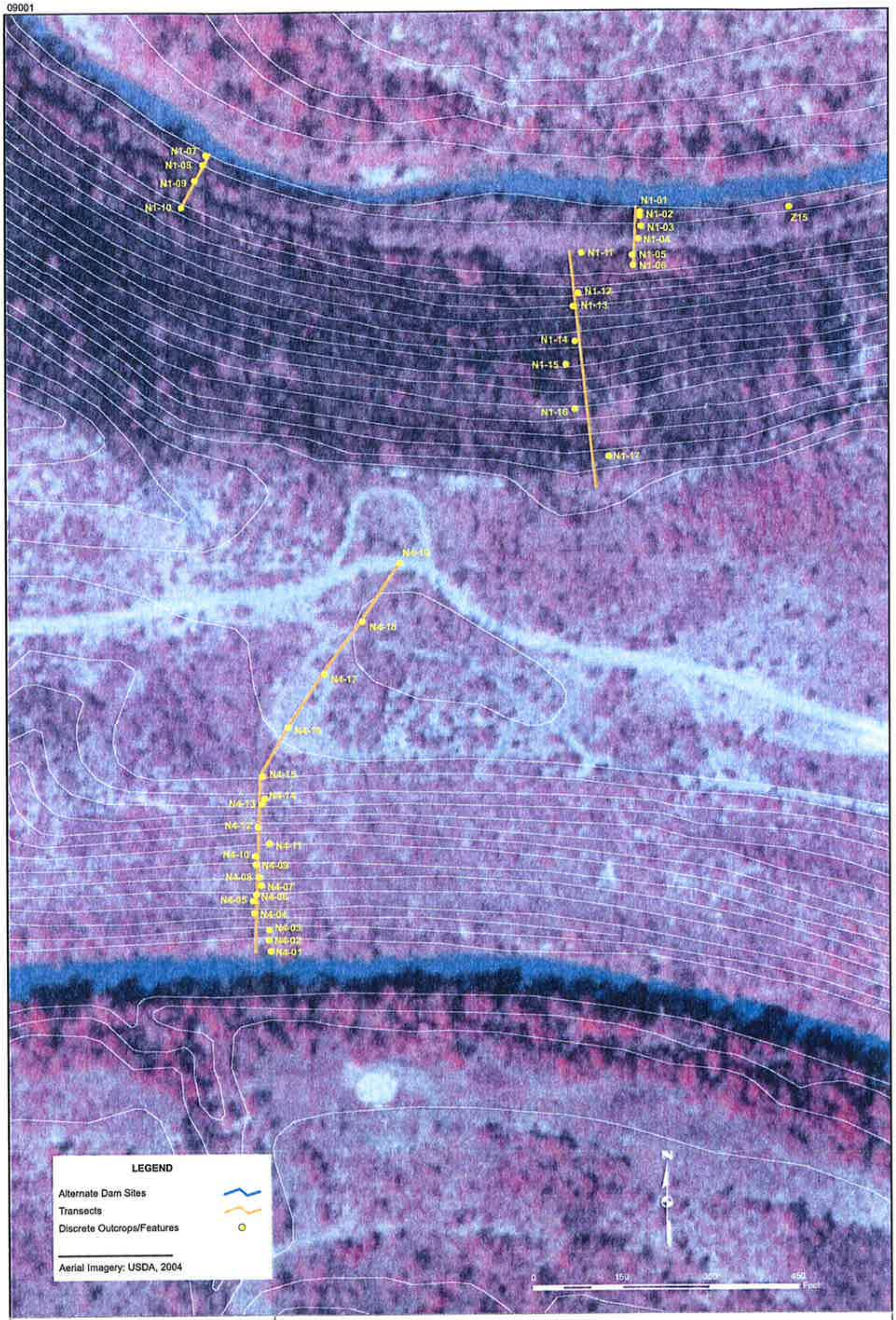

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FIGURE 5

GEOLOGIC TRANSECTS AND OUTCROPS
GOOSENECK TRANSECTS 1 AND 4

Cedar Ridge Reservoir Project

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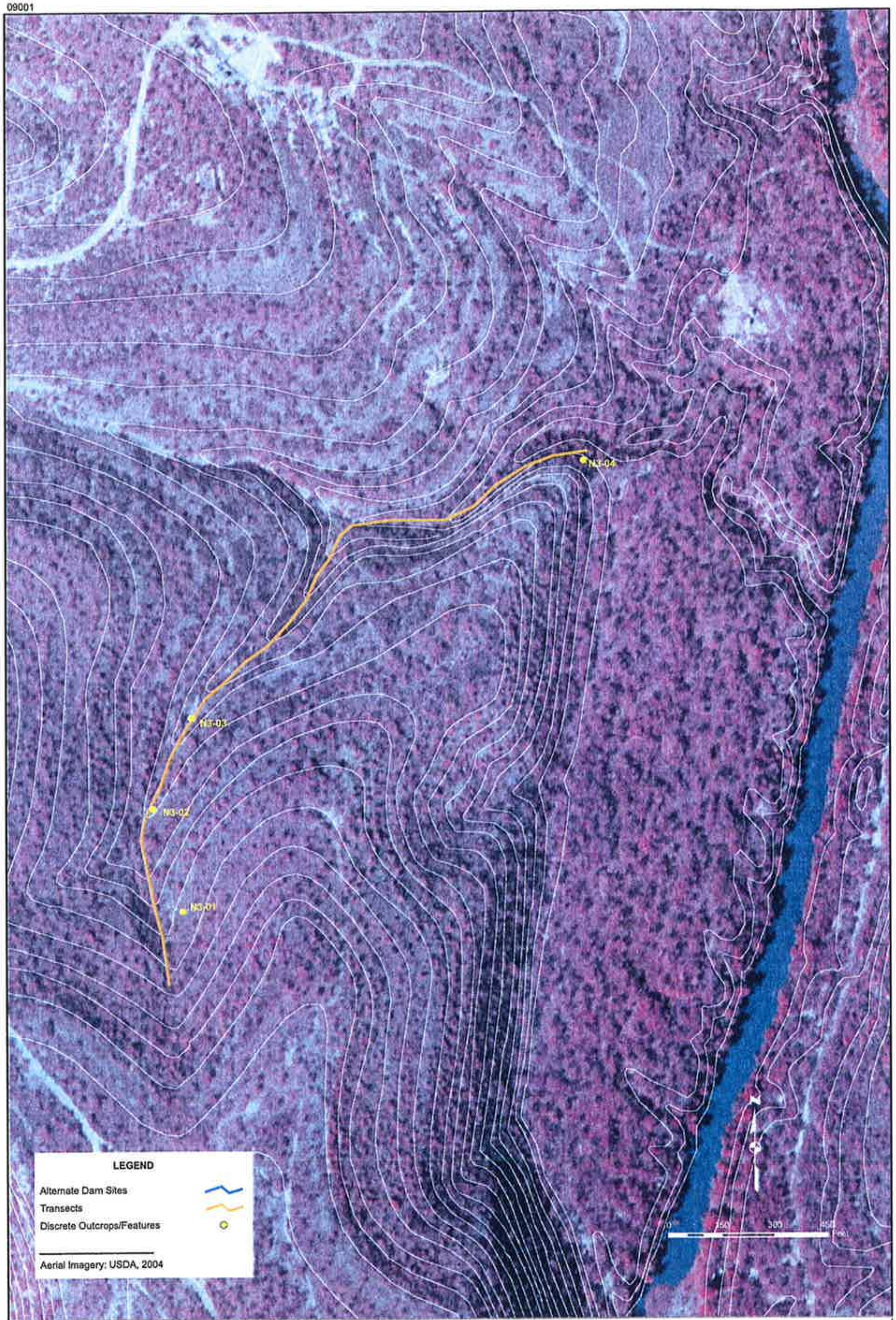

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FIGURE 6

GEOLOGIC TRANSECTS AND OUTCROPS
GOOSENECK TRANSECT 3

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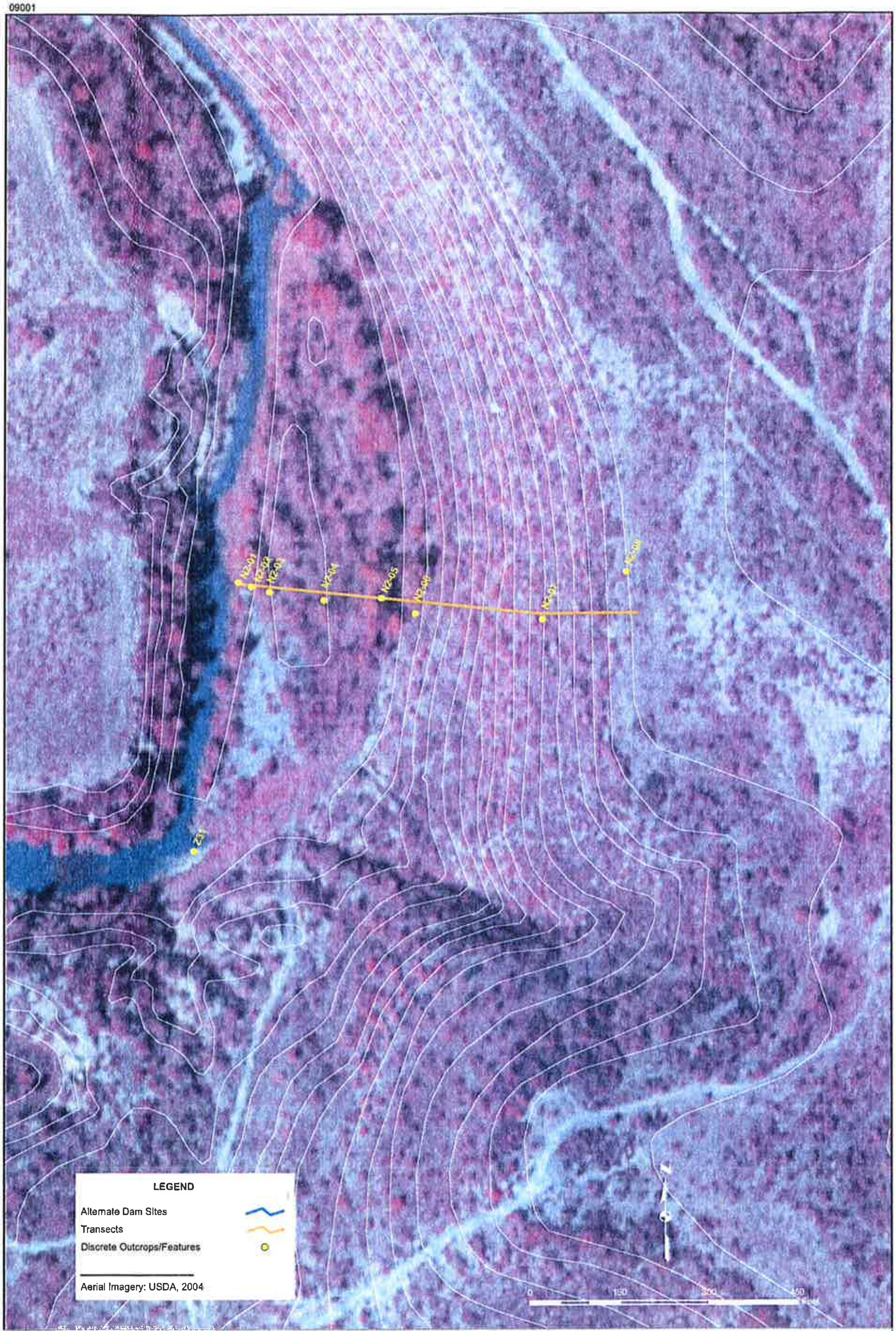

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FIGURE 7

GEOLOGIC TRANSECTS AND OUTCROPS
GOOSENECK TRANSECT 2

Cedar Ridge Reservoir Project

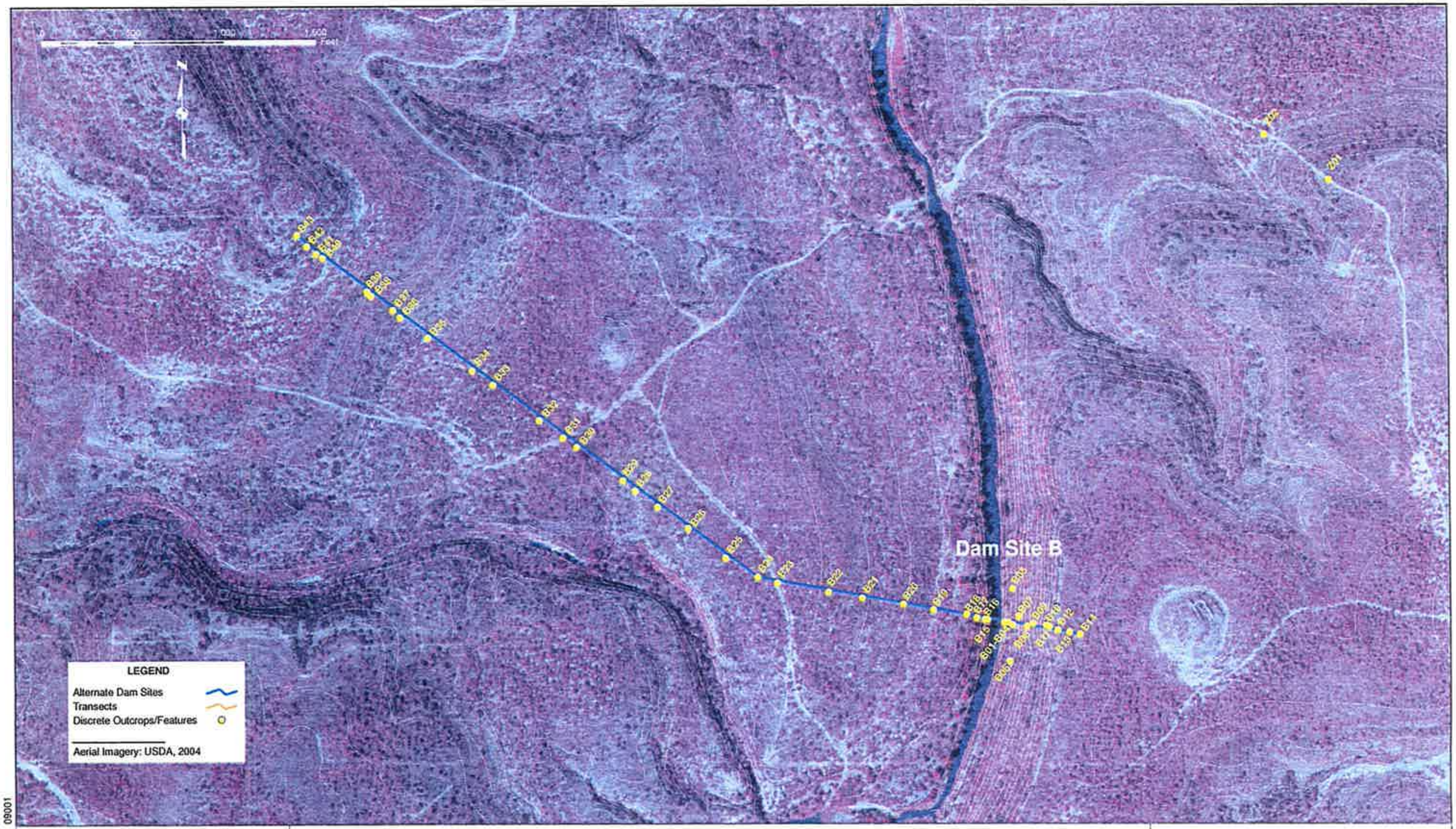

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FIGURE 8

GEOLOGIC TRANSECTS AND OUTCROPS
DAM SITE B

Cedar Ridge Reservoir Project

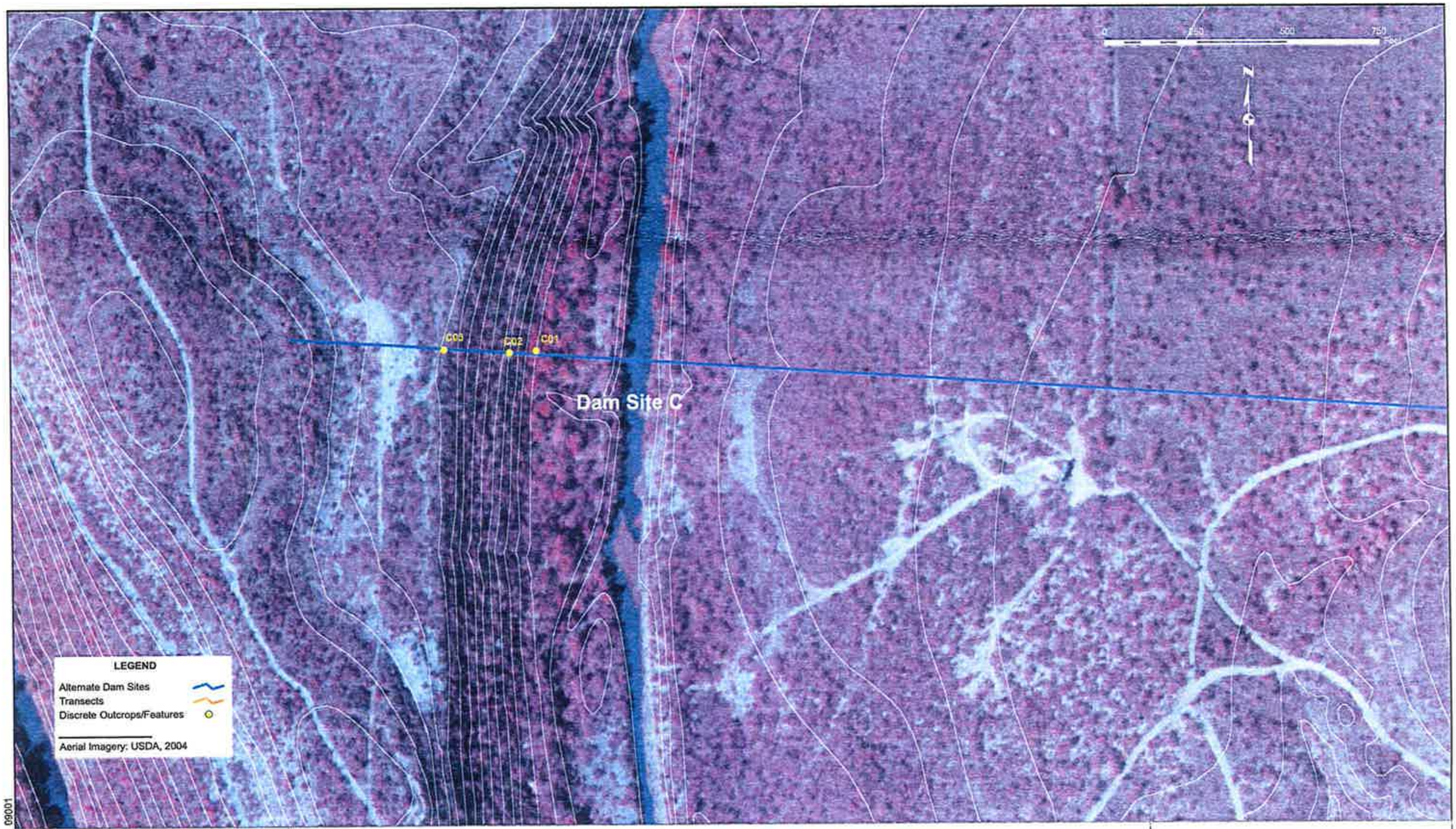

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FIGURE 9

GEOLOGIC TRANSECTS AND OUTCROPS
DAM SITE C

Cedar Ridge Reservoir Project

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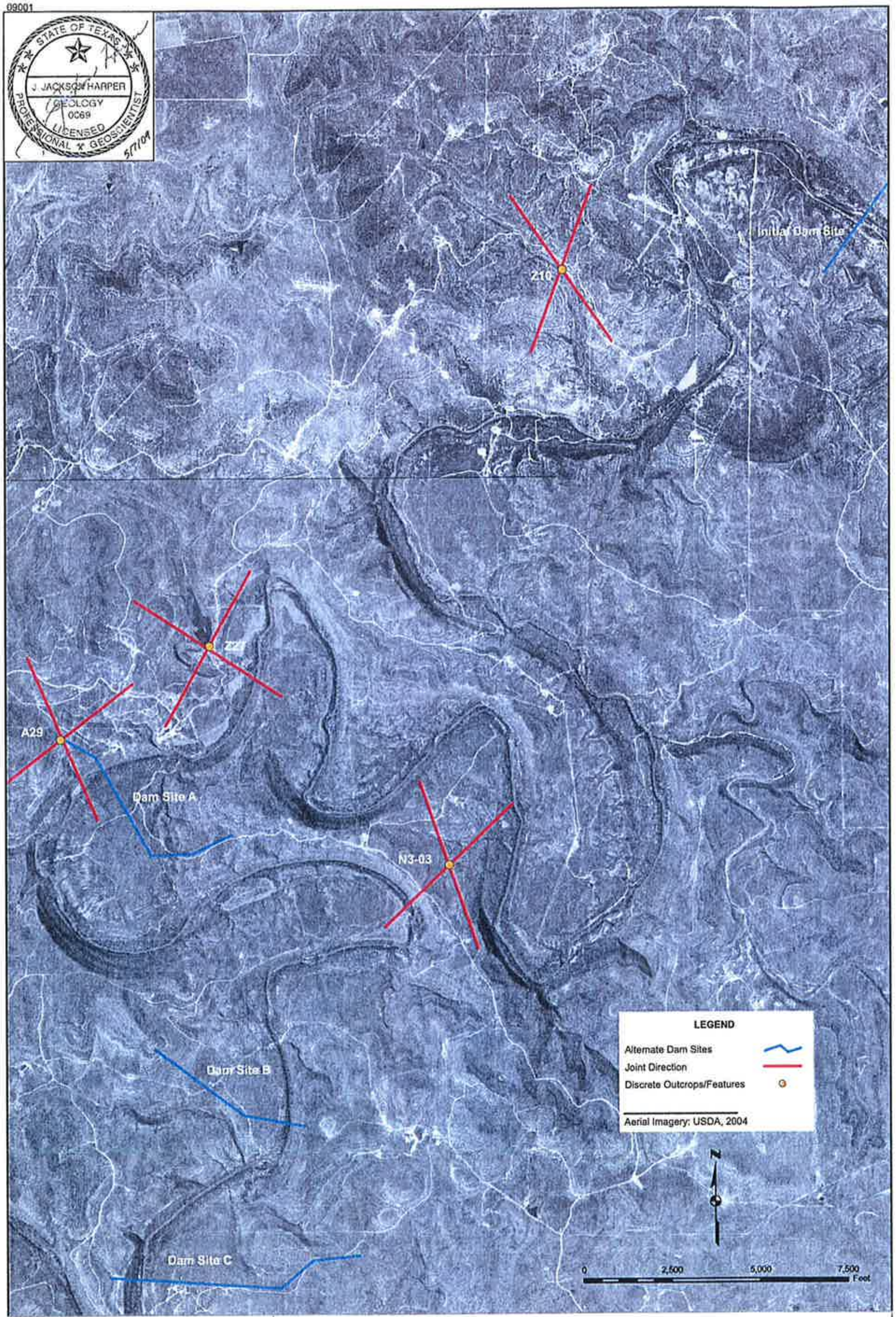

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FIGURE 10

JOINTING PATTERNS

Cedar Ridge Reservoir Project

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5/7/09

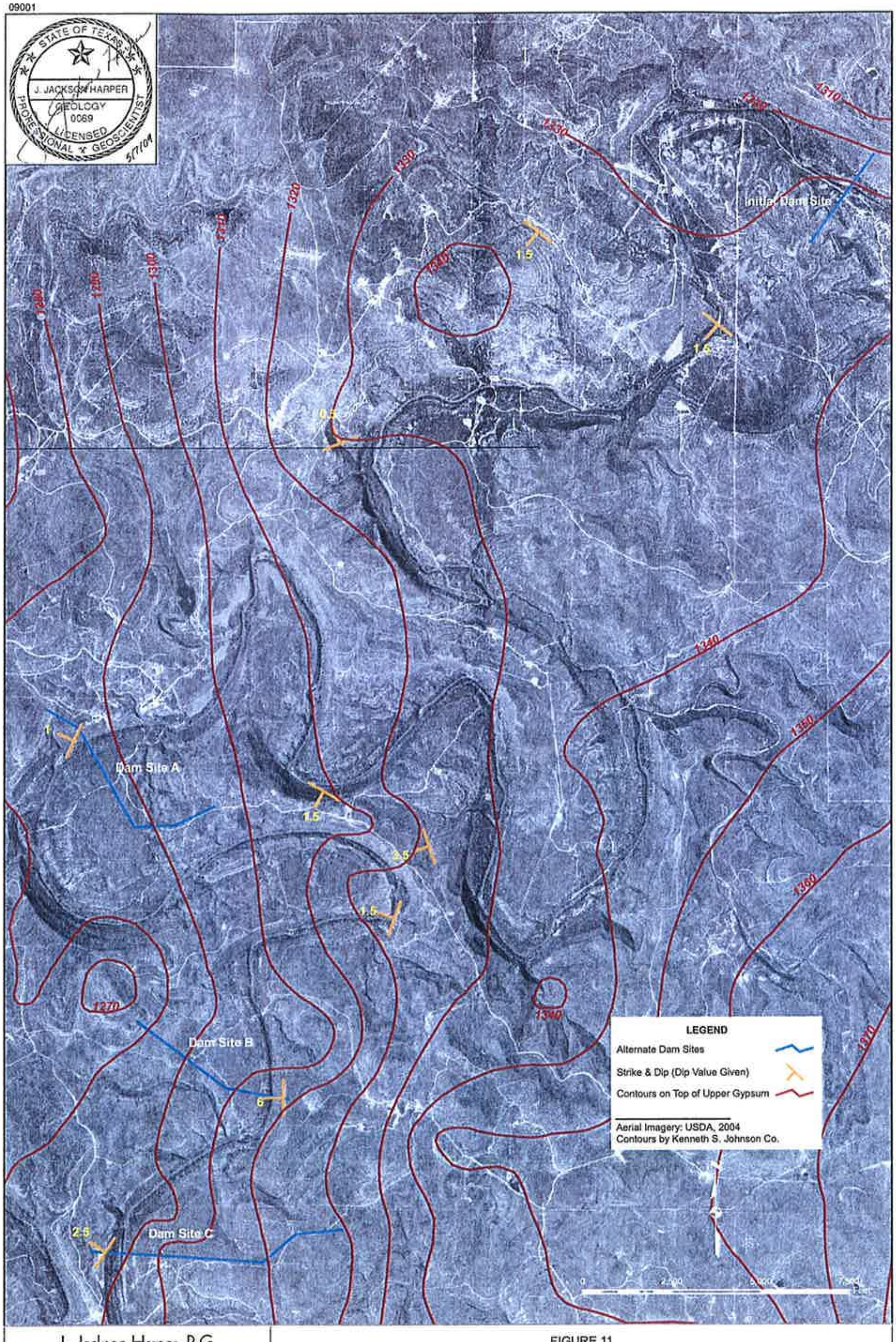

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FIGURE 11

STRUCTURAL CONTOURS ON THE TOP OF THE UPPER GYPSUM ZONE AND STRIKE/DIP MEASUREMENTS

Cedar Ridge Reservoir Project

APPENDIX A

FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

Location	Elevation NAVD (ft)	Notes	Photo
A01	1353.1	Qal contact with hillside colluvium.	A01b
A02	1359.5	Qal contact with hillside colluvium. Strike/dip of probable in situ bedrock = 205°/1°.	
A03	1359.9	Qal contact with hillside colluvium.	
A03 to A06	1359.9	Colluvium consisting of blocks of argillaceous limestone and shale mixed with pale yellowish brown silty, clayey, sand.	
A06	1385.0	Interbedded argillaceous limestone and indurated shale exposure. Limestone beds are ~8"-10" thick, very light to light gray, w/ ripple casts. Strike/dip = 77°/8.5°.	A06
A10	1434.2	Approximate Pbe/Pgc contact, as indicated by reduction of hillside slope. Material above contact is primarily shale w occasional 1' thick limestone beds. Stair-stepped to A12.	
A11	1451.1	Photo of slumped block uphill of A11.	A11
A12	1474.3	Base of vertical exposure of resistant Pgc. Nodular, 8-10" thick beds, very fossiliferous (turritella, bivalves, gastropods, Belemnites) and noticeable bioturbated. Pale yellowish-orange Fe staining on light gray limestone. Abundant calcite fossil casts. Strike/dip of slumped bedrock block = 39°/4°.	A12
A13	1494.4	Slope change to nearly level ground at top of steep hillside.	
A14	1494.0	Slope change to nearly level ground at top of steep hillside and ~240' WSW of A13. Strike/dip of slumped bedrock block = 55°/5°.	
A15	1493.8	Turn in Dam A alignment.. Photos overlooking river at Dam A.	A15a, b, c
A15 to A25		Flat to gently rising ground NW of A15.	
A25	1495.9	Moderate increase in ground rise and increase of loose, limestone (Pgc) boulders on ground surface .	
A29	1516.5	Fugro stake at end of left abutment of the Dam A alignment. Horizontal exposure of limestone bedrock with deeply incised, weathered joints (i.e., "boulder-field" appearance). Jointing = 52° & 157°.	
A30	1347.9	Qal. East bank of river at water's edge and ~5' above water level.	
A31 to A34	1348.8	Qal.	
A34	1373.8	Probable Qal contact with older and higher Qt.	
A41	1389.6	Some scattered limestone cobbles and small boulders with Qt.	
A59	1490.1	Transition from sandy Qt to overlying very gravelly and cobbly Qt.	
A60	1495.8	Transition to argillaceous limestone bedrock w/ thin to absent overlying Qt..	
B01	1369.7	Qal. East bank of river and ~2' above water level.	

APPENDIX A

FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

Location	Elevation NAVD (ft)	Notes	Photo
B02 to B04	1370.8	Qal.	
B04	1379.6	Qal. contact with hillside colluvium.	B04
B05	1380.6	Qal. contact with hillside colluvium.	
B06	1384.6	Qal. contact with hillside colluvium.	
B08	1424.1	Photo of slumped bedrock blocks.	B08
B09	1443.5	Probable Pbe/Pgc contact based on change (reduction) in hillside slope.	
B10	1475.5	Base of vertical exposure of resistant Pgc exposure. Interbedded argillaceous limestone and shale. Limestone beds ~1-1.5 ft thick. Shale beds 2"-8" thick. Shale is predominantly indurated, but some beds deeply weathered. Limestone is very pale orange to grayish yellow; fossiliferous (bivalves, Belemnites), and bioturbated.	B10
B11	1490.3	Top of vertical Pgc exposure. Strike/dip = 180°/6°.	B11
B14	1512.1	End of Dam B alignment left abutment. Boulder field similar to A29.	
B15	1379.2	Qal. West bank of river; 7' from water's edge and 10' above water level.	
B19	1394.0	Probable Qal contact with Qt.	
B20	1403.9	Photo looking east across river at hillside and Dam B right abutment.	B20
B29	1431.7	Transition from Qt to limestone (Pbe).	
B34	1441.1	Transition from limestone bedrock to overlying shale (i.e., clayey soil). Pbe/Pgc contact.	
B35	1453.0	Transition from shale to limestone cobbles on surface.	
B36	1463.4	Transition from limestone cobbles to shale.	
B37	1464.8	Transition to limestone cobbles on surface (followed by shale 10' further).	
B38	1472.9	Transition from shale to limestone cobbles on surface.	
B39	1473.9	Limestone bedrock (Pgc).	
B41	1495.8	Moderate increase in slope due to resistant Pgc.	
C01	1394.1	Qal contact with hillside colluvium.	
C02	1424.2	Notable change (reduction) in slope on hillside above colluvium.	
C03	1480.3	Pgc. Strike/dip = 215°/2.5°.	
N1-01	1324.7	Limestone bedrock (Pbe) at river's edge and at water level.	
N1-02	1330.0	Qal. Top of bank nearest river.	

APPENDIX A

FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

Location	Elevation NAVD (ft)	Notes	Photo
N1-06	1348.3	Qal contact with hillside colluvium.	
N1-07	1325.1	Qal at river's edge at river level.	
N1-10	1357.6	Qal contact with hillside colluvium.	
N1-11	1341.8	Photos of alluvium upstream and downstream of N1-11.	N1-11a, b
N1-13	1372.6	Exposed limestone ledge (Pbe) on steep hillside. Probably in situ. Strike/dip = 120°/1.5°.	
N1-14	1403.4	Photo of exposed Pbe limestone.	N1-14
N1-15	1424.4	Pbe exposure. 1'-1.5' thick argillaceous limestone beds w/ some 3" thick shale interbeds; fossiliferous and bioturbated. Just below change in slope.	
N1-16	1462.6	Pbe/Pgc contact based on change (reduction) in hillside slope.	N1-16
N1-17	1493.4	Base of vertical exposure of resistant Pgc limestone. 11' thick. Lithlogy same as that described at B10 and A12.	
N2-01	1358.7	Point bar at rivers's edge and at water level.	
N2-02	1364.0	Top of first slope adjacent to river. West flank of wide point bar in river floodplain. Medium to coarse gravel and small cobbles; hummocky surface (5' undulations).	N2-02
N2-04	1366.1	Mid point of point bar.	
N2-05	1368.1	East edge of point bar at top of bank above point bar cutoff chute.	
N2-06	1373.1	Qal at contact with hillside alluvium.	
N2-07	1467.9	Probable Pbe/Pgc contact at change (reduction) in hillside slope.	
N2-08	1514.5	Top of vertical exposure of resistant Pgc. Same as described at A12 and B10.	
N3-01	1466.6	Pbe/Pgc contact.	
N3-02	1428.4	Pbe exposure in floor of drainage. Strike/dip = 162°/3.5°.	N3-02
N3-03	1413.8	Pbe exposure in floor of drainage. Jointing = 46° & 161°.	
N3-04	1362.7	Qal contact with hillside colluvium on uphill side of oil well pad.	N3-04
N4-01	1357.1	Qal. 3' from river's edge and 3' above water level.	
N4-03	1366.8	Qal contact with hillside colluvium.	
N4-04 to N4-13	1381.9	Colluvium. Pbe/Pgc contact is not discernable due to steep slope.	
N4-13	1491.0	Base of vertical exposure of resistant Pgc limestone. Lithlogy same as that described at B10 and A12.	

APPENDIX A

FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

Location	Elevation NAVD (ft)	Notes	Photo
N4-14	1503.2	Top of vertical Pgc exposure.	
Z01	1492.1	Top of resistant vertical Pgc exposure along road North of Dam B alignment.	Z01
Z02	1454.0	Approximately 10 ft above Pbe/Pgc contact .	
Z03	---	Limestone (Pbe) outcrop at river level. Strike/dip = 210°/1°.	Z03
Z07	1291.5	20' thick section of interbedded limestone and shale (Pjv) exposed on East bank of river below terrace deposit. No gypsum evident.	Z07
Z08	1290.7	Shale (Pjv) outcrop on East bank of river and 0-6 ft above river level. Overlain by Qal/Qt. Strike/dip = 129°/1.5°. No gypsum evident.	
Z09	---	Limestone (Pbe) outcrops forming banks of Buffalo Draw drainage channel.	Z09
Z10	---	Strike/dip of bedrock floor of drainage = 100°/1°. Jointing = 20° & 145°.	Z10
Z11	1360.0	Shale (Pjv) exposures in road cut and adjacent gullys. No gypsum evident.	Z11a
Z12	---	Shale (Pjv) exposures on hillside. No gypsum evident.	
Z13	1421.1	Limestone (Pbe) w/ some agillaceous limestone interbeding. Strike/dip = 248°/0.5°.	Z13a
Z14	1326.8	Qal/ Pbe contact at transition from hillside to terrace.	
Z15	---	Limestone (Pbe) breakdown slabs exposed at river level.	Z15
Z16	---	Shale and limestone (Pjv) outcrops along road. No gypsum evident.	
Z17	1525.4	Base of vertical exposure of resistant Pgc limestone.	
Z18	1509.2	Pbe/Pgc contact at top of steep hillside.	
Z19	1516.0	Pbe/Pgc contact at top of steep hillside.	
Z20	1507.1	Pbe/Pgc contact at top of steep hillside.	
Z21	1528.4	Base of vertical exposure of resistant Pgc limestone.	
Z22	1504.0	Base of vertical exposure of resistant Pgc limestone.	
Z23	1511.1	Pbe/Pgc contact at top of steep hillside.	
Z24	1524.6	Base of vertical exposure of resistant Pgc limestone.	
Z25	1514.4	Base of vertical exposure of resistant Pgc limestone.	
Z26	1505.1	Pbe/Pgc contact at top of steep hillside.	
Z27	1400.2	Horizontal limestone (Pbe) exposure in channel downstream of lake. Dip is not discernable. Jointing = 29° & 123°.	Z27a

APPENDIX A

FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

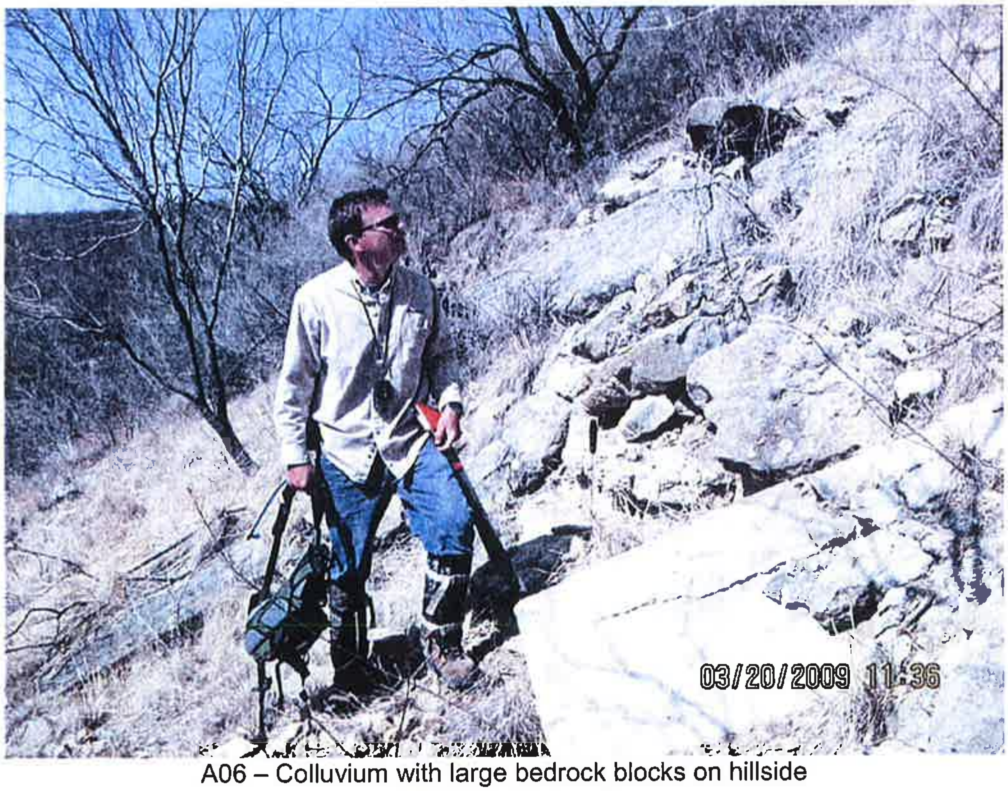
Location	Elevation NAVD (ft)	Notes	Photo
Z29	1370.1	Pbe exposures at pour off downstream of Z27. Dip is not discernable. Mostly limestone with some shale laminae. Limestone is light gray; very fossiliferous (bivalves, gastropods, Belemnites) with extensive worm burrows.	Z29a
Z30	1440.4	Dozer-cut slope on uphill side of graded oil well pad. Pbe/Pgc contact on top of resistant limestone bed.	Z30a
Z31	---	Bedrock limestone (Pbe) exposure at river level. Strike/dip = 200°/1.5°.	Z31
Z32	---	Thick Quaternary terrace (Qt) adjacent to Clear Fork channel.	Z32

APPENDIX B
PHOTOGRAPHS

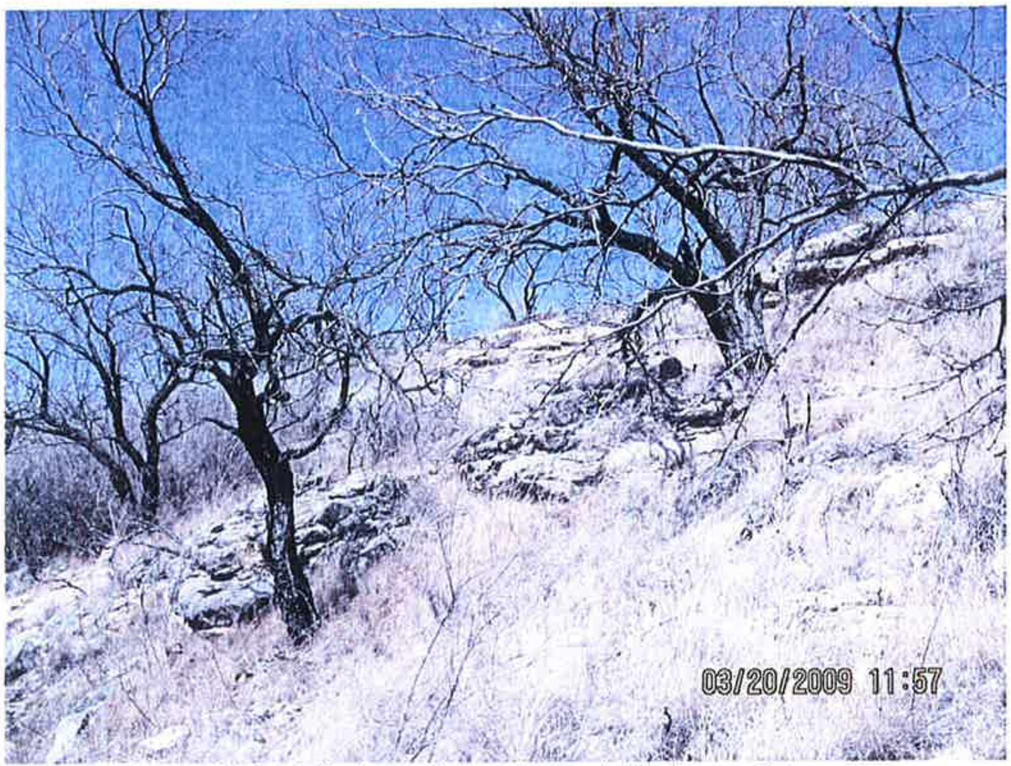
A01a – View to southwest from point A01 on north side of river.
Quaternary alluvium on both sides of river.

A01b – View north and uphill from point A01.
Alluvium/colluvium contact near cactus patch.

A01c - View to northeast from point A01 on north side of river.
Quaternary alluvium on both sides of river



A06 – Colluvium with large bedrock blocks on hillside
at Dam A alignment.



A11 – Colluvium with large bedrock blocks masking lowermost Grape Creek Formation

A12 – Vertical exposure of resistant Grape Creek Formation. Argillaceous limestone with interbedded shale, Key marker interval throughout the project area.

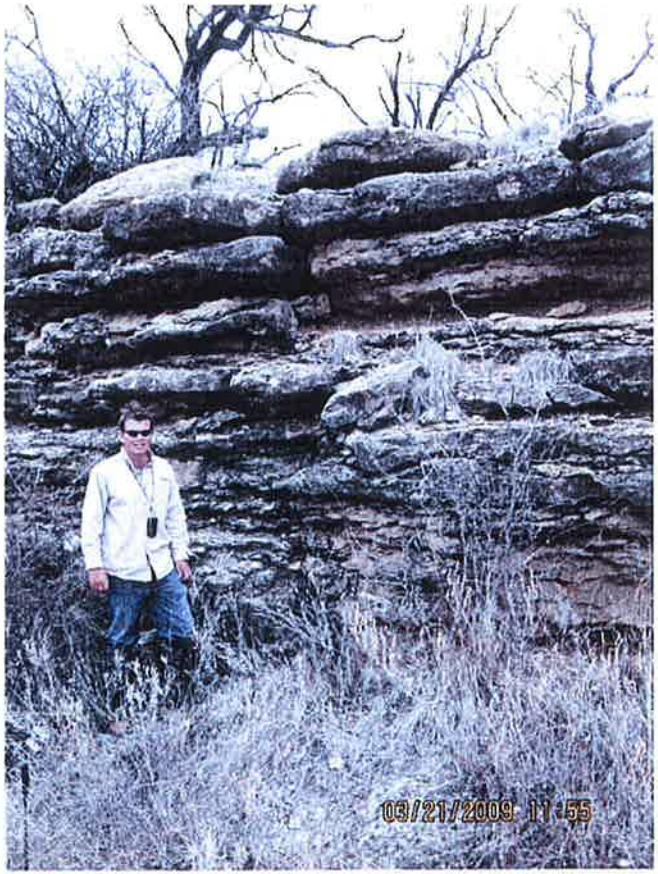
A15a – View to southwest from point A15 at top of steep slope on north side of river along Dam A alignment.

A15b - View to northeast from point A15 at top of steep slope on north side of river along Dam A alignment.

A15c - View directly across river from point A15 at top of steep slope on north side of river along Dam A alignment.

B04 - View of alluvium/colluvium contact at base of hillside on east side of river along Dam B alignment.

B08 – Downhill creep of bedrock blocks at Bam B alignment



B10 – 14-ft thick section of resistant Grape Creek Formation.
Argillaceous limestone with thin interbedded shale,

B11a – View to southwest of alluvium across river from
Dam B alignment.

B11b - View to west of alluvium across river from
Dam B alignment

B11c - View to northwest of alluvium across river from
Dam B alignment

B20 – View from point B20 of hillside on east side of river along
Dam B Alignment

N1-11a - Upstream (west) view of alluvium surface at base of hillside on north side of narrow gooseneck.

N1-11b – Downstream (east) view of alluvium surface at base of hillside on north side of narrow gooseneck.

N1-14 – Exposure of detached Bead Mountain limestone beds on steep slope on north side narrow gooseneck.

N1-16 – View of Grape Creek Formation upslope of contact with underlying Bead Mountain Formation.

N1-17 – View west along north facing slope of narrow gooseneck
From top of resistant Grape Creek limestone interval.

N2-02 – Surface of point bar consisting of
medium to coarse gravel and cobbles.

N3-02 – Thin, Bead Mountain limestone and underlying shale in drainage on north side of gooseneck.

N3-04 – Colluvium deposited over (or interfingered with) alluvium at base of hillside on north side of gooseneck.

Z01 – Road cut across prominent resistant Grape Creek limestone interval north of Dam B Alignment.

Z03 – Outcrop of in situ Bead Mountain limestone at river level.

Z07 – 20-ft thick section of interbedded limestone and shale of the Jagger Bend-Valera formations overlain by Quaternary terrace deposits.

Z09 – Pbe outcrop along north bank of Buffalo Draw

Z10 – Pbe Formation jointing in floor of Buffalo Draw.

Z11a - 20-ft thick section of Jagger Bend-Valera formations exposed in gully.

Z11b – Calcite boxwork specimen collected at site Z11.

Z13a – Outcrop of Bead Mountain limestone at point Z13
in steep drainage on west side of Shinnery Bend.

Z13b – Massive blocks of Bead Mountain limestone downstream of point Z13.

Z13c – Thick bed of Bead Mountain limestone in channel downstream of Point Z13.

Z15 – Intermixed alluvium and colluvium (i.e., loose slabs of Limestone at river level).

Z27a –Jointed Bead Mountain limestone forming floor of Wolf Creek downstream of small lake northwest of Krooked River Lodge.

Z27b – View downstream of point Z27.

Z27c – Stair-stepped exposure of Bead Mountain limestone downstream of point Z27.

Z29a – Interbedded Bead Mountain limestone and shale at pour off in Wolf Creek

Z29b – Mixed colluvium and Quaternary terrace deposits (?) on flank of Wolf Creek drainage at point Z29.

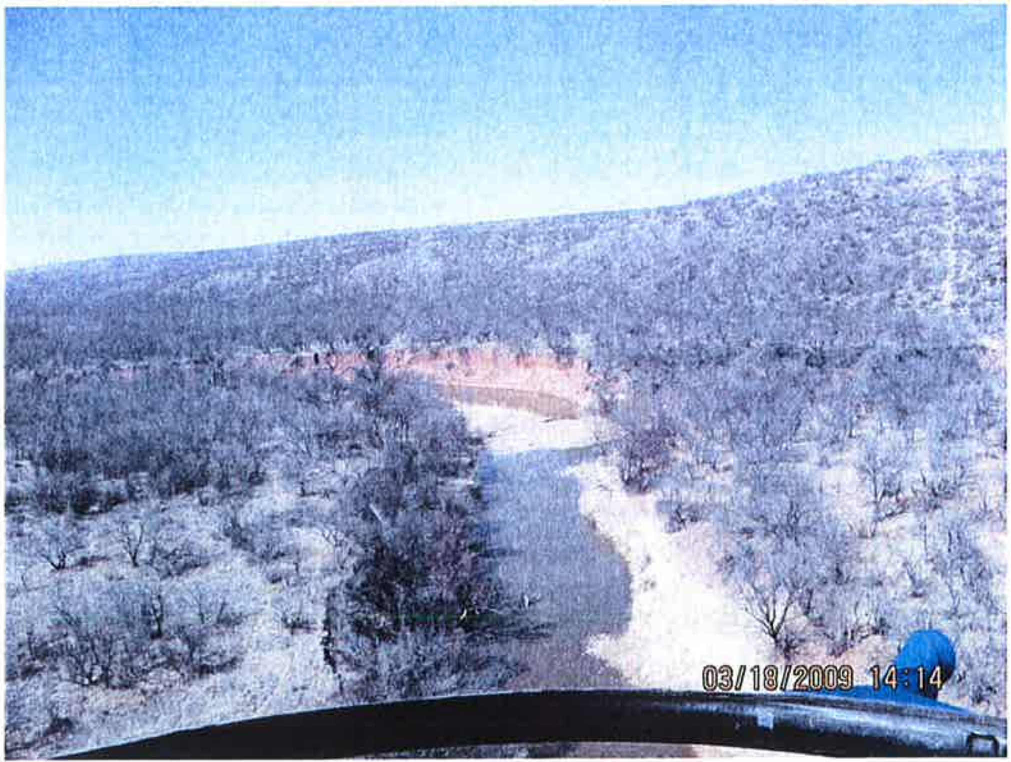
Z29c - Mixed colluvium and Quaternary terrace deposits (?) on flank
of Wolf Creek drainage at point Z29.

Z30a – Cut exposure of Grape Creek Formation at oil well site.
Probable contact with underlying Bead Mountain Formation
Is the limestone bed In foreground.

Z30b – Grape Creek Formation upslope from preceding photo.

Z30c – Weathered Grape Creek Formation shale at point Z30.

Z31 – Outcrop of in situ Bead Mountain limestone at sharp bend in river.



Z32 – Thick Quaternary terrace (Qt) at cut bank of Clear Fork channel.

APPENDIX C

APPENDIX C

GPS MEASURED POSITIONS OF GEOLOGIC FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

Location	UTM Easting (m)	UTM Northing (m)	Elevation NAVD (ft)	Comment
A01	455554.0	3649225.7	1353.1	Dam A - left abutment at river edge; ~10 ft above water level
A02	455467.6	3649198.5	1359.5	Dam A
A03	455624.3	3649257.0	1359.9	Dam A
A04	455617.9	3649260.3	1366.9	Dam A
A05	455614.2	3649265.6	1378.1	Dam A
A06	455613.8	3649271.5	1385.0	Dam A
A07	455610.2	3649275.8	1399.7	Dam A
A08	455609.9	3649280.4	1409.2	Dam A
A09	455608.9	3649290.8	1425.5	Dam A
A10	455608.4	3649294.9	1434.2	Dam A
A11	455602.5	3649307.9	1451.1	Dam A
A12	455590.0	3649318.7	1474.3	Dam A
A13	455579.9	3649330.7	1494.4	Dam A
A14	455510.7	3649304.9	1494.0	Dam A
A15	455506.7	3649310.7	1493.8	Dam A
A16	455494.3	3649317.8	1491.8	Dam A
A17	455475.6	3649328.0	1489.7	Dam A
A18	455457.8	3649337.9	1489.1	Dam A
A19	455438.3	3649349.9	1488.0	Dam A
A20	455407.9	3649367.2	1492.0	Dam A
A21	455386.1	3649379.1	1492.1	Dam A
A22	455359.6	3649393.1	1492.3	Dam A
A23	455337.6	3649406.1	1493.9	Dam A
A24	455316.8	3649418.6	1493.9	Dam A
A25	455290.6	3649433.5	1495.9	Dam A
A26	455281.0	3649439.2	1497.6	Dam A
A27	455266.1	3649447.6	1501.3	Dam A
A28	455243.5	3649459.7	1507.9	Dam A
A29	455222.9	3649473.2	1516.5	Dam A
A30	455573.6	3649196.2	1347.9	Dam A - right abutment at river edge; ~5 ft above water level
A31	455573.5	3649191.1	1348.8	Dam A
A32	455574.5	3649189.1	1351.6	Dam A
A33	455578.8	3649181.4	1365.0	Dam A
A34	455581.5	3649178.8	1373.8	Dam A
A35	455587.9	3649165.0	1371.5	Dam A
A36	455595.0	3649154.3	1374.7	Dam A
A37	455603.4	3649136.9	1373.4	Dam A
A38	455615.0	3649117.4	1374.5	Dam A
A39	455622.0	3649105.0	1376.1	Dam A
A40	455648.7	3649056.5	1383.6	Dam A
A41	455659.9	3649036.1	1389.6	Dam A

APPENDIX C

GPS MEASURED POSITIONS OF GEOLOGIC FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

Location	UTM Easting (m)	UTM Northing (m)	Elevation NAVD (ft)	Comment
A42	455670.3	3649017.8	1395.2	Dam A
A43	455683.8	3648991.8	1402.1	Dam A
A44	455703.6	3648957.3	1410.5	Dam A
A45	455721.3	3648925.6	1420.0	Dam A
A46	455738.4	3648892.7	1427.4	Dam A
A47	455761.4	3648854.8	1436.6	Dam A
A48	455781.9	3648818.3	1440.2	Dam A
A49	455812.5	3648761.4	1447.7	Dam A
A50	455849.8	3648695.9	1459.4	Dam A
A51	455874.0	3648649.5	1466.4	Dam A
A52	455906.4	3648591.5	1476.4	Dam A
A53	455940.6	3648531.4	1482.3	Dam A
A54	455987.7	3648454.3	1486.2	Dam A
A55	456032.4	3648454.0	1490.5	Dam A
A56	456068.9	3648455.9	1488.6	Dam A
A57	456140.1	3648457.7	1488.8	Dam A
A58	456205.3	3648459.4	1484.9	Dam A
A59	456253.5	3648461.1	1490.1	Dam A
A60	456303.7	3648462.5	1495.8	Dam A
A61	456342.4	3648468.2	1499.9	Dam A
A62	456365.6	3648480.0	1504.4	Dam A
A63	456386.2	3648488.3	1502.2	Dam A
A64	456419.3	3648504.1	1506.6	Dam A
A65	456466.8	3648526.2	1510.9	Dam A
A66	456532.7	3648556.8	1511.7	Dam A
A67	456576.2	3648576.7	1512.0	Dam A
A68	456621.9	3648597.9	1515.2	Dam A
A69	456656.7	3648615.1	1517.3	Dam A
A70	456691.0	3648634.1	1520.7	Dam A
B01	457190.8	3646135.2	1369.7	Dam B - right abutment at river bank; ~2 ft above water level
B02	457195.2	3646134.8	1370.8	Dam B
B03	457197.7	3646134.4	1377.4	Dam B
B04	457204.5	3646130.7	1379.6	Dam B
B05	457204.7	3646191.0	1380.6	Dam B
B06	457200.3	3646070.1	1384.6	Dam B
B07	457215.2	3646145.4	1401.2	Dam B
B08	457228.4	3646127.8	1424.1	Dam B
B09	457238.8	3646132.9	1443.5	Dam B
B10	457260.9	3646129.2	1475.5	Dam B
B11	457266.5	3646127.7	1490.3	Dam B
B12	457280.2	3646122.1	1504.3	Dam B

APPENDIX C

GPS MEASURED POSITIONS OF GEOLOGIC FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

Location	UTM Easting (m)	UTM Northing (m)	Elevation NAVD (ft)	Comment
B13	457299.7	3646118.7	1507.1	Dam B
B14	457317.3	3646115.0	1512.1	Dam B
B15	457162.7	3646139.9	1379.2	Dam B - left abutment at river bank; ~10 ft above water level
B16	457158.3	3646139.6	1379.1	Dam B
B17	457144.8	3646142.4	1380.2	Dam B
B18	457127.9	3646148.7	1394.4	Dam B
B19	457072.3	3646155.8	1394.0	Dam B
B20	457022.1	3646165.2	1403.9	Dam B
B21	456953.0	3646175.5	1413.8	Dam B
B22	456896.9	3646185.3	1420.9	Dam B
B23	456811.4	3646200.7	1426.8	Dam B
B24	456778.8	3646210.8	1428.6	Dam B
B25	456724.9	3646242.5	1431.8	Dam B
B26	456662.2	3646291.9	1434.1	Dam B
B27	456611.3	3646327.6	1432.0	Dam B
B28	456574.0	3646355.0	1434.7	Dam B
B29	456553.3	3646372.2	1431.7	Dam B
B30	456476.6	3646428.0	1427.9	Dam B
B31	456454.0	3646443.5	1430.8	Dam B
B32	456413.7	3646473.2	1433.7	Dam B
B33	456336.7	3646532.9	1439.1	Dam B
B34	456301.8	3646556.3	1441.1	Dam B
B35	456228.5	3646611.7	1453.0	Dam B
B36	456181.9	3646646.4	1463.4	Dam B
B37	456169.8	3646658.9	1464.8	Dam B
B38	456133.2	3646682.6	1472.9	Dam B
B39	456126.5	3646689.3	1473.9	Dam B
B40	456052.9	3646745.3	1494.5	Dam B
B41	456042.0	3646752.4	1495.8	Dam B
B42	456026.3	3646765.5	1507.2	Dam B
B43	456009.9	3646783.8	1521.6	Dam B
C01	455811.8	3644806.4	1394.1	Dam C
C02	455789.4	3644804.7	1424.2	Dam C
C03	455734.8	3644807.6	1480.3	Dam C
D1	458549.2	3647716.7	1519.2	Proposed drill site 1
D2	457867.8	3648617.1	1507.1	Proposed drill site 2
D3	455475.1	3649405.2	1495.8	Proposed drill site 3
D4	456822.5	3647601.1	1490.2	Proposed drill site 4
D5	454904.5	3646410.8	1485.0	Proposed drill site 5
D6	457450.1	3645934.6	1517.0	Proposed drill site 6
N1-01	457648.1	3648808.0	1324.7	South bank of river; at water level

APPENDIX C

GPS MEASURED POSITIONS OF GEOLOGIC FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

Location	UTM Easting (m)	UTM Northing (m)	Elevation NAVD (ft)	Comment
N1-02	457647.8	3648805.8	1330.0	
N1-03	457648.3	3648800.5	1331.2	
N1-04	457647.0	3648794.1	1339.9	
N1-05	457643.9	3648785.7	1341.8	
N1-06	457644.3	3648780.4	1348.3	
N1-07	457423.4	3648838.4	1325.1	South bank of river; at water level
N1-08	457421.7	3648833.3	1332.3	
N1-09	457417.4	3648825.3	1346.7	
N1-10	457410.3	3648811.4	1357.6	
N1-11	457617.7	3648787.0	1341.8	
N1-12	457615.8	3648766.2	1356.7	
N1-13	457613.2	3648759.3	1372.6	
N1-14	457614.2	3648741.2	1403.4	
N1-15	457609.4	3648729.5	1424.4	
N1-16	457614.0	3648706.3	1462.6	
N1-17	457631.5	3648681.8	1493.4	
N2-01	458241.8	3647805.1	1358.7	East bank of river; at water level
N2-02	458248.5	3647802.9	1364.0	
N2-03	458257.7	3647800.2	1365.5	
N2-04	458285.4	3647795.8	1366.1	
N2-05	458315.0	3647797.0	1368.1	
N2-06	458332.2	3647789.0	1373.1	
N2-07	458397.5	3647785.7	1467.9	
N2-08	458440.5	3647810.0	1514.5	
N3-01	458540.1	3648197.2	1466.6	
N3-02	458514.3	3648285.7	1428.4	
N3-03	458548.0	3648363.5	1413.8	
N3-04	458885.7	3648584.2	1362.7	
N4-01	457455.8	3648426.1	1357.1	North bank of river; approx 5 ft above water level
N4-02	457454.7	3648432.0	1365.5	
N4-03	457455.2	3648437.2	1366.8	
N4-04	457447.3	3648445.8	1381.9	
N4-05	457446.9	3648452.2	1390.9	
N4-06	457448.5	3648455.5	1399.1	
N4-07	457450.8	3648460.2	1408.6	
N4-08	457449.9	3648464.5	1418.7	
N4-09	457448.2	3648471.1	1434.2	
N4-10	457447.9	3648475.4	1443.3	
N4-11	457455.3	3648482.0	1456.6	
N4-12	457449.4	3648490.5	1471.0	
N4-13	457451.3	3648502.4	1491.0	

APPENDIX C

GPS MEASURED POSITIONS OF GEOLOGIC FIELD OBSERVATIONS
CEDAR RIDGE RESERVOIR PROJECT

Location	UTM Easting (m)	UTM Northing (m)	Elevation NAVD (ft)	Comment
N4-14	457453.0	3648505.2	1503.2	
N4-15	457451.8	3648516.9	1515.1	
N4-16	457465.2	3648542.1	1521.7	
N4-17	457484.0	3648569.6	1523.5	
N4-18	457503.8	3648596.8	1526.2	
N4-19	457522.8	3648627.0	1527.7	
Z01	457736.0	3646874.2	1492.1	
Z02	457629.1	3646950.3	1454.0	
Z03	456393	3649294	---	
Z07	460932.7	3653104.3	1297.5	
Z08	460993.3	3652755.5	1296.7	
Z09	459456	3653555	---	
Z10	459526	3653502	---	
Z11	458920.1	3651964.6	1360.0	
Z12	459573	3652302	---	
Z13	457748.5	3651748.0	1421.1	
Z14	457935.0	3651577.9	1326.8	
Z15	457725	3648810	---	
Z16	461198	3654316	---	
Z17	459929.5	3654465.3	1525.4	
Z18	459970.1	3654373.6	1509.2	
Z19	459877.5	3654297.4	1516.0	
Z20	458866.2	3653685.1	1507.1	
Z21	458521.7	3653735.1	1528.4	
Z22	458022.2	3652310.5	1504.0	
Z23	457824.2	3651851.2	1511.1	
Z24	457700.6	3652017.1	1524.6	
Z25	457197.0	3651184.6	1514.4	
Z26	457197.8	3651126.0	1505.1	
Z27	456478.2	3650244.7	1400.2	
Z29	456511.7	3650158.9	1370.1	
Z30	455797.3	3649394.2	1440.4	
Z31	458219.0	3647667.0	---	
Z32	460056	3649822	---	

GPS positions measured using Trimble Pro-XH receiver and subsequently differentially corrected using four TXDOT base stations in the region.

Positions Z03, Z09, Z10, Z12, Z15, Z16, Z31, and Z32 measured using a WAAS-enabled Garmin GPS-MAP 76CSx receiver.

Horizontal datum = NAD 1983
Vertical datum = NAVD 1988

APPENDIX C

BORING LOGS AND KEY TO TERMS AND SYMBOLS

LOG OF BORING B-1

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ LOCATION: See Plate 2

SURF. EL. 1532.68 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			9	Reddish-brown sandy lean CLAY. CL (Residual Soil)	1530.7 2.0							
			50/4"	Tan sandy lean CLAY with gravel. CL (Completely Weathered Limestone)	1529.9 2.8							
			53 (25)	Tan LIMESTONE, moderately weathered, hard, fractured, w/abundant fossil fragments, vugs, and shale seams and layers. (Grape Creek)								
5			90 (63)	*-tan shale seam from 5.0 to 5.2 ft* *-w/numerous tan shale seams (up to 1.5") from 5.2 to 10.0 ft*								
10			100 (75)	*-red, brown and bluish-gray shale layer from 10.0 to 13.7 ft* *[20% drilling fluid loss at 12.5 ft]*								
15			100 (88)	*[100% drilling fluid return at 15.0 ft]* *-red, brown and bluish-gray shale layer from 15.6 to 17.6 ft* *-w/numerous open vugs (up to 0.5") from 17.6 to 20.7 ft*								
20			100 (90)	*-tan shale layer from 20.7 to 21.3 ft* *-tan shale layer from 23.1 to 23.4 ft* *-w/numerous open vugs (up to 2.5") from 25.8 to 28.8 ft*								
25			100 (95)	*[20% drilling fluid loss at 28.1 ft]*								
30			92 (85)	*[100% drilling fluid return at 30.0 ft]*	1502.3 30.4							
				-red, brown and bluish-gray from 30.4 to 36.2 ft Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek)								
35			100 (73)	*-tan limestone from 36.2 to 37.9 ft* *-tan from 37.9 to 38.5 ft* ***-gypsum seams (0.25") at 38.4, 39.5 and 40.0 ft***								

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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LOG OF BORING B-1

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1532.68 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			96 (67)	*-gray limestone from 38.5 to 39.3 ft* *-tan from 39.3 to 40.0 ft* Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek) *-gray limestone from 42.3 to 43.2 ft*								
45			100 (100)	*-gray limestone from 44.7 to 46.6 ft*								
50			97 (97)	*-red, brown and bluish-gray shale layer from 50.0 to 53.2 ft*								
55			100 (100)	*-red, brown and bluish-gray shale layer from 55.0 to 60.8 ft*								
60			95 (93)	*-gray limestone from 62.3 to 63.1 ft*								
65			100 (100)									
				Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain)	1464.8 67.9							
70			100 (100)	*-dark gray shale layer from 69.5 to 71.9 ft*								
75			100 (100)	*-w/very close horizontal discontinuities from 75.0 to 75.8 ft* *-vertical fracture, open from 76.1 to 76.8 ft* *-w/very close horizontal discontinuities from 77.3 to 80.0 ft*								

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

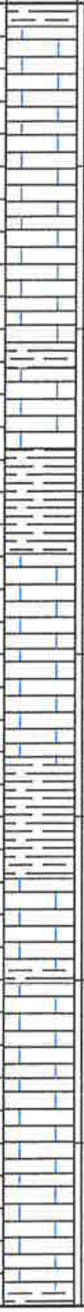
DRILL DATE: 03/31/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ LOCATION: See Plate 2

SURF. EL. 1532.68 ft Job No. 04.30091001



DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			93 (88)	*-dark gray shale layer from 80.0 to 80.7 ft* Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain)								
85			97 (75)	*-w/very close horizontal discontinuities from 85.0 to 90.4 ft*								
90			100 (100)	*-dark gray shale layer from 90.4 to 91.2 ft*								
				-bluish-gray shale layer from 93.7 to 96.9 ft								
95			100 (97)									
100			100 (93)	*-w/very close horizontal discontinuities from 100.9 to 102.5 ft*								
				-dark gray shale layer from 103.4 to 106.9 ft								
105			100 (97)									
110			100 (95)	*-bluish-gray shale layer from 109.7 to 110.1 ft*								
				-dark gray shale layer from 112.8 to 113.0 ft								
115			100 (100)	*[20% drilling fluid loss from 114.5 ft to termination depth]* *-vertical fracture, open from 114.5 to 116.4 ft*								

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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LOG OF BORING B-1

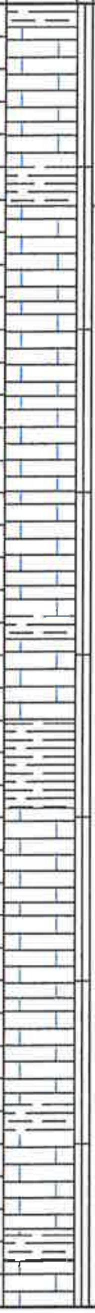
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1532.68 ft

Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (100)	*-dark gray shale layer from 119.6 to 120.7 ft* Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain)								
125	100 (100)	*-bluish-gray shale layer from 125.0 to 126.2 ft*	1406.5 126.2							
		Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain)								
130	100 (100)	*-w/very close horizontal discontinuities from 131.0 to 135.0 ft*								
135	100 (100)									
		-dark gray shale layer from 138.8 to 139.5 ft								
140	100 (100)	*-w/open vugs (up to 0.25") from 141.5 to 141.6 ft* *-dark gray shale layer from 142.1 to 144.7 ft*								
145	100 (100)									
150	100 (100)	*-dark gray shale seam from 149.3 to 149.5 ft*								
		-dark gray shale layer from 153.8 to 154.7 ft								
155	100 (100)	*-w/very close horizontal discontinuities from 156.9 to 157.4 ft* *-dark gray shale layer from 157.8 to 158.6 ft*								

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

U = Unconfined
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T = Torvane

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LOG OF BORING B-1

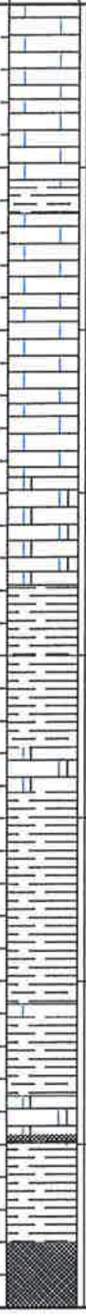
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1532.68 ft

Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (100)	Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain)								
		-w/very close horizontal discontinuities from 162.9 to 163.9 ft								
		-w/numerous micro-vugs from 164.0 to 165.6 ft								
165	100 (100)	*-dark gray shale layer from 165.6 to 166.4 ft*								
170	96 (96)									
			1358.2 174.5							
175	99 (99)	*-grayish-brown dolomitic limestone layer from 174.5 to 177.9 ft* Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *-dark gray shale layer from 177.9 to 180.0 ft*								
180	100 (100)									
		-grayish-brown dolomitic limestone layer, w/micro-vugs from 182.8 to 184.2 ft								
185	99 (99)									
190	98 (98)	*-gray limestone layer from 190.7 to 191.1 ft*								
		-grayish-brown dolomitic limestone layer, w/micro-vugs from 193.5 to 195.0 ft								
195	98 (98)	***-pink, white to light gray GYPSUM seam, low hardness, vitreous from 194.7 to 194.9 ft***								
		-white to light gray GYPSUM layer, low hardness, vitreous from 198.0 to 201.7 ft	1334.7 198.0							

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

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U = Unconfined
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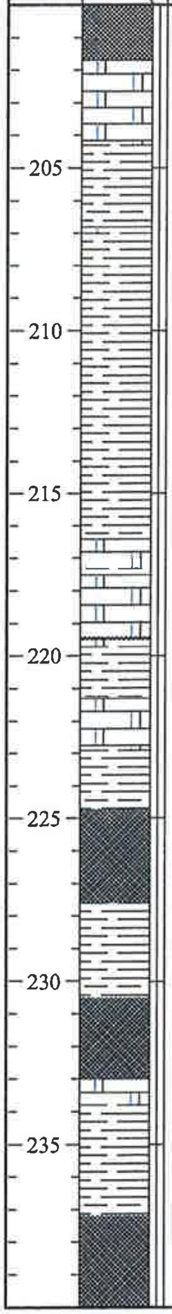
LOG OF BORING B-1

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ LOCATION: See Plate 2

SURF. EL. 1532.68 ft Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (100)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)	1331.0 201.7							
		-grayish-brown dolomitic limestone layer, w/micro-vugs from 201.7 to 204.3 ft								
		-gypsum seam (0.5") at 201.9 ft								
		-gypsum seam (1.0") at 203.5 ft								
205	100 (100)									
		-gray limestone layer from 206.8 to 207.0 ft								
210	100 (93)									
215	100 (90)									
		-grayish-brown dolomitic limestone layer from 216.4 to 217.3 ft								
		-grayish-brown dolomitic limestone layer from 217.5 to 219.7 ft								
220	98 (78)	***-pink, white to light gray GYPSUM seam, low hardness, vitreous from 219.4 to 219.5 ft***								
		-grayish-brown dolomitic limestone layer from 221.3 to 222.9 ft								
225	100 (100)	***-white to light gray GYPSUM layer, low hardness, vitreous from 224.7 to 227.6 ft***	1308.0 224.7							
		-vertical fracture, healed from 227.0 to 227.6 ft	1305.1 227.6							
230	100 (100)	***-white to light gray GYPSUM layer, low hardness, vitreous from 230.5 to 233.0 ft***	1302.2 230.5							
		-grayish-brown dolomitic limestone layer from 233.0 to 233.8 ft	1299.7 233.0							
235	98 (98)									
		-white to light gray GYPSUM layer, low hardness, vitreous from 237.2 to 240.5 ft	1295.5 237.2							

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

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T = Torvane

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LOG OF BORING B-1

FUGRO

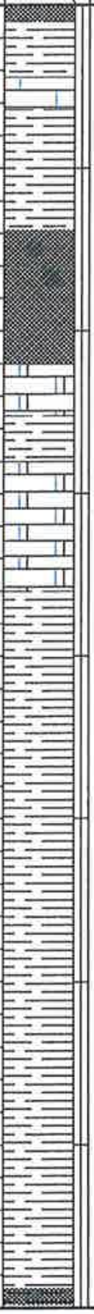
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1532.68 ft

Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	95 (95)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *-gray limestone layer from 242.2 to 243.2 ft*	1292.2 240.5							
245	96 (96)	***-white to light gray GYPSUM layer, low hardness, vitreous from 246.9 to 251.0 ft***	1285.8 246.9							
250	100 (100)	*-grayish-brown dolomitic limestone layer from 251.0 to 252.6 ft*	1281.7 251.0							
255	98 (95)	*-grayish-brown dolomitic limestone layer from 254.0 to 258.0 ft*								
260	100 (100)									
265	99 (99)	*-red, brown and bluish-gray from 264.6 to 268.7 ft* ***-reddish-brown to pink gypsum nodule (2.5") at 264.7 ft***								
270	100 (95)	*-red, brown and bluish-gray from 273.7 to 274.3 ft*								
275	100 (100)	***-gypsum seam (0.25") at 276.3 ft*** ***-gypsum seam (0.25") at 277.0 ft*** ***-gypsum seam (0.25") at 278.1 ft***								

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

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P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-1

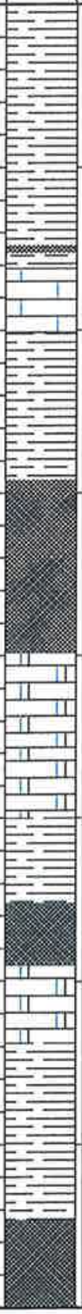
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1532.68 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (93)	***-pink, white to light gray GYPSUM layer, low hardness, vitreous from 279.4 to 279.9 ft***								
				Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)								
				-gypsum seam (0.5") at 281.3 ft								
285			100 (100)	*-alternating dolomitic limestone/shale, wmultiple healed vertical fractures from 285.8 to 287.3 ft*								
				-pink, white to light gray GYPSUM seam, low hardness, vitreous from 287.4 to 287.6 ft								
				-gypsum seam (0.25") at 287.7 ft								
290				*-gray limestone layer from 288.1 to 290.1 ft*								
			97 (77)	***-gypsum seam (0.25") at 290.8 ft***								
295				***-high angle (75°) gypsum seam (0.25") at 294.2 ft***	1238.1 294.6							
			100 (100)	***-white to light gray GYPSUM layer, low hardness, vitreous from 294.6 to 299.9 ft***								
300			100 (100)	*-grayish-brown dolomitic limestone layer, w/micro-vugs from 299.9 to 305.0 ft*	1232.8 299.9							
305			100 (90)	***-gypsum seam (0.25") at 305.2 ft*** ***-gypsum seam (0.25") at 305.3 ft*** ***-gypsum seam (0.25") at 305.8 ft*** ***-gypsum seam (0.5") at 306.9 ft***								
				-white to light gray GYPSUM layer, low hardness, vitreous from 307.6 to 309.5 ft	1225.1 307.6							
310			97 (97)	*-grayish-brown dolomitic limestone layer, w/micro-vugs from 309.5 to 311.9 ft*	1223.2 309.5							
				-w/gypsum nodules (up to 0.5") from 311.0 to 311.3 ft								
				-gypsum seam (1.0") at 312.0 ft								
				-gypsum seam (0.25") at 313.0 ft								
315			100 (98)									
				-gypsum seam (0.25") at 316.5 ft	1215.4 317.3							
				-white to light gray GYPSUM layer, low hardness, vitreous from 317.3 to 328.2 ft								

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

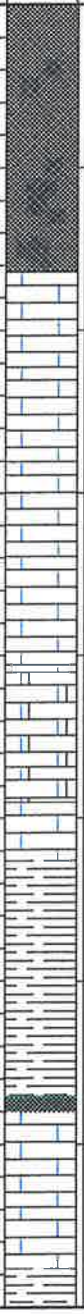
DRILL DATE: 03/31/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-1

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ LOCATION: See Plate 2



DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION SURF. EL. 1532.68 ft Job No. 04.30091001	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (100)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)								
325			100 (100)									
				Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/shale seams and layers. (Jagger Bend/Valera)	1204.5 328.2							
330			98 (98)									
				-gypsum seam (2.5") at 334.0 ft								
335			98 (98)	*-w/numerous dark gray shale laminations from 334.2 to 340.4 ft* ***-gypsum seam (0.25") at 335.2 ft***								
				-gypsum seam (0.25") at 338.0 ft								
340			100 (100)	***-gypsum seam (0.25") at 339.6 ft*** ***-gypsum seam (0.25") at 340.1 ft*** ***-gypsum seam (0.25") at 340.2 ft*** *-grayish-brown dolomitic limestone layer, w/micro-vugs from 340.5 to 344.5 ft* ***-gypsum seam (1.0") at 342.0 ft*** ***-gypsum seam (0.25") at 343.6 ft***								
345			100 (100)	*-dark gray shale layer from 346.3 to 353.5 ft*								
350			100 (92)									
				-w/numerous gypsum seams (up to 0.5") from 352.3 to 353.5 ft ***-pink, white to light gray GYPSUM layer, low hardness, vitreous from 353.5 to 354.0 ft***	1179.2 353.5 1178.7 354.0							
355			100 (100)	***-gypsum seam (0.25") at 356.3 ft*** ***-gypsum seam (0.5") at 357.6 ft*** *-dark gray shale layer from 358.8 to 363.1 ft*								

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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LOG OF BORING B-1

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ LOCATION: See Plate 2

SURF. EL. 1532.68 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (100)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/shale seams and layers. (Jagger Bend/Valera) *-gypsum seam (0.25") at 362.9 ft*								
365					1167.7 365.0							
				NOTES: *1) Boring was advanced dry to the 3.5-ft depth and groundwater was not encountered above that depth prior to coring.* *2) SPT Blowcounts were performed using a 170-lb hammer.*								
370												
375												
380												
385												
390												
395												

COMPLETION DEPTH: 365.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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SHEET 10 of 10

LOG OF BORING B-2

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ LOCATION: See Plate 2

SURF. EL. 1529.20 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			10	Reddish-brown sandy lean CLAY with gravel. CL (Residual Soil)								
			16									
			62									
5					1523.7 5.5							
			27	Tan SHALE, weathered, low hardness, w/limestone layers. (Grape Creek)								
					1521.1 8.1							
			50/1.5" 100 (39)	Tan LIMESTONE, moderately weathered, hard, fractured, w/abundant fossil fragments, vugs, and shale seams and layers. (Grape Creek)								
10			100 (75)	*-tan shale layer from 8.9 to 9.5 ft* *-tan shale layer from 10.8 to 11.4 ft*								
				-tan shale layer from 12.2 to 13.0 ft *-fracture (~70°), open from 13.0 to 13.5 ft* *-tan shale layer from 13.8 to 14.2 ft*								
15			97 (83)	*-tan and gray shale layer from 15.9 to 20.0 ft*								
20			100 (58)	*-tan and gray shale layer from 20.9 to 22.8 ft*								
25			100 (38)	*-tan shale layer from 26.0 to 26.7 ft*								
				-tan shale layer from 28.5 to 29.0 ft *-w/shale seams (up to 1") from 29.0 to 36.8 ft*								
30			100 (62)									
35			100 (70)									
					1492.4 36.8							
				Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek) *-tan from 36.8 to 39.3 ft*								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/04/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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LOG OF BORING B-2

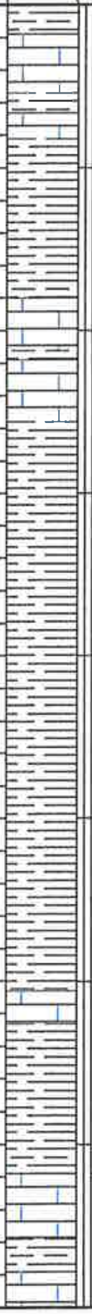
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1529.20 ft

Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	98 (96)	Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek) *-tan limestone layer from 40.9 to 42.7 ft* *-calcite-coated vug (1.0") at 41.0 ft* *[20% drilling fluid loss from 42.0 to 45.0 ft]*								
45	100 (97)	*-dark gray from 42.7 to 43.3 ft* *-gray limestone layer from 43.3 to 44.1 ft* *[100% drilling fluid loss from 45.0 to 50.0 ft]*								
50	98 (98)	*-gray limestone layer from 49.0 to 50.6 ft* *[25% drilling fluid loss from 50.0 to 320.0 ft]* *-dark gray from 50.6 to 50.9 ft* *-gray limestone layer from 50.9 to 52.8 ft*								
55	97 (97)	*-red, brown and bluish-gray shale layer from 54.6 to 58.7 ft*								
60	100 (98)									
65	100 (98)	*-red, brown and bluish-gray shale layer from 63.6 to 67.8 ft*								
70	100 (100)	*-gray limestone layer from 70.3 to 71.3 ft*								
75	98 (98)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain) *-gray shale layer from 77.9 to 78.9 ft* *-w/very close horizontal discontinuities from 78.9 to 87.0 ft*	1453.3 75.9							

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/04/09

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U = Unconfined
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LOG OF BORING B-2

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ LOCATION: See Plate 2

SURF. EL. 1529.20 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (95)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain)								
				-vertical fracture, clay-filled from 83.5 to 84.2 ft								
85			100 (100)									
				-dark gray shale layer from 87.0 to 87.9 ft								
90			100 (100)									
				-dark gray shale layer from 91.8 to 92.8 ft								
				-w/very close horizontal discontinuities from 92.8 to 100.5 ft								
95			98 (98)									
100			100 (98)	*-calcite-coated vug (2.0") at 100.0 ft* *-bluish-gray shale layer from 100.5 to 103.5 ft*								
105			98 (98)									
110			100 (100)	*-gray shale layer from 110.6 to 114.0 ft*								
115			100 (100)	*-dark gray shale layer from 115.1 to 115.5 ft*								
				-dark gray shale layer from 118.5 to 119.3 ft								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/04/09

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U = Unconfined
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SHEET 3 of 9

LOG OF BORING B-2

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1529.20 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			97 (97)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain) *-dark gray shale layer from 121.0 to 121.4 ft* *-w/very close horizontal discontinuities from 121.4 to 122.2 ft*								
125			100 (100)	*-dark gray shale layer from 128.0 to 129.1 ft* *-w/very close horizontal discontinuities from 129.1 to 130.2 ft*								
130			97 (97)	*-w/numerous open vugs (up to 0.5") from 133.2 to 133.4 ft* *-bluish-gray shale layer from 133.6 to 135.4 ft*								
135			100 (100)									
140			100 (100)	Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain) *-w/very close horizontal discontinuities from 140.0 to 148.4 ft*	1389.2 140.0							
145			100 (100)	*-dark gray shale layer from 148.4 to 149.1 ft*								
150			100 (100)	*-dark gray shale layer from 151.3 to 154.3 ft*								
155			100 (100)	*-w/very close horizontal discontinuities from 156.3 to 156.7 ft*								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/04/09

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Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1529.20 ft

Job No. 04.30091001

DEPTH, FT	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
		98 (98)	*-w/very close horizontal discontinuities from 159.4 to 160.0 ft* Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain) *-dark gray shale layer from 163.7 to 164.4 ft*								
165		97 (92)	*-dark gray shale layer from 167.5 to 169.0 ft* *-w/very close horizontal discontinuities from 169.5 to 171.5 ft*								
170		100 (100)	*-w/numerous open vugs (up to 0.5") from 173.3 to 176.5 ft*								
175		98 (98)	*-dark gray shale layer from 176.8 to 177.1 ft* *-w/very close horizontal discontinuities from 177.1 to 177.4 ft*								
180		97 (97)	*-dark gray shale layer from 181.1 to 181.6 ft* *-w/very close horizontal discontinuities from 183.8 to 188.9 ft*								
185		100 (100)		1340.3 188.9							
190		90 (78)	*-grayish-brown dolomitic limestone layer from 188.9 to 190.0 ft* Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) ***-gypsum seam (0.25") at 189.3 ft*** *-grayish-brown dolomitic limestone layer from 193.4 to 194.8 ft*								
195		98 (98)	***-pink gypsum nodule (1.5") at 194.3 ft*** *-w/numerous slickensided joints (~35°) from 197.0 to 198.3 ft*								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/04/09

U = Unconfined
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LOG OF BORING B-2

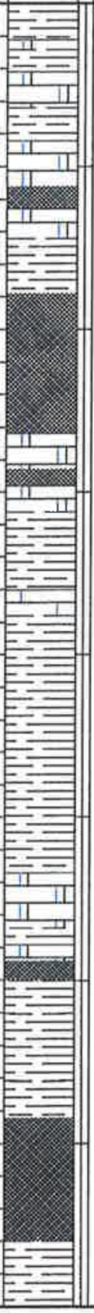
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1529.20 ft

Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	98 (98)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)								
		-grayish-brown dolomitic limestone layer from 201.1 to 201.4 ft								
		-grayish-brown dolomitic limestone layer, w/shale seams (up to 0.5") from 202.1 to 203.2 ft								
205	100 (100)	*-grayish-brown dolomitic limestone layer from 204.2 to 205.6 ft*	1323.6 205.6							
		-gypsum seam (0.25") at 205.2 ft	1322.9 206.3							
		-white to light gray GYPSUM layer, low hardness, vitreous from 205.6 to 206.3 ft								
		-grayish-brown dolomitic limestone layer from 206.3 to 207.2 ft	1320.3 208.9							
210	98 (96)	*-slickensided joint (~20°) at 208.9 ft*								
		-white to light gray GYPSUM layer, low hardness, vitreous from 208.9 to 213.2 ft								
		-grayish-brown dolomitic limestone layer from 213.2 to 214.3 ft	1316.0 213.2							
215	100 (95)	***-white to light gray GYPSUM layer, low hardness, vitreous from 214.3 to 214.8 ft***	1314.9 214.3							
		-slickensided joint (~20°) at 216.4 ft	1314.4 214.8							
		-grayish-brown dolomitic limestone layer from 214.8 to 215.6 ft								
		-slickensided joint (~20°) at 216.1 ft								
		-gray limestone layer from 218.0 to 218.8 ft								
220	100 (100)									
		-w/numerous dolomitic seams (up to 2.0") from 221.2 to 223.8 ft								
		-w/numerous gypsum seams (up to 1.0") from 222.2 to 222.7 ft								
225	100 (93)									
		-grayish-brown dolomitic limestone layer from 226.7 to 228.4 ft								
		-gypsum seam (0.25") at 228.4 ft	1299.8 229.4							
230	100 (100)	*-grayish-brown dolomitic limestone layer from 228.9 to 229.4 ft*	1299.2 230.0							
		-white to light gray GYPSUM layer, low hardness, vitreous from 229.4 to 230.0 ft								
		-dark gray, w/dolomitic seams (up to 2.0") from 231.5 to 232.6 ft								
		-slickensided joint (~45°) at 233.1 ft	1295.0 234.2							
235	97 (93)	***-white to light gray GYPSUM layer, low hardness, vitreous from 234.2 to 238.0 ft***								
			1291.2 238.0							
		-slickensided joint (~45°) at 238.8 ft								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/04/09

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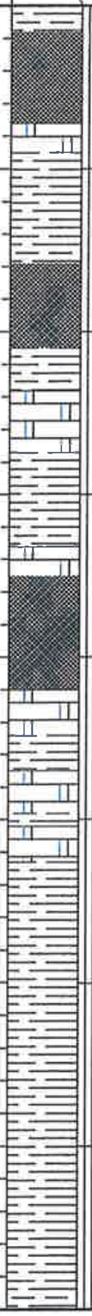
LOG OF BORING B-2

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ LOCATION: See Plate 2

SURF. EL. 1529.20 ft Job No. 04.30091001



DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			98 (98)	***-vertical fracture, gypsum-coated from 239.4 to 240.0 ft*** Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)	1288.4 240.8							
				-gypsum seam (0.25") at 240.5 ft	1285.6 243.6							
				-white to light gray GYPSUM layer, low hardness, vitreous from 240.8 to 243.6 ft								
245			98 (95)	*-grayish-brown dolomitic limestone layer from 243.6 to 244.5 ft* *-slickensided joint (~40°) at 245.0 ft*								
				-white to light gray GYPSUM layer, low hardness, vitreous from 247.9 to 250.5 ft	1281.3 247.9							
250			100 (100)		1278.7 250.5							
				-grayish-brown dolomitic limestone layer from 251.8 to 253.7 ft								
255			100 (100)									
				-gray dolomitic limestone layer from 256.6 to 257.5 ft	1271.7 257.5							
				-white to light gray GYPSUM layer, low hardness, vitreous from 257.5 to 261.0 ft								
260			93 (72)		1268.2 261.0							
				-grayish-brown dolomitic limestone layer, w/shale seams (up to 1.0") from 261.0 to 262.4 ft *-dark gray from 262.4 to 263.5 ft* *-grayish-brown dolomitic limestone layer from 263.5 to 264.8 ft*								
265			100 (100)	*-dark gray from 264.8 to 265.2 ft* *-grayish-brown dolomitic limestone layer from 265.2 to 266.3 ft* *-slickensided joint (~45°) at 266.5 ft* *-slickensided joint (~45°) at 267.2 ft*								
270			100 (95)									
				-red, brown and bluish-gray from 272.7 to 278.5 ft								
275			100 (88)	***-gypsum seam (0.25") at 274.6 ft***								
				-vertical fracture, gypsum-coated from 278.5 to 281.7 ft								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/04/09

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P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-2

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ

LOCATION: See Plate 2

SURF. EL. 1529.20 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (100)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)								
285												
			100 (88)	***-gypsum seam (0.5") at 286.2 ft***	1242.9 286.3							
				-pink, white to light gray GYPSUM layer, low hardness, vitreous from 286.3 to 287.3 ft	1241.9 287.3							
290												
			100 (97)	*-grayish-brown dolomitic limestone layer, w/micro-vugs and shale seams (up to 2.0") from 291.8 to 294.0 ft*								
				-pink, white to light gray GYPSUM layer, low hardness, vitreous from 294.0 to 294.4 ft	1235.2 294.0 1234.8 294.4							
295			100 (98)	*-gray dolomitic limestone layer from 294.4 to 296.6 ft*								
300			96 (96)	***-white to light gray GYPSUM layer, low hardness, vitreous from 300.0 to 305.2 ft***	1229.2 300.0							
305			100 (100)	*-gray limestone layer from 305.2 to 307.9 ft*	1224.0 305.2							
				-dark gray from 307.9 to 309.0 ft								
				-gypsum seam (1.5") at 308.8 ft								
310			100 (87)	***-grayish-brown dolomitic limestone layer, w/gypsum seams (up to 1.0") from 309.0 to 313.0 ft***								
				-vertical fracture, healed from 311.1 to 311.7 ft								
				-dark gray, w/dolomitic seams from 313.0 to 317.9 ft *-slickensided joint (~10°) at 313.2 ft*								
315			90 (67)	***-gypsum seam (0.5") at 315.5 ft*** *-slickensided joint (~30°) at 316.0 ft*								
				-white to light gray GYPSUM layer, low hardness, vitreous from 317.9 to 327.5 ft	1211.3 317.9							

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/04/09

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LOG OF BORING B-2

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - HQ LOCATION: See Plate 2

SURF. EL. 1529.20 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (97)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *[20% drilling fluid loss from 320.0 to 330.0 ft]*								
325			100 (100)									
				-w/micro-vugs from 327.5 to 330.0 ft	1201.7 327.5							
330			97 (97)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/shale seams and layers. (Jagger Bend/Valera) ***-gypsum seam (2.0") at 329.3 ft*** ***-w/occasional gypsum nodules (up to 1.0") from 330.0 to 335.3 ft*** *[10% drilling fluid loss from 330.0 to 350.0 ft]*								
335			100 (100)	*-w/very close horizontal discontinuities from 335.0 to 340.0 ft*								
340			100 (87)	***-gypsum seam (0.25") at 339.3 ft*** ***-gypsum seam (0.25") at 341.9 ft*** *-w/micro-vugs from 342.1 to 342.7 ft* ***-gypsum seam (0.25") at 343.2 ft*** ***-gypsum seam (0.5") at 343.8 ft***								
345			98 (80)	*-dark gray shale layer from 345.9 to 350.0 ft*								
350					1179.2 350.0							
355				*NOTES:* *1) Boring was advanced dry to the 8.5-ft depth and groundwater was not encountered above that depth prior to coring.* *2) SPT Blowcounts were performed using a 170-lb hammer.*								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/04/09

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LOG OF BORING B-3

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1497.24 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
				Reddish-brown sandy fat CLAY, stiff. CH (Residual Soil)	1496.2 1.0							1.25(P)
			71 (30)	Tan LIMESTONE, moderately weathered, hard, fractured, w/abundant fossil fragments, vugs, and shale seams and layers. (Grape Creek) *-tan shale layer from 2.2 to 4.4 ft*								
5			92 (66)	*-tan shale layer from 5.0 to 5.6 ft* *-vertical fracture, open from 5.6 to 6.4 ft*								
				-tan shale layer from 9.1 to 13.5 ft								
10			98 (94)									
15			100 (80)	*-tan shale layer from 14.5 to 15.5 ft*								
				-tan shale layer from 18.3 to 19.2 ft								
20			100 (50)	*-tan shale layer from 20.8 to 21.3 ft* *-vertical fracture, open from 21.7 to 22.6 ft* *-w/numerous open vugs (up to 1.0") from 23.4 to 27.5 ft*								
25			100 (56)									
30			100 (72)	*-red, brown and bluish-gray shale layer from 30.5 to 32.8 ft* *[100% drilling fluid loss at 32.0 ft]* *-calcite-coated vug (0.25") at 33.1 ft* *-calcite-coated vug (0.5") at 33.2 ft*								
35			100 (72)	*-tan shale layer from 34.4 to 35.1 ft* *[100% drilling fluid return at 35.0 ft]*	1460.3 36.9							
				Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek) *-gray limestone layer from 39.3 to 40.3 ft*								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-3

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1497.24 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (95)	Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek) *-gray limestone layer from 40.6 to 42.2 ft* *-gray limestone layer from 43.1 to 44.0 ft* *-calcite-coated vug (1.0") at 43.8 ft*								
45			100 (100)	*-red, brown and bluish-gray layer from 46.3 to 60.0 ft*								
50			100 (100)									
55			100 (72)									
60			100 (95)	*-gray limestone layer from 62.7 to 63.7 ft*								
65			94 (76)	*-gray limestone layer from 67.6 to 69.7 ft*								
70			100 (74)		1425.8 71.4							
				Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain)								
75			100 (100)	*-dark gray shale layer from 76.0 to 79.2 ft*								

COMPLETION DEPTH: 350.0 ft

DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

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Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1497.24 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (97)	-*calcite-coated vug (0.5") at 79.5 ft* Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain) -*dark gray shale layer from 76.0 to 79.2 ft*								
85			97 (97)									
90			100 (96)	-*bluish-gray shale layer from 90.1 to 94.0 ft*								
95			100 (82)									
100			100 (100)	-*bluish-gray shale layer from 100.8 to 103.8 ft* -*w/very close horizontal discontinuities from 103.8 to 104.7 ft*								
105			100 (100)	-*dark gray shale layer from 104.7 to 105.1 ft* -*grayish-brown from 105.1 to 107.5 ft* -*dark gray shale layer from 107.5 to 108.6 ft*								
110			100 (96)	-*dark gray shale layer from 109.6 to 110.0 ft* -*w/very close horizontal discontinuities from 110.0 to 112.1 ft* -*calcite-coated vug (0.5") at 111.1 ft*								
115			100 (94)	-*dark gray shale layer from 117.0 to 118.1 ft*								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-3

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1497.24 ft

Job No. 04.30091001

DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (93)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain) *-dark gray shale layer from 121.7 to 124.0 ft*								
125	99 (98)	*-grayish-brown dolomitic limestone layer from 124.0 to 124.5 ft* *-w/very close horizontal discontinuities from 124.5 to 136.5 ft*								
130	100 (100)	Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain)	1368.6 128.6							
135	100 (93)	*-vertical fracture, open from 135.0 to 136.5 ft* *-dark gray shale layer from 136.5 to 137.1 ft*								
140	100 (88)	*-dark gray shale layer from 140.5 to 141.7 ft*								
145	100 (100)	*-dark gray shale seam from 145.7 to 145.9 ft* *-vertical fracture, healed from 146.4 to 147.8 ft* *-dark gray shale seam from 148.5 to 148.7 ft*								
150	100 (100)									
155	100 (98)	*-w/very close horizontal discontinuities from 155.0 to 158.3 ft*								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1497.24 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			99 (99)	Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain) *-dark gray shale seam from 160.5 to 160.7 ft* *-dark gray shale seam from 163.0 to 163.2 ft* *-dark gray shale seam from 163.4 to 163.6 ft*								
165			100 (100)									
170			98 (85)		1325.5 171.7							
				Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *-alternating shale and dolomitic limestone (up to 0.5") from 171.7 to 173.6 ft*	1323.3 173.9							
175			98 (86)	***-white to light gray GYPSUM layer, low hardness, vitreous from 173.9 to 175.2 ft*** ***-w/gypsum nodules (up to 0.25") from 174.3 to 174.8 ft*** *-grayish-brown dolomitic limestone layer, w/micro-vugs from 175.2 to 178.4 ft* ***-w/pink gypsum nodules (up to 1.0") from 175.9 to 176.2 ft*** ***-w/gypsum nodules (up to 1.0") from 177.2 to 177.5 ft***	1322.0 175.2							
180			99 (99)	*-grayish-brown dolomitic limestone layer from 180.3 to 181.4 ft* *-grayish-brown dolomitic limestone layer from 182.3 to 183.5 ft*								
185			100 (94)									
190			100 (93)	***-gypsum seam (0.5") at 192.1 ft***								
195			98 (74)	***-gypsum seam (1.0") at 194.2 ft*** ***-gypsum seam (0.25") at 194.8 ft*** *-grayish-brown dolomitic limestone layer from 196.5 to 197.7 ft* ***-w/pink gypsum seams (up to 0.25") from 197.4 to 197.7 ft*** ***-pink gypsum seam (2.5") at 197.7 ft***								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

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P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-3

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1497.24 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (95)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)	1295.7 201.5							
				-white to light gray GYPSUM layer, low hardness, vitreous from 201.5 to 204.3 ft	1292.9 204.3							
205			100 (94)	*-grayish-brown dolomitic limestone layer from 204.3 to 205.3 ft*	1291.9 205.3							
				-gypsum seam (0.5") at 205.0 ft								
				-white to light gray GYPSUM layer, low hardness, vitreous from 205.3 to 205.9 ft	1291.3 205.9							
				-grayish-brown dolomitic limestone layer from 205.9 to 206.8 ft								
				-gypsum nodule (0.5") at 206.3 ft								
210			100 (94)	*-grayish-brown dolomitic limestone layer from 208.4 to 210.2 ft*								
				-w/gypsum nodules (up to 0.5") from 209.0 to 210.0 ft								
				-w/dolomitic limestone seams (up to 1.0") from 212.3 to 213.6 ft								
215			100 (82)	***-white to light gray GYPSUM layer, low hardness, vitreous from 213.6 to 215.5 ft***	1281.7 215.5							
				-grayish-brown dolomitic limestone layer, w/numerous shale seams (up to 3.0") from 217.6 to 225.0 ft								
				-slickensided joint (~45°) at 218.6 ft								
220			88 (88)									
225			95 (72)	***-white to light gray GYPSUM layer, low hardness, vitreous from 225.0 to 228.7 ft***	1272.2 225.0							
				-dark gray from 228.7 to 229.4 ft	1268.5 228.7							
230			100 (82)	*-gray dolomitic limestone layer from 229.4 to 229.7 ft*								
				-white to light gray GYPSUM layer, low hardness, vitreous from 231.5 to 235.2 ft	1265.7 231.5							
235			98 (98)	*-grayish-brown dolomitic limestone layer from 235.2 to 237.7 ft*	1262.0 235.2							
				-w/numerous shale seams (up to 2.0") from 236.6 to 237.7 ft								
				-gypsum seam (1.0") at 236.8 ft	1259.5 237.7							
				-white to light gray GYPSUM layer, low hardness, vitreous from 237.7 to 239.7 ft	1257.5							

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

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T = Torvane

LOG OF BORING B-3

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ　　LOCATION: See Plate 2

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION SURF. EL. 1497.24 ft　Job No. 04.30091001	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (97)	*-dark gray from 239.7 to 241.1 ft* Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)	239.7							
				-grayish-brown dolomitic limestone layer from 241.1 to 242.4 ft	1254.8 242.4							
245				***-white to light gray GYPSUM layer, low hardness, vitreous from 242.4 to 243.2 ft***	1254.0 243.2							
			100 (61)	*-grayish-brown dolomitic limestone layer from 243.2 to 244.8 ft*								
				-gypsum nodule (3.0") at 243.5 ft	1249.8 247.4							
				-white to light gray GYPSUM layer, low hardness, vitreous from 247.4 to 252.1 ft								
250			99 (58)									
				-pink gypsum from 251.8 to 252.1 ft	1245.1 252.1							
				-gray dolomitic limestone layer from 252.1 to 252.6 ft ***-gypsum seam (0.25") at 252.2 ft***	1244.6 252.6							
255			100 (52)	***-pink GYPSUM layer, low hardness, vitreous from 252.6 to 252.9 ft***	1244.3 252.9							
				-gray dolomitic limestone layer from 252.9 to 253.9 ft ***-gypsum seam (0.25") at 253.4 ft***								
				-dark gray from 253.9 to 255.9 ft								
				-gray dolomitic limestone layer from 255.9 to 257.7 ft								
260			100 (82)									
				-grayish-brown dolomitic limestone layer, w/numerous vertical fractures, healed from 261.4 to 261.9 ft								
				-grayish-brown dolomitic limestone layer from 262.5 to 263.0 ft								
265				*-red, brown and bluish-gray from 264.0 to 266.6 ft*								
			100 (65)									
270			100 (100)	*-gray limestone layer from 270.3 to 271.0 ft*								
				-dark gray from 271.0 to 276.6 ft ***-gypsum seam (0.25") at 271.4 ft*** ***-gypsum seam (0.5") at 272.7 ft***								
275			100 (84)	***-gypsum seam (0.25") at 274.6 ft***								
				-pink, white to light gray GYPSUM layer, low hardness, vitreous from 276.6 to 277.5 ft	1220.6 276.6 1219.7 277.5							
				-dark gray from 277.5 to 280.0 ft ***-gypsum seam (0.25") at 277.8 ft***								

COMPLETION DEPTH: 350.0 ft　　DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-3

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1497.24 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			99 (77)	*-grayish-brown dolomitic limestone seam from 279.4 to 279.6 ft*								
				-grayish-brown dolomitic limestone layer, w/micro-vugs from 280.0 to 281.6 ft								
				Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)								
285			98 (58)	***-gypsum nodule (3.0") at 281.3 ft***								
				-dark gray from 281.6 to 282.1 ft								
				-grayish-brown dolomitic limestone layer, w/micro-vugs from 282.1 to 282.6 ft	1209.7 287.5							
				-grayish-brown limestone layer from 282.6 to 285.2 ft								
				-gypsum seam (0.5") at 286.8 ft								
290			100 (92)	***-gypsum seam (0.5") at 287.0 ft***								
				-white to light gray GYPSUM layer, low hardness, vitreous from 287.5 to 293.7 ft								
				-grayish-brown dolomitic limestone layer, w/micro-vugs from 293.7 to 296.7 ft	1203.5 293.7							
295			99 (99)									
				-gypsum seam (1.0") at 297.1 ft								
				-grayish-brown limestone layer from 297.4 to 299.5 ft								
300			98 (78)	*-grayish-brown dolomitic limestone layer from 299.5 to 301.1 ft*								
				-w/dolomitic limestone seams (up to 2.0") from 302.8 to 305.2 ft								
305			100 (100)	***-white to light gray GYPSUM layer, low hardness, vitreous from 305.2 to 315.8 ft***	1192.0 305.2							
310			100 (100)									
315			100 (100)									
				-grayish-brown dolomitic limestone layer, w/micro-vugs from 315.8 to 318.5 ft	1181.4 315.8							
				Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/shale seams and layers. (Jagger Bend/Valera)								
				-gray limestone layer from 318.5 to 331.4 ft								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

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LOG OF BORING B-3

FUGRO

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1497.24 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			98 (94)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/shale seams and layers. (Jagger Bend/Valera)								
325			100 (88)									
330			100 (75)	***-gypsum seam (0.25") at 330.2 ft*** *-bluish-gray shale layer from 331.4 to 336.7 ft*								
335			97 (73)	***-alternating shale, dolomitic limestone and gypsum (up to 0.25") from 335.5 to 336.7 ft***	1160.5 336.7							
				-white to light gray GYPSUM layer, low hardness, vitreous from 336.7 to 341.8 ft								
340			100 (88)		1155.4 341.8							
				-w/micro-vugs from 343.9 to 345.0 ft								
345			98 (98)	*-w/very close horizontal discontinuities from 345.4 to 348.4 ft*								
350					1147.2 350.0							
355												

NOTES:
1) Boring was advanced dry to the 1.5-ft depth and groundwater was not encountered above that depth prior to coring.
2) SPT Blowcounts were performed using a 140-lb hammer.

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

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U = Unconfined
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T = Torvane

LOG OF BORING B-5

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ   LOCATION: See Plate 2

SURF. EL. 1496.28 ft   Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
				Reddish-brown sandy lean CLAY, very stiff to hard. CL (Residual Soil)								4.5+(P)
				-w/calcareous particles below 2.0 ft								3.0(P)
			30	*-w/limestone fragments below 4.0 ft*								
5												
			75									
			55									
10												
			50/1.75"		1482.3 14.0							
				Tan SHALE, weathered, low hardness, w/limestone layers. (Grape Creek)								
15												
			50/3"									
20												
			50/0.5"									
25												
				-bluish-gray shale layer from 27.0 to 30.0 ft								
			50/2"		1466.3 30.0							
30			100 (78)	Gray LIMESTONE, moderately weathered, hard, fractured, w/abundant fossil fragments, vugs, and shale seams and layers. (Grape Creek)								
				-dark gray shale layer from 30.4 to 34.6 ft *-gray dolomitic limestone seam from 32.0 to 32.2 ft* *-gray dolomitic limestone layer from 32.8 to 33.1 ft*								
35			100 (97)									
				-dark gray shale layer from 37.6 to 38.1 ft								
				-dark gray shale layer from 39.0 to 39.6 ft								

COMPLETION DEPTH: 355.0 ft   DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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SHEET 1 of 9

LOG OF BORING B-5

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1496.28 ft

Job No. 04.30091001

DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (98)	Gray LIMESTONE, moderately weathered, hard, fractured, w/abundant fossil fragments, vugs, and shale seams and layers. (Grape Creek)								
		-dark gray shale layer from 42.8 to 48.1 ft								
45	100 (68)									
50	100 (73)	*-dark gray shale layer from 49.6 to 50.0 ft*								
		-dark gray shale layer from 53.6 to 54.2 ft								
55	100 (100)	*-dark gray shale layer from 55.8 to 56.1 ft*								
60	100 (100)									
65	100 (89)	Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek)	1431.4 64.9							
		-gray limestone layer from 66.9 to 68.6 ft								
		-gray limestone layer from 69.2 to 70.4 ft								
70	97 (95)	*-gray limestone layer from 71.6 to 72.3 ft*								
		-gray limestone layer from 73.5 to 74.4 ft								
75	100 (82)	*-gray limestone layer from 75.1 to 77.3 ft*								
		-gray limestone layer from 78.6 to 80.4 ft								

COMPLETION DEPTH: 355.0 ft

DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

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Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1496.28 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			98 (93)	Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek) *-red, brown and bluish-gray shale layer from 82.2 to 84.3 ft*								
85			100 (76)									
90			100 (88)	*-gray limestone layer from 92.4 to 93.0 ft* *-gray limestone layer from 93.3 to 94.1 ft*								
95			100 (100)	*-gray limestone layer from 98.1 to 100.2 ft*								
100			100 (100)	*-gray limestone layer from 101.9 to 102.2 ft*	1393.2 103.1							
				Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain)								
105			100 (100)	*-w/very close horizontal discontinuities from 105.0 to 109.2 ft*								
110			100 (100)	*-dark gray shale layer from 110.0 to 111.3 ft*								
115			100 (98)	*-dark gray shale layer from 115.4 to 117.5 ft* *-w/very close horizontal discontinuities from 118.2 to 121.1 ft*								

COMPLETION DEPTH: 355.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial

P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-5

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1496.28 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (100)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain)								
125			100 (94)	*-dark gray shale layer from 125.3 to 126.0 ft*								
				-open vug (0.25") at 127.6 ft								
				-dark gray shale layer from 129.1 to 129.6 ft								
130			100 (95)									
				-dark gray shale layer from 132.4 to 133.1 ft								
135			100 (100)	*-bluish-gray shale layer from 134.5 to 136.5 ft*								
140			98 (98)	*-bluish-gray shale layer from 140.2 to 141.1 ft*								
				-w/very close horizontal discontinuities from 143.6 to 145.8 ft								
145			100 (100)	*-calcite-coated vug (0.5") at 145.0 ft*								
150			100 (100)	*-bluish-gray shale layer from 150.6 to 152.1 ft*								
155			99 (99)									
				-bluish-gray shale layer from 156.3 to 158.2 ft								
				-w/multiple open vugs (up to 0.25") from 158.4 to 158.5 ft								

COMPLETION DEPTH: 355.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
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LOG OF BORING B-5

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1496.28 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (98)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain)	1333.4 162.9							
165			97 (97)	Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain) *-w/very close horizontal discontinuities from 162.9 to 168.6 ft* *-dark gray shale layer from 168.6 to 169.6 ft*								
170			100 (100)									
175			100 (100)	*-dark gray shale layer from 175.5 to 176.9 ft*								
180			100 (100)	*-open vug (0.5") at 180.7 ft*								
185			100 (100)	*-dark gray shale layer from 186.8 to 187.7 ft*								
190			100 (100)	*-dark gray shale layer from 191.2 to 192.0 ft* *-w/very close horizontal discontinuities from 192.0 to 195.0 ft*								
195			100 (100)	*-dark gray shale layer from 196.0 to 196.7 ft* *-w/numerous micro-vugs from 197.0 to 200.0 ft*								

COMPLETION DEPTH: 355.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

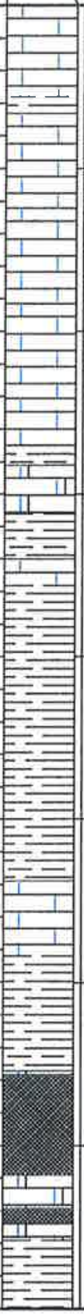
5/28/2009 2:46:47 PM

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1496.28 ft Job No. 04.30091001



DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			98 (98)	Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain)								
				-dark gray shale layer from 202.8 to 203.3 ft								
205			99 (99)									
210			100 (83)	***-w/numerous gypsum seams (up to 0.5") from 210.8 to 212.8 ft***								
				Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)	1282.8 213.5							
215			100 (100)	*-grayish-brown dolomitic limestone layer from 214.1 to 215.6 ft* ***-gypsum nodule (0.25") at 215.9 ft*** *-alternating limestone, shale and dolomitic limestone (up to 0.5") from 217.0 to 217.8 ft*								
220			98 (98)									
225			100 (97)									
230			99 (96)	***-gypsum seam (2.5") at 229.4 ft***								
				-grayish-brown dolomitic limestone seam from 232.7 to 232.8 ft	1263.5 232.8							
235			100 (90)	***-white to light gray GYPSUM layer, low hardness, vitreous from 232.8 to 235.9 ft***	1260.4 235.9							
				-grayish-brown dolomitic limestone seam from 235.9 to 236.9 ft	1259.4 236.9							
				-gypsum seam (0.5") at 236.5 ft								
				-white to light gray GYPSUM layer, low hardness, vitreous from 236.9 to 237.4 ft	1258.9 237.4							

COMPLETION DEPTH: 355.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-5

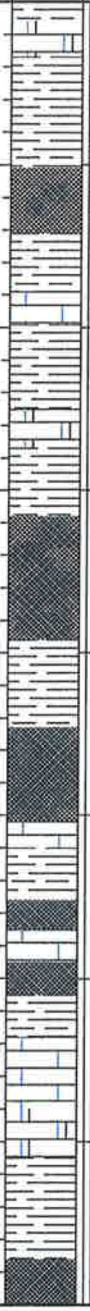
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1496.28 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (87)	*-grayish-brown dolomitic limestone layer from 237.4 to 237.9 ft* ***-gypsum seam (0.25") at 238.1 ft*** Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)								
				-grayish-brown dolomitic limestone layer from 240.6 to 241.7 ft								
245			99 (84)	***-white to light gray GYPSUM layer, low hardness, vitreous from 245.1 to 247.1 ft***	1251.2 245.1 1249.2 247.1							
				-gray limestone layer from 248.9 to 249.9 ft								
250			98 (80)									
				-grayish-brown dolomitic limestone layer from 252.5 to 253.7 ft *-w/numerous gypsum-coated slickensided joints (~45°) from 253.7 to 255.8 ft*								
255			98 (87)	***-white to light gray GYPSUM layer, low hardness, vitreous from 255.8 to 259.6 ft***	1240.5 255.8							
260			100 (75)		1236.7 259.6							
				-white to light gray GYPSUM layer, low hardness, vitreous from 262.3 to 265.2 ft	1234.0 262.3							
265			100 (90)	*-gray limestone layer from 265.2 to 266.0 ft*	1231.1 265.2							
				-white to light gray GYPSUM layer, low hardness, vitreous from 267.6 to 268.5 ft *-gray limestone layer from 268.5 to 269.5 ft*	1227.8 268.5 1226.8 269.5							
270			100 (100)	***-white to light gray GYPSUM layer, low hardness, vitreous from 269.5 to 270.5 ft*** ***-gypsum seam (0.5") at 270.8 ft*** ***-gypsum nodule (2.5") at 271.8 ft*** ***-w/numerous gypsum nodules (up to 4.0") from 272.1 to 274.3 ft***	1225.8 270.5							
275			100 (98)	*-grayish-brown dolomitic limestone layer from 274.0 to 275.5 ft*								
				-white to light gray GYPSUM layer, low hardness, vitreous from 278.6 to 282.2 ft	1217.7 278.6							

COMPLETION DEPTH: 355.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

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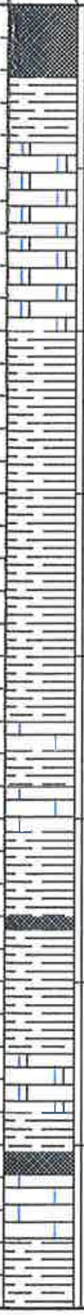
U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-5

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1496.28 ft Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (85)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)	1214.1 282.2							
285	100 (87)	*-alternating shale/dolomitic limestone from 284.0 to 290.0 ft*								
290	95 (83)									
		-red, brown and bluish-gray from 293.4 to 294.1 ft								
295	100 (87)	*-red, brown and bluish-gray from 295.0 to 298.4 ft*								
300	100 (99)									
		-gray limestone layer from 302.0 to 302.9 ft								
		-gypsum seam (0.25") at 304.3 ft								
305	100 (90)	***-gypsum seam (0.25") at 305.3 ft***								
		-pink, white to light gray GYPSUM layer, low hardness, vitreous from 308.0 to 308.4 ft	1188.3 308.0 1187.9 308.4							
310	100 (87)									
		-grayish-brown dolomitic limestone layer, w/micro-vugs from 312.2 to 314.0 ft								
		-w/gypsum seams (up to 0.25") from 314.0 t0 314.4 ft								
315	100 (93)	***-white to light gray GYPSUM layer, low hardness, vitreous, w/occasional pink nodules (up to 1.0") from 315.2 to 315.9 ft***	1181.1 315.2 1180.4 315.9							
		-vertical fracture, healed from 315.9 to 318.0 ft								

COMPLETION DEPTH: 355.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

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LOG OF BORING B-5

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1496.28 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (73)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) ***-white to light gray GYPSUM layer, low hardness, vitreous from 321.5 to 326.0 ft***	1174.8 321.5							
325			100 (100)	*-gray limestone layer from 326.0 to 329.6 ft* ***-gypsum seam (0.25") at 328.0 ft***	1170.3 326.0							
330			100 (70)	***-gypsum seam (0.25") at 329.4 ft*** *-grayish-brown dolomitic limestone layer from 329.6 to 333.5 ft*								
335			100 (92)	***-white to light gray GYPSUM layer, low hardness, vitreous from 336.2 to 346.0 ft***	1160.1 336.2							
340			97 (97)									
345			100 (100)									
				Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/shale seams and layers. (Jagger Bend/Valera) ***-gypsum seam (2.0") at 348.0 ft***	1150.3 346.0							
350			100 (100)									
355				*NOTES:* *1) Boring was advanced dry to the 30.0-ft depth and groundwater was not encountered above that depth prior to coring.* *2) SPT Blowcounts were performed using a 140-lb hammer.*	1141.3 355.0							

COMPLETION DEPTH: 355.0 ft DEPTH TO WATER: See Note

DRILL DATE: 03/31/09

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T = Torvane

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LOG OF BORING B-6

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1519.20 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
				Reddish-brown sandy lean CLAY, hard, w/scattered limestone fragments. CL (Residual Soil)	1518.0 1.2							4.5+(P)
			47 (30)	Tan LIMESTONE, moderately weathered, hard, fractured, w/abundant fossil fragments, vugs, and shale seams and layers. (Grape Creek) *-tan shale layer from 3.7 to 4.2 ft* *-fracture (~70°), open from 4.2 to 4.8 ft*								
5			89 (47)	*-tan and gray shale layer from 5.0 to 7.3 ft* *-w/numerous shale seams from 8.1 to 10.2 ft*								
10			98 (71)	*-tan shale layer from 10.2 to 10.9 ft* *-tan shale layer from 11.5 to 13.0 ft*								
15			72 (55)	*-tan and gray shale layer from 15.6 to 21.3 ft*								
20			81 (51)	*-tan and gray, w/abundant vugs (up to 0.5") from 21.3 to 26.5 ft*								
25			100 (58)	*-tan shale layer from 26.5 to 27.2 ft*	1492.0 27.2							
				Gray LIMESTONE, moderately weathered, hard, fractured, w/abundant fossil fragments, vugs, and shale seams and layers. (Grape Creek)								
30			100 (77)	*-dark gray shale layer from 30.6 to 31.4 ft*								
35			100 (82)	Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek)	1483.4 35.8							

COMPLETION DEPTH: 350.0 ft   DEPTH TO WATER: See Note

DRILL DATE: 04/05/09

5/28/2009 2:46:51 PM

U = Unconfined
Q = Unconsolidated Undrained Triaxial
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SHEET 1 of 9

LOG OF BORING B-6

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION SURF. EL. 1519.20 ft Job No. 04.30091001	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (98)	Bluish-gray SHALE, moderately weathered, low hardness, non-calcareous, w/pale yellow and reddish brown silt seams and limestone layers. (Grape Creek) *-gray limestone layer from 40.4 to 41.9 ft* *-gray limestone layer from 42.9 to 43.5 ft*								
45			100 (88)	*-gray limestone layer from 46.0 to 47.2 ft* *-bluish-gray shale seam from 47.0 to 47.2 ft*								
50			100 (82)	*-gray limestone layer from 50.8 to 52.4 ft*								
55			100 (85)	*-red, brown and bluish-gray shale layer from 55.0 to 64.0 ft*								
60			100 (98)									
65			100 (80)	*-gray limestone layer from 65.9 to 66.6 ft*								
70			100 (95)	*-gray limestone layer from 71.1 to 72.6 ft*								
75			100 (58)									
				Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain) *-gray shale layer from 78.6 to 79.2 ft*	1443.2 76.0							

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/05/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-6

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1519.20 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (83)	*-w/shale seams (up to 2.0") from 79.2 to 83.3 ft* Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain)								
				-dark gray shale layer from 83.3 to 84.4 ft								
85			100 (74)									
				-dark gray shale layer from 87.5 to 88.2 ft *-w/very close horizontal discontinuities from 88.2 to 90.8 ft*								
90			100 (78)	*-dark gray shale layer from 90.8 to 91.5 ft*								
95			98 (91)									
				-bluish-gray shale layer from 96.6 to 98.9 ft								
100			100 (81)									
105			100 (77)	*-bluish-gray shale layer from 105.9 to 108.9 ft*								
				-tan and gray from 108.9 to 112.5 ft								
110			100 (98)									
				-bluish-gray shale layer from 112.5 to 113.8 ft								
115			100 (90)	*-dark gray shale layer from 115.5 to 115.8 ft*								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/05/09

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LOG OF BORING B-6

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ   LOCATION: See Plate 2

SURF. EL. 1519.20 ft   Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (98)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/abundant fossil fragments and shale seams and layers. (Bead Mountain) *-dark gray shale layer from 121.7 to 122.6 ft*	1396.6 122.6							
125			100 (87)	*-w/very close horizontal discontinuities from 122.6 to 125.9 ft* Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain) *-dark gray shale layer from 125.9 to 126.2 ft* *-w/very close horizontal discontinuities from 126.2 to 127.6 ft* *-bluish-gray shale layer from 127.6 to 129.0 ft*								
130			98 (94)	*-w/very close horizontal discontinuities from 132.4 to 140.0 ft*								
135			100 (92)									
140			95 (93)	*-dark gray shale layer from 141.3 to 142.2 ft*								
145			100 (99)	*-dark gray shale layer from 145.0 to 146.9 ft*								
150			100 (100)	*-w/very close horizontal discontinuities from 151.0 to 151.9 ft*								
155			100 (90)	*-open vug (0.25") at 154.6 ft* *-dark gray shale layer, w/limestone laminations from 156.0 to 157.0 ft* *-w/numerous open vugs (up to 0.25") from 159.1 to 159.3 ft*								

COMPLETION DEPTH: 350.0 ft   DEPTH TO WATER: See Note

DRILL DATE: 04/05/09

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LOG OF BORING B-6

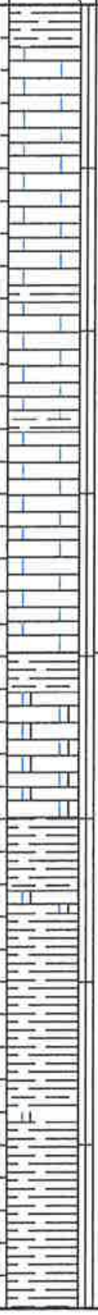
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1519.20 ft

Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (87)	*-dark gray shale layer from 160.0 to 161.3 ft* Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain) *-w/very close horizontal discontinuities from 161.3 to 164.5 ft*								
165	100 (94)	*-w/very close horizontal discontinuities from 166.2 to 166.8 ft* *-dark gray shale layer from 168.6 to 169.1 ft*								
170	100 (100)	*-dark gray shale layer from 172.7 to 173.1 ft* *-w/numerous dark gray shale seams (up to 1.0") from 173.1 to 179.9 ft*								
175	100 (87)		1339.3 179.9							
180	100 (79)	*-dark gray from 179.9 to 181.1 ft* Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *-grayish-brown dolomitic limestone layer from 181.1 to 185.0 ft* ***-w/gypsum nodules (up to 1.0") from 183.0 to 183.4 ft***								
185	100 (75)	*-grayish-brown dolomitic limestone layer from 187.2 to 187.9 ft* *-w/dolomitic limestone seams (up to 1.5") from 189.0 to 190.0 ft*								
190	100 (100)									
195	99 (88)	*-grayish-brown dolomitic limestone layer from 194.0 to 194.3 ft* *-dolomitic limestone seam from 194.8 to 195.0 ft* *-w/dolomitic limestone seams (up to 3.0") from 196.8 to 199.0 ft*								

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/05/09

5/28/2009 2:46:51 PM

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LOG OF BORING B-6

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1519.20 ft   Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (78)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)	1317.2 202.0							
				-white to light gray GYPSUM layer, low hardness, vitreous from 202.0 to 204.1 ft	1315.1 204.1							
				-gray dolomitic limestone layer from 204.1 to 205.0 ft								
205			93 (52)	***-gypsum seam (1.0") at 205.0 ft***								
				-pink gypsum seam (2.0") at 208.7 ft								
210			100 (96)	*-grayish-brown dolomitic limestone layer from 209.6 to 211.8 ft*								
215			100 (73)	***-pink, white to light gray GYPSUM layer, low hardness, vitreous from 215.0 to 215.6 ft*** *-slickensided joint (~30°) at 215.7 ft*	1304.2 215.0 1303.6 215.6							
220			100 (83)									
225			97 (57)									
				-w/numerous gypsum seam (up to 0.25") from 227.3 to 227.5 ft	1291.7 227.5							
				-white to light gray GYPSUM layer, low hardness, vitreous from 227.5 to 230.5 ft								
230			100 (85)	*-dark gray from 230.5 to 231.5 ft* ***-gypsum seam (0.5") at 230.9 ft***	1288.7 230.5							
				-grayish-brown dolomitic limestone layer from 231.5 to 232.3 ft ***-gypsum seam (0.25") at 232.7 ft***	1285.5 233.7							
235			97 (75)	***-white to light gray GYPSUM layer, low hardness, vitreous from 233.7 to 236.8 ft***	1282.4 236.8							
				-gypsum seam (0.5") at 238.3 ft *-slickensided joint (~35°) at 238.7 ft*								

COMPLETION DEPTH: 350.0 ft   DEPTH TO WATER: See Note

DRILL DATE: 04/05/09

5/28/2009 2:46:51 PM

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SHEET 6 of 9

LOG OF BORING B-6

FUGRO

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1519.20 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (93)	*-slickensided joint (~45°) at 239.4 ft* *-slickensided joint (~15°) at 240.0 ft* Dark bluish-gray SHALE --See Previous Page-- ***-white to light gray GYPSUM layer, low hardness, vitreous from 241.0 to 244.5 ft***	1278.2 241.0							
245			99 (90)	*-grayish-brown dolomitic limestone layer from 245.8 to 247.4 ft* ***-w/gypsum nodules (up to 0.25") from 246.7 to 247.2 ft*** *-alternating bluish-gray/dark gray from 247.4 to 251.1 ft*	1274.7 244.5							
250			99 (99)	***-white to light gray GYPSUM layer, low hardness, vitreous from 251.1 to 255.3 ft***	1268.1 251.1							
255			100 (70)	*-grayish-brown dolomitic limestone layer, w/micro-vugs from 255.3 to 256.7 ft* ***-gypsum nodule (1.0") at 255.9 ft*** *-dark gray from 256.7 to 259.3 ft* *-grayish-brown dolomitic limestone layer from 259.3 to 262.3 ft*	1263.9 255.3							
260			98 (98)									
265			100 (60)	*-red, brown and bluish-gray from 267.2 to 273.9 ft*								
270			98 (56)									
275			98 (93)	*-red, brown and bluish-gray from 277.0 to 283.8 ft*								

COMPLETION DEPTH: 350.0 ft

DEPTH TO WATER: See Note

DRILL DATE: 04/05/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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LOG OF BORING B-6

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1519.20 ft

Job No. 04.30091001

DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (96)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) ***-gypsum seam (0.25") at 281.1 ft***								
		-pink GYPSUM layer, low hardness, vitreous from 283.8 to 284.1 ft	1235.4 283.8 1235.1 284.1							
285	98 (75)									
290	100 (88)	*-grayish-brown dolomitic limestone layer from 290.3 to 291.3 ft* *-dark gray from 291.3 to 292.5 ft* ***-gypsum seam (4.0") at 293.5 ft***								
295	97 (63)	***-gypsum seam (0.5") at 295.6 ft***								
		-gypsum seam (0.5") at 299.0 ft	1219.8 299.4							
300	100 (93)	***-white to light gray GYPSUM layer, low hardness, vitreous from 299.4 to 300.0 ft*** *-gray dolomitic limestone layer from 300.0 to 300.7 ft* ***-white to light gray GYPSUM layer, low hardness, vitreous from 300.7 to 305.0 ft***	1219.2 300.0 1218.5 300.7							
305	96 (95)	*-gray dolomitic limestone layer from 305.0 to 309.6 ft* ***-w/gypsum nodules (up to 0.5") from 307.2 to 309.2 ft*** ***-gypsum seam (0.25") at 307.9 ft***	1214.2 305.0							
310	100 (90)	*-dark gray from 309.6 to 310.4 ft* ***-gypsum seam (1.0") at 310.3 ft*** *-grayish-brown dolomitic limestone layer from 310.4 to 314.2 ft* ***-w/gypsum nodules (up to 0.25") from 313.5 to 314.2 ft***								
315	100 (62)		1200.4 318.8							

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/05/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

LOG OF BORING B-6

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1519.20 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (100)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) ***-white to light gray GYPSUM layer, low hardness, vitreous from 318.8 to 330.0 ft***								
325			98 (88)									
330			100 (100)	Gray LIMESTONE, slightly weathered, hard, slightly fractured, w/shale seams and layers. (Jagger Bend/Valera)	1189.2 330.0							
335			100 (94)	***-gypsum seam (1.5") at 334.6 ft***								
340			100 (77)	***-gypsum seam (0.5") at 340.4 ft*** ***-gypsum seam (1.0") at 341.5 ft*** ***-gypsum seam (0.5") at 341.9 ft***								
345			100 (43)	*-bluish-gray shale layer from 344.2 to 350.0 ft*								
350					1169.2 350.0							
355												

NOTES:

1) Boring was advanced dry to the 1.2-ft depth and groundwater was not encountered above that depth prior to coring.

2) SPT Blowcounts were performed using a 140-lb hammer.

COMPLETION DEPTH: 350.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/05/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

LOG OF BORING SB-1

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1370.83 ft

Job No. 04.30091001

DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
		Reddish-brown silty SAND, w/scattered roots. SM (Alluvium)								
	70	*-light brown w/gravel from 1.5 to 3.0 ft*								
	24	*-limestone boulder from 3.0 to 3.5 ft*								
5			1365.4 5.4							
	17	Reddish-brown to brown well-graded GRAVEL with clay and sand, medium dense to dense, w/large gravel and cobbles. GW-GC (Alluvium) *[10-min water level reading at 5.7 ft]*								
	32									
10			1359.8 11.0							
	70 (37)	Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain) *-w/shale interbeds from 11.5 to 13.2 ft*								
15	100 (90)	*-w/limestone laminations from 16.0 to 16.8 ft*								
20	100 (85)									
		-vertical fracture, healed from 22.5 to 23.1 ft								
25	100 (93)									
30	100 (62)	*-w/very close horizontal discontinuities from 31.7 to 33.3 ft*								
35	100 (82)	*-w/numerous micro-vugs from 36.7 to 37.7 ft*								

COMPLETION DEPTH: 85.0 ft

DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

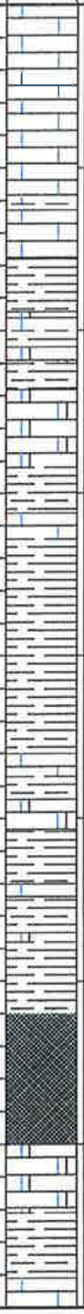
SHEET 1 of 3

LOG OF BORING SB-1

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1370.83 ft Job No. 04.30091001



DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			97 (90)	Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain)								
45			98 (72)	*-dark gray shale seam from 46.1 to 46.3 ft* *-w/very close horizontal discontinuities from 46.3 to 47.8 ft*								
50			100 (25)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *-grayish-brown dolomitic limestone seam, w/micro-vugs from 49.4 to 49.6 ft* *-gray limestone layer from 49.6 to 50.0 ft* ***-gypsum seam (0.25") at 50.0 ft*** *-grayish-brown dolomitic limestone layer, w/micro-vugs from 50.5 to 51.0 ft* ***-w/pink gypsum nodules (up to 0.25") from 50.6 to 50.8 ft*** ***-pink gypsum seam (0.5") at 50.9 ft*** ***-pink gypsum seam (1.5") at 51.0 ft*** *-grayish-brown dolomitic limestone layer, w/micro-vugs from 51.8 to 54.2 ft* ***-w/pink gypsum nodules (up to 0.5") from 53.5 to 53.8 ft***	1323.0 47.8							
55												
60			100 (67)									
65			99 (80)	*-grayish-brown dolomitic limestone layer, w/micro-vugs from 64.4 to 65.4 ft* ***-w/pink gypsum seams (up to 0.25") from 68.6 to 68.8 ft***								
70			100 (82)	*[10% drilling fluid loss from 70.0 to 73.0 ft]* ***-white to light gray GYPSUM layer, low hardness, vitreous from 71.0 to 75.0 ft*** *[20% drilling fluid loss from 73.0 to 76.0 ft]*	1299.8 71.0							
75			100 (58)	*-grayish-brown dolomitic limestone layer, w/micro-vugs from 75.0 to 77.1 ft* *[10% drilling fluid loss from 76.0 to 85.0 ft]* ***-gypsum seam (0.25") at 77.3 ft*** ***-gypsum seam (0.25") at 78.5 ft*** *-gray limestone layer from 79.1 to 80.6 ft*	1295.8 75.0							

COMPLETION DEPTH: 85.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

SHEET 2 of 3

LOG OF BORING SB-1

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1370.83 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			100 (72)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera)								
				-grayish-brown dolomitic limestone seam, w/micro-vugs from 83.2 to 83.4 ft	1287.4 83.4							
85				***-white to light gray GYPSUM layer, low hardness, vitreous from 83.4 to 84.3 ft***	1286.5 84.3							
				-dark gray from 84.3 to 85.0 ft	1285.8 85.0							
				-pink gypsum nodule (1.5") at 84.5 ft								
90												
95												
100												
105												
110												
115												

NOTES:

1) Boring was advanced dry to the 11.2-ft depth and groundwater was encountered after a 10-minute waiting period at 5.7-ft.

2) SPT Blowcounts were performed using a 170-lb hammer.

COMPLETION DEPTH: 85.0 ft

DEPTH TO WATER: See Note

DRILL DATE: 04/15/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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LOG OF BORING SB-2

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1385.89 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
5			27	Reddish-brown silty SAND, medium dense. SM (Alluvium)								
			100 (92)	Gray LIMESTONE, slightly weathered, hard, fractured, w/numerous dark gray horizontal discontinuities and shale seams and layers. (Bead Mountain) *-tan from 6.4 to 6.5 ft* *-tan from 6.7 to 6.8 ft*	1380.3 5.6							
10			100 (100)	*-w/multiple vertical fractures, healed from 10.0 to 10.6 ft* *-w/very close horizontal discontinuities from 11.7 to 12.4 ft*								
15			100 (100)	*-w/very close horizontal discontinuities from 14.5 to 15.0 ft* *-vertical fracture, healed from 15.8 to 16.3 ft* *-w/calcite-coated vug (0.25") at 17.5 ft*								
20			100 (98)									
25			100 (100)	*-w/very close horizontal discontinuities from 25.7 to 27.0 ft*								
30			99 (99)	*-w/numerous calcite-coated vugs (up to 0.25") from 30.1 to 30.5 ft*								
35			100 (87)	*-w/very close horizontal discontinuities from 36.5 to 36.9 ft*								

COMPLETION DEPTH: 80.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/18/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

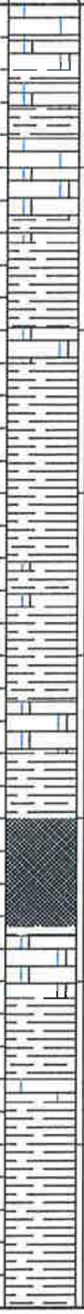
SHEET 1 of 3

LOG OF BORING SB-2

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1385.89 ft Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (82)	Gray LIMESTONE --See Previous Page--	1344.8 41.1							
		Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *-grayish-brown dolomitic limestone layer from 41.1 to 42.0 ft* *-grayish-brown dolomitic limestone layer from 42.7 to 43.2 ft*								
45	98 (85)	*-grayish-brown dolomitic limestone layer from 45.0 to 46.6 ft* *-grayish-brown dolomitic limestone layer from 47.0 to 47.3 ft*								
50	14 (0)	*-grayish-brown dolomitic limestone layer from 49.9 to 51.0 ft*								
55	88 (75)	*-grayish-brown dolomitic limestone layer from 57.1 to 57.4 ft* *-grayish-brown dolomitic limestone layer, w/micro-vugs and vertical fracture, healed from 58.1 to 58.5 ft*								
60	100 (59)	*-grayish-brown dolomitic limestone layer from 61.4 to 63.0 ft* ***-w/gypsum seams (up to 0.25") from 62.6 to 62.7 ft*** ***-pink and gray gypsum seam (2.0") at 62.7 ft***								
65	100 (95)	***-white to light gray GYPSUM layer, low hardness, vitreous from 65.0 to 68.3 ft***	1320.9 65.0							
			1317.6 68.3							
70	100 (87)	*-grayish-brown dolomitic limestone layer from 68.6 to 70.5 ft* ***-w/multiple gypsum filled vertical fractures from 68.6 to 68.9 ft*** *-slickensided joint (~45°) at 71.2 ft* *-slickensided joint (~45°) at 71.6 ft* *-slickensided joint (~5°) at 72.3 ft* ***-w/gypsum seams (up to 0.25") from 72.7 to 72.8 ft*** *-gray limestone layer, w/very close horizontal discontinuities from 73.0 to 73.7 ft*								
75	98 (98)									
			1305.9							

COMPLETION DEPTH: 80.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/18/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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LOG OF BORING SB-2

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ LOCATION: See Plate 2

SURF. EL. 1385.89 ft Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
				NOTES: *1) Boring was advanced dry to the 6.0-ft depth and groundwater was not encountered above that depth prior to coring.* *2) SPT Blowcounts were performed using a 140-lb hammer.*	80.0							
85												
90												
95												
100												
105												
110												
115												

COMPLETION DEPTH: 80.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/18/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

SHEET 3 of 3

LOG OF BORING SB-3

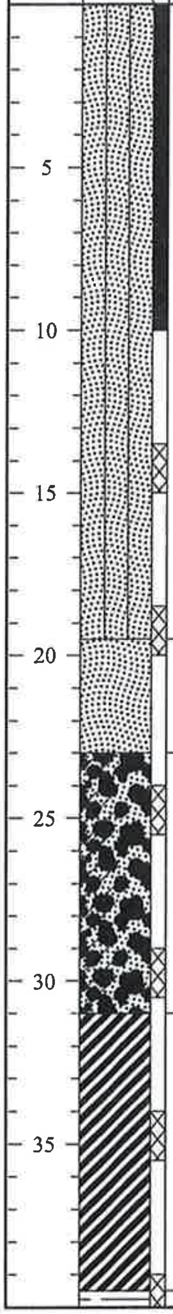
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1366.72 ft

Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
		Reddish-brown silty SAND, loose to medium dense. SM (Alluvium)								4.5+(P)
										3.5(P)
										1.5(P)
5										4.5+(P)
										4.5+(P)
10										
	8									
15		*-w/scattered gravel below 15.0 ft*								
	18		1347.2 19.5							
20		Tan poorly graded SAND with gravel, medium dense, w/rounded to subrounded gravel. SP (Alluvium)								
		▽	1343.7 23.0							
	42	Reddish-brown and tan well-graded GRAVEL with clay and sand, dense, w/occasional cobbles. GW-GC (Alluvium) *[10-min water level reading at 23.8 ft]*								
25		*-w/clayey sand layer from 27.5 to 29.0 ft*								
	33									
30			1335.7 31.0							
		Gray fat CLAY with sand, w/scattered gravel. CH (Alluvium)								
35	WOH									
	51		1327.2							

COMPLETION DEPTH: 85.0 ft

DEPTH TO WATER: See Note

DRILL DATE: 04/17/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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SHEET 1 of 3

LOG OF BORING SB-3

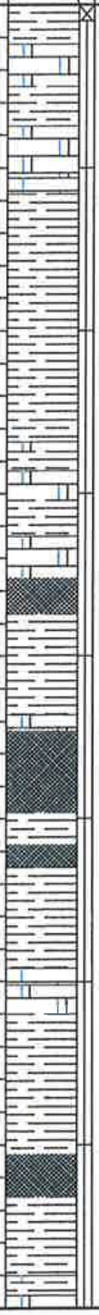
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1366.72 ft

Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (69)	Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *[100% drilling fluid loss from 40.5 to 85.0 ft]* *-grayish-brown dolomitic limestone layer from 41.2 to 42.5 ft* *-grayish-brown dolomitic limestone layer, w/micro-vugs from 43.7 to 45.3 ft*	39.5							
45	100 (85)									
50	100 (93)									
		-grayish-brown dolomitic limestone layer, w/micro-vugs from 53.4 to 53.7 ft								
55	98 (64)	*-grayish-brown dolomitic limestone layer from 54.3 to 55.2 ft*								
		-grayish-brown dolomitic limestone layer from 56.3 to 57.6 ft	1309.1 57.6							
		-pink, white to light gray GYPSUM layer, low hardness, vitreous from 57.6 to 58.7 ft	1308.0 58.7							
		-grayish-brown dolomitic limestone seam from 58.2 to 58.4 ft								
60	97 (87)									
		-slickensided joint (~35°) at 61.6 ft	1304.4 62.3							
		-grayish-brown dolomitic limestone layer, w/multiple vertical fractures, healed from 61.8 to 62.3 ft								
65	100 (80)	***-white to light gray GYPSUM layer, low hardness, vitreous from 62.3 to 64.8 ft***	1301.9 64.8							
		-gypsum seam (0.25") at 65.2 ft	1300.9 65.8							
		-white to light gray GYPSUM layer, low hardness, vitreous from 65.8 to 66.5 ft	1300.2 66.5							
		-gypsum seam (1.5") at 66.7 ft								
70	93 (83)	***-grayish-brown dolomitic limestone layer, w/gypsum nodules (up to 0.25") from 70.1 to 71.0 ft***								
75	100 (67)	***-gypsum seam (0.25") at 74.4 ft*** ***-gypsum seam (0.5") at 74.6 ft***	1291.4 75.3							
		-white to light gray GYPSUM layer, low hardness, vitreous from 75.3 to 76.6 ft	1290.1 76.6							
		-grayish-brown dolomitic limestone layer from 79.6 to 81.5 ft								

COMPLETION DEPTH: 85.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/17/09

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U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

SHEET 2 of 3

LOG OF BORING SB-3

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1366.72 ft

Job No. 04.30091001

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
			90 (85)	***-slickensided joint (~25°), w/gypsum seam (0.25") at 79.6 ft*** Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *-slickensided joint (~30°) at 82.4 ft* *-grayish-brown dolomitic limestone layer, w/micro-vugs from 82.5 to 83.2 ft*	1281.7 85.0							
85				*NOTES:* *1) Boring was advanced dry to the 40.5-ft depth and groundwater was encountered after a 10-minute waiting period at 23.8-ft.* *2) SPT Blowcounts were performed using a 170-lb hammer.*								
90												
95												
100												
105												
110												
115												

COMPLETION DEPTH: 85.0 ft

DEPTH TO WATER: See Note

DRILL DATE: 04/17/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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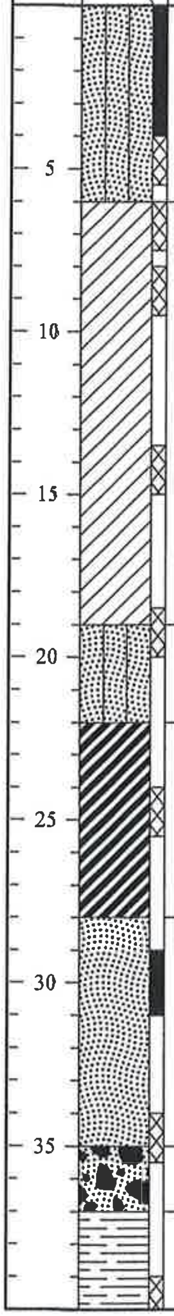
SHEET 3 of 3

LOG OF BORING SB-4

Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ   LOCATION: See Plate 2

SURF. EL. 1350.50 ft   Job No. 04.30091001



DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
				Reddish-brown silty SAND, medium dense. SM (Alluvium)								4.5+(P)
			13									
5												
			15	Reddish-brown lean CLAY with sand, w/scattered shell fragments. CL (Alluvium)	1344.5 6.0							
			19									
10												
			27									
15												
			20									
				Reddish-brown silty SAND, medium dense. SM (Alluvium)	1331.5 19.0							
20												
				Reddish-brown fat CLAY with sand. CH (Alluvium)	1328.5 22.0							
			33									
25												
				Tan poorly graded SAND with gravel, dense, w/rounded to subrounded gravel. SP (Alluvium)	1322.5 28.0							
30												
				[10-min water level reading at 31.0 ft]	▽							
			32									
35				Reddish-brown well-graded GRAVEL with sand, dense, w/occasional cobbles. GW (Alluvium)	1315.5 35.0							
				Tan and gray SHALE, weathered, low to moderately hard, non-calcareous, w/limestone seams and layers. (Jagger Bend/Valera)	1313.5 37.0							
			20									

COMPLETION DEPTH: 70.0 ft   DEPTH TO WATER: See Note

DRILL DATE: 04/19/09

U = Unconfined
Q = Unconsolidated Undrained Triaxial
P = Pocket Penetrometer
T = Torvane

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SHEET 1 of 2

LOG OF BORING SB-4

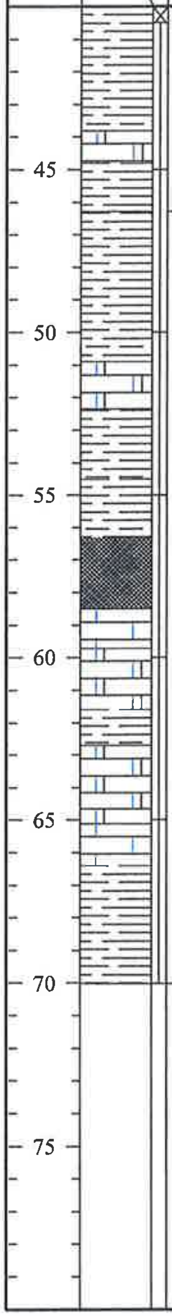
Cedar Ridge Reservoir Alternative Dam Sites
Throckmorton County, Texas

TYPE: Sample/Wet Rotary - NQ

LOCATION: See Plate 2

SURF. EL. 1350.50 ft

Job No. 04.30091001



DEPTH, FT	BLOWS PER FOOT OR REC/(RQD),%	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT, %	PLASTICITY INDEX(PI),%	PASSING NO. 4 SIEVE,%	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	COMPRESSIVE STRENGTH, TSF
	100 (65)	Tan and gray SHALE, weathered, low to moderately hard, non-calcareous, w/limestone seams and layers. (Jagger Bend/Valera) *[100% drilling fluid loss from 40.5 to 55.0 ft]*								
45	92 (87)	*-grayish-brown dolomitic limestone layer, w/micro-vugs from 43.8 to 44.8 ft* *-vertical fracture, healed from 44.5 to 44.8 ft*								
		Dark bluish-gray SHALE, fresh, low to moderately hard, non-calcareous, w/gypsum and limestone seams and layers. (Jagger Bend/Valera) *-tan from 48.7 to 48.9 ft*	1304.2 46.3							
50	100 (75)	*-grayish-brown dolomitic limestone layer, w/micro-vugs from 50.9 to 52.4 ft* ***-w/gypsum nodules (up to 1.0") from 51.4 to 51.7 ft***								
55	100 (85)	*[No drilling fluid loss from 55.0 to 70.0 ft]*								
		-white to light gray GYPSUM layer, low hardness, vitreous from 56.3 to 58.5 ft	1294.2 56.3							
			1292.0 58.5							
60	99 (73)	*-grayish-brown dolomitic limestone layer from 59.7 to 61.6 ft* ***-w/gypsum nodules (up to 0.5") from 60.2 to 60.7 ft*** ***-gypsum seam (0.25") at 61.3 ft*** *-grayish-brown dolomitic limestone layer from 62.7 to 65.1 ft* *-vertical fracture, clay-coated from 62.7 to 63.3 ft* *-w/shale seams (up to 2.0") from 63.3 to 64.6 ft* ***-gypsum seam (1.0") at 64.4 ft***								
65	100 (85)	***-gypsum seam (0.25") at 66.7 ft*** *-slickensided joint (~35°) at 67.0 ft* *-slickensided joint (~10°) at 69.6 ft* *-slickensided joint (~35°) at 69.8 ft*	1280.5 70.0							

NOTES:
1) Boring was advanced dry to the 40.5-ft depth and groundwater was encountered after a 10-minute waiting period at 31.0-ft.
2) SPT Blowcounts were performed using a 140-lb hammer.

COMPLETION DEPTH: 70.0 ft DEPTH TO WATER: See Note

DRILL DATE: 04/19/09

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U = Unconfined
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P = Pocket Penetrometer
T = Torvane

TERMS & SYMBOLS USED ON BORING LOGS FOR SOIL

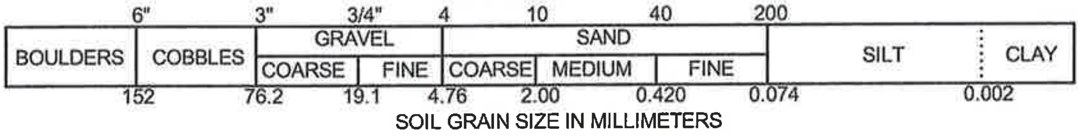
SOIL TYPES

- ▨ CH, Fat Clay
- ▧ CL, Lean Clay
- ▥ ML, Silt
- ▩ Fill, Unclassified
- ░ SP, Poorly-Graded Sand
- ▨ SC, Clayey Sand
- ▒ SM, Silty Sand
- ▓ SW, Well-Graded Sand
- ● GP, Poorly-Graded Gravel
- ● GC, Clayey Gravel
- ● GM, Silty Gravel
- ● GW, Well-Graded Gravel

SAMPLER TYPES

- ■ Seamless Push Tube
- ☒ Standard Penetration Test
- ☰ THD Cone Penetrometer Test
- ▯ Core
- ▯ Auger
- ▮ Auger Sample

SOIL GRAIN SIZE



STRENGTH OF COHESIVE SOILS(1)

CONSISTENCY	COMPRESSIVE STRENGTH Tons Per Sq. Ft.
Very Soft	Less Than 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very Stiff	2.00 to 4.00
Hard	Greater Than 4.00

DENSITY OF GRANULAR SOILS(1)

NUMBER OF BLOWS PER FT., N	RELATIVE DENSITY
0-4	Very Loose
4-10	Loose
10-30	Medium
30-50	Dense
Over 50	Very Dense

1) Peck, Hanson, and Thornburn, (1974), Foundation Engineering.

ASTM D 2488 · TABLE 7 · Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

ASTM D 2488 · TABLE 3 · Criteria for Describing Moisture Condition

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

ASTM D 2488 · Note 15 · Criteria for Describing Percentages of Gravel, Sand and Fines

Description	Criteria
Trace	Particles are present but estimated to be less than 5 %
Few	5 to 10 %
Little	15 to 25 %
Some	30 to 45 %
Mostly	50 to 100 %

Criteria for Describing Inclusions

Description	Criteria
Parting	Inclusion <1/8" thick extending through sample
Seam	Inclusion 1/8" to 3" thick extending through sample
Layer	Inclusion >3" thick extending through sample

TERMS & SYMBOLS USED ON BORING LOGS FOR ROCK

ROCK TYPES

▦	LIMESTONE	▦	DOLOMITE	▓	SANDSTONE
▨	HIGHLY WEATHERED LIMESTONE	▨	HIGHLY WEATHERED DOLOMITE	▤	SHALE
▦	DOLOMITIC LIMESTONE	▒	GYPSUM	▤	CLAYSHALE

SAMPLER TYPES

█	Seamless Push Tube	▯	Core
☒	Standard Penetration Test	▯	Auger
▤	TxDOT Cone Penetration Test	▮	Auger Sample

HARDNESS

Friable	- Crumbles under hand pressure
Low Hardness	- Can be carved with a knife
Moderately Hard	- Can be scratched easily with a knife
Hard	- Can be scratched with a knife with difficulty

SOLUTION & VOID CONDITIONS

Void	Interstice; a general term for pore space or other opening in rock.
Cavities	Small solutional concavities.
Vuggy	Containing small cavities, usually lined with a mineral of different composition from that of the surrounding rock.
Vesicular	Containing numerous small, unlined cavities, formed by expansion of gas bubbles or steam during solidification of the rock.
Porous	Containing pore, interstices, or other openings which may or may not interconnect.
Cavernous	Containing cavities or caverns, sometimes quite large. Most frequent in limestones and dolomites.

WEATHERING GRADES OF ROCKMASS (1)

TERM	DESCRIPTION
Slightly	Discoloration indicates weathering of rock material and discontinuity surfaces.
Moderately	Less than half of the rock material is decomposed or disintegrated to a soil
Highly	More than half of the rock material is decomposed or disintegrated to a soil.
Completely	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.
Residual Soil	All rock material is converted to soil. The mass structure and material fabric are destroyed.

BEDDING THICKNESS (2)

Very Thick	>4'
Thick	2' - 4'
Thin	2" - 2'
Very Thin	1/2" - 2"
Laminated	0.08" - 1/2"
Thinly-Laminated	<0.08"

JOINT DESCRIPTION

SPACING	INCLINATION	SURFACES
Very Close <2"	Horizontal 0 - 5	Slickensided - Polished, grooved
Close 2" - 12"	Shallow 5 - 35	Smooth - Planar
Medium Close 12" - 3'	Moderate 35 - 65	Irregular - Undulating or granular
Wide >3'	Steeply 65 - 85	Rough - Jagged or pitted
	Vertical 85 - 90	

REFERENCES:

1) British Standard (1981) Code of Practice for Site Investigation , BS 5930

2) The Bridge Div., Tx. Highway Dept. Foundation Exploration & Design Manual 2nd Edition, revised June, 1974.

TASK 2

GEOTECHNICAL ADVISORY GROUP MEETINGS

Meeting Notes
For
Geotechnical Advisory Group Meeting
For
Cedar Ridge Reservoir
(February 20, 2009)

Item 1. - Review of Previous Geotechnical Work (Lewis Yates)
- Overview of 2008 Geotechnical investigation and findings. Reports delivered to HDR, City and eHT.

Item 2.- Preliminary findings of Geologic Literature Review (Mark Wilkerson)
- Overview of 1932 Report of geology of Throckmorton County. Copies of key maps were provided on Friday.

Item 3.- Preliminary findings of Geologic Structure-Contour Mapping (Kenneth Johnson)
- Presentation on results of review of oil and gas logs for evidence of gypsum and comparison with 2008 boring log at Cedar Ridge Dam site.
- Presentation on development of maps showing the estimated top and bottom elevations of gypsum near sites A, B and C.
- Because of occurrence of gypsum at initial dam site – focus on new sites A, B, C.

Item 4. - Review of year 2060 Water Supply Needs (Ken Choffel)
- Handout chart – 2060 supplies and 2060 demands showing additional 2-year safe yield need of 20,000 acft/yr.
- Focus on two-year safe yield supply scenario – Need of 20,000 acft/yr in 2060.
- Going from a 2-yr to 1-yr safe yield increases the yield of the original Cedar Ridge site about 10%.

Item 5.- Elevation-Area-Capacity (EAC) data for 4 Potential Dam Sites (Ken Choffel)
- Handout of EAC's for initial and 3 alternative dam sites.
- For preliminary evaluations, limit PMF level to maximum of 1520 ft-msl.
- Figure 1 – Capacity vs. Area – shows an indication of the efficiencies of the sites.

Item 6. - Safe Yield Analyses (Cory Shockley)
- Figure 2 – 2-year safe yields versus conservation pool capacity.
- Figure 5 – Comparison of surface areas for various conservation pool capacities.

Item 7. - Preliminary Conservation Pool & Spillway Elevations (Ken Choffel)
- Figure 3 – Preliminary estimates of PMF, emergency spillway and conservation pool capacities at sties A, B and C assuming similar spillways as initial site.

- Sites B and C will require larger spillway capacities which will allow reservoir spills earlier in the spill event, possibly tainter gates.
- Figure 4 – Estimated Range of Conservation Pool Elevations for all sites vs. Capacity and discussion of lines of equal yield and lines of equal surface area.

Item 8. – Preliminary Dam Embankment Requirements (Ken Choffel)

- Figure 6 – Comparison of Embankment Volumes and reservoir storage.
- Figure 7 – Comparison of Dam Profiles for all sites.

Item 9. – Discussion of Siting and Sizing Issues (All)

- Site A feasibility depends on results of the next geotechnical investigation.
- Site B appears to have good characteristics in terms of distance above Gypsum and reservoir side-wall thickness.
- Site C can probably be eliminated from consideration – but wait until findings of next geotechnical investigation are known.

Item 10. – Status of Site Access Agreements and Helicopter Reconnaissance Dates (All)

- Helicopter flight – 1st week of March possibly second week.
    - Sooner the better since vegetation is beginning to come out.
    - 2 geologists and Cory Shockley will be on the helicopter flight.
- Hendrick agreement should be signed next week.
- Lambshead we have permission to fly over (asked to limit during spring break).
- Will take video of Clear Fork from Lueders to Cedar Ridge site.
- Detailed site recon during helicopter flight limited to Hendrick Ranch.
- Geological field work might be started 9th or 16th of March
- Drilling in April on Hendrick is a possibility given the proposed schedule.

Item 11. – Discussion of Schedule and Future Work Activities (All)

- Geologic Field Mapping scheduled to be started 9th or 16th of March
- Initial Environmental Field Reconnaissance – late March
    - Water Quality
    - Riparian Corridor
    - Bird Surveys
    - Snake Surveys
    - Fish Surveys
    - Mussel Surveys
- Draft Project Management Plan (PMP) for COE – Draft in March
    - Meeting with COE – This is not a critical path item, will wait until final dam site is selected to ensure the most complete document is developed before approaching the COE. (no earlier than May)
- Region G coordination – need some discussion with David Dunn on when to present this to the Brazos G Regional Planning Group.
    - Following meeting - David Dunn indicated that the preferred presentation timeframe to the planning group would likely be August or possibly October. This would allow the Cedar Ridge team to

    complete enough of the work so that the presentation to the planning group contains the most complete information.
- Initial Geological Core Borings – Tentatively scheduled in April dependent on helicopter and field recon results.
    - Lewis Yates indicated that drilling on the 1490 contour would likely result in the most economical drilling program for the next phase.
    - Placed sticky notes on site map to indicate potential boring locations.
        - See photos provided by Ken Johnson of these locations.
- Meetings with Ranches – This was not discussed in depth at the meeting.
- Use of TWDB funds; Tommy and Scott to meet and provide TWDB with appropriate work plan and scope.

Summary of Current Deliverables:

- 1 Map of Project Area with scale of 1" = 3,000' (Provided to all)
- 11 x 17 Map Set with scale of 1" = 1,000' (Provided to all)
- 22 x 34 Map Set with scale of 1" = 500' (1 Set provided to Mark Wilkerson)
- 2 Maps of Geologic Structure (estimated top and bottom elevations of gypsum) provided by Kenneth Johnson.

Upcoming Deliverables:

- Geologic Structure Report (after field geologic recon work).
- Geologic Report (after field geologic recon work).
- Technical Memo on EAC data, embankment and spillway quantities (after next drilling program.)
- Draft PMP for COE and potential meeting with COE (delayed to May at the earliest).

Meeting Notes

For

Geotechnical Advisory Group Meeting

For

Cedar Ridge Reservoir

(June 4 and 5, 2009)

Item 1 – Abilene's water needs & future supply requirements – Dunn

- Handout of the 2006 Brazos G plan – Summary for Abilene
- Handout of the DRAFT 2011 Brazos G Plan – Summary for Abilene
- Handout of safe yield comparisons between the 2006 and 2011 plans
- Demands compared to existing supplies show a need for additional water supplies

Item 2 - Yields at sites A&B - Choffel

- Supply available from Cedar Ridge (Sites A and B)
- Discussion of assumptions used to develop the numbers
- Handout of comparison of physical characteristics of the two sites
- Site A is preferred considering its higher yield, however site B is acceptable in terms of meeting future water supply shortages

Item 3 – Environmental Studies –Cory Shockley & James Thomas

- Video clips from Helicopter flight & summary of initial site visit – Shockley
- Summary of literature review – James
- Review of May 2009 snake survey - James
- Results of interview with CRMWD staff – James
- Recommended short and long-term monitoring program – James
- Comparison of Sites A & B (acreage) with initial Site – James
- Discussion of preliminary CREZ Transmission Routes - James
- Discussion of expanding survey area to include area outside of project site
- Tommy asked James to develop an executive summary of Env. Activities.
- HDR will draft a letter for the City that addresses the CREZ corridors through the potential reservoir sites and coordinate with Martin Rochelle

Item 4 - Findings of Fugro's and Ken Johnson's work – Lewis, Mark & Ken

- Handouts and discussion of Work – Mark and Lewis
- Dr. Johnson presented his findings on regional structure
- Significant discussion on the pros and cons of the various dam sites in relation to the regional geology and the detailed boring logs - All
- Decision was unanimous to drop Sites A and C from further study and to proceed with detailed geotechnical investigation of Site B

Item 5 - Update and Recap for David Vela.

- Abilene's needs
- Geology Recap
- Discussion of landowner access issues
    - Schedule – City to discuss access for Roger's property on June 19th

Item 6 - Schedule for next phase of drilling at Site B

- Start drilling 6/15/09; will need survey data - Lewis
- Meeting to discuss drilling results – 8/27/09 and 8/28/09

Item 7 - Presentation to Council – date pending

- 15 minutes for Demands
- 15 minutes for Gypsum
- 15 minutes for Costs
- 15 minutes for questions
- May include 5 to 10 minute version of video - Lueders to Dam Site B
- Add property owners to video for reference from Swenson down
- David Vela to check with the mayor on these dates

Item 8 - Surveying

- Not currently in any budgets or SOW; Oct – Jan of 2010 at earliest
- For water rights permit we will need a map of the original survey corners in the area of dam site B – Scott Hibbs

Item 9 - New USGS gages

- Streamflow and water quality monitoring stations may be needed
- HDR will review sites prior to next GAG meeting

Item 10 - Discussion of next phase of drilling program

- Handout and discussion of various Site B dam/spillway configurations – Rich
- Ken Johnson indicated that all dam alignments discussed for Site B were acceptable from the perspective of the depth to gypsum.

Follow-up and next steps:

- Rich and Ken to talk to Lewis by next Thursday with plan for drilling Site B
- Cory will let ranch know that drillers will be back out on 6/15/09
- Next GAG meeting set for 8/27 and 8/28
- Ken and Scott begin budget discussions for FY 2010 work
- Set up meeting with COE after the Council meeting coordinate with James
- HDR to contact mussel expert (Howells) to perform preliminary survey.
- Tommy and Scott to meet with TWDB regarding coordination with COE funds – may accelerate the PMP schedule.
- Lewis to finalize report and send out Final Draft for review; consider adding "Definition of Terms".
- Tommy authorized HDR & Fugro staff to meet with Warren Samuelson (TCEQ – Dam Safety Program) to discuss the overall project.

Meeting Notes

For

Geotechnical Advisory Group Meeting

For

Cedar Ridge Reservoir

(August 27 and 28, 2009)

Item 1 – Findings of Geologic Investigation of Site B – Lewis Yates, Mark Wilkerson, & Ken Johnson

- Discussion of the up to date findings on the latest drilling investigation. Some of the lab tests are still underway - Yates
- Discussion on the preliminary report – Yates
- General discussion on results of the packer tests
- Presentation of the results on the geology from the latest round of drilling investigation - Wilkerson
  - Good news on the results for the structural geology- Favorable for reservoir site
  - Stratigraphy – Confirmation of earlier findings
  - Summary – Confirmation of what was predicted at earlier meetings.
- Various discussions on drilling fluid loss, gypsum nodules, and other related issues
- Tommy O'Brien asked if the team felt that the site would hold water along the perimeter of the reservoir (lateral loss). Consensus is "yes"; good site for holding water.

Item 2 - Engineering Geology Overview – Rich Shoemaker and Lewis Yates

- Discussion of spillway sites, potential material borrow sources, and potential riprap sources near site (foundation treatment/grouting) - Shoemaker and Yates
- Discussion of grouting program, cutoff trench, dam design, and general engineering geology – Shoemaker
- General discussion of dam construction and ability to obtain construction materials

Item 3 - Final GAG Discussion of Findings of Site B Geologic Investigations – Yates, Choffel, and Shoemaker

- General discussion of O'Brien's comments on the Preliminary geotechnical report
- Discussion on Jackson Harper's Report
- Yates will go back and finalize all reports. Signed, sealed and converted to PDF – Estimated schedule next week (8/31)

- Results of meeting with Warren Samuelson with TCEQ dam safety unit – Shoemaker, Choffel, and Yates
    - Mentioned the Gypsum issue with Warren and looking at additional dam sites - Choffel
    - Choffel stated that Warren mentioned oil and gas wells, from the statewide perspective, have never been a problem in his experience.
- Need for Future Geotechnical Investigations
    - Question - Is there any need to investigate the pool area from a geologic perspective to ensure that it holds water? Consensus is "no" based on regional geology
    - Surveying – The USGS maps match very closely to the completed surveying. For permitting purposes, the existing data is probably sufficient, so the detailed surveying can be delayed to the future. Will discuss this with Maxey Shepherd about his thoughts on the accuracy of the USGS maps.

Item 4 - Region G Summary of Abilene's Water Needs and Supplies (2010 to 2060) – Shockley, O'Brien, and Hibbs

- Water Supply for Cedar Ridge (2- year safe yield without return flows) – Shockley
    - Presentation on yield and reservoir site characteristics
    - Handout of Brazos G WWP Table
    - Discussion on WWP tables and realization that the supplies from FPHR and WCTMWD could change, pending the Board's decision on use of 2-year safe yield.
- Other Region G Issues – O'Brien and Hibbs

Item 5 - Property Access Status – O'Brien and Hibbs

- Lueders Dam (possible streamgage site)
    - Dam no longer owned by City of Stamford
    - One lady owns the portion of the dam to which the project needs access
    - Talk to USGS about visiting the Lueders site for locating stream and water quality gage - October 2010 target date for starting measurements.
- Lambshead Ranch Property access (water quality/fish/snake/mussel sampling)
    - O'Brien would like to present the Lambshead with a final access agreement for the remaining activities. Time and location are the key issues for the ranch. HDR will provide a revised list of access needed to O'Brien and Hibbs for activities planned for the future.
- Other Property Owners - Possibly collaborate with Michelle to identify a plan for access
- Discussion of potential briefing to Hendrick, Lambshead and other ranches
- Mayor is handling the communications with the ranches.

Item 6 - Abilene City Council meeting to Present Findings (Date and Approach) – O'Brien

- Council Meeting will not happen in October - November or December most likely
- Council meets on the 5th and 19th of November
- December 3rd or 17th are also possibilities
- O'Brien is waiting for direction from the Mayor and Council on selecting a date
- Ken Johnson to provide available dates to Tommy
- This presentation would likely occur at a workshop rather than a council meeting. A workshop at the end of the council meeting is a possibility.
- Attendees: Dr. Ken Johnson, David Dunn, Scott Hibbs, Ken Choffel, Lewis Yates(?)
- Agenda – To be finalized sometime after all of the reports are done
- Go back to May 2008 and set the stage and timeline - Good strategy
- Goal is to have everything pulled together by the end of September
- Plan to meet the day before the council meeting
- Need a 5 – 10 minute video summary
    - Add property owner names
    - Start at Lueders
    - Focus on Dam Site
    - Go all the way to the Perry Cabin

Follow-up and Next Steps:

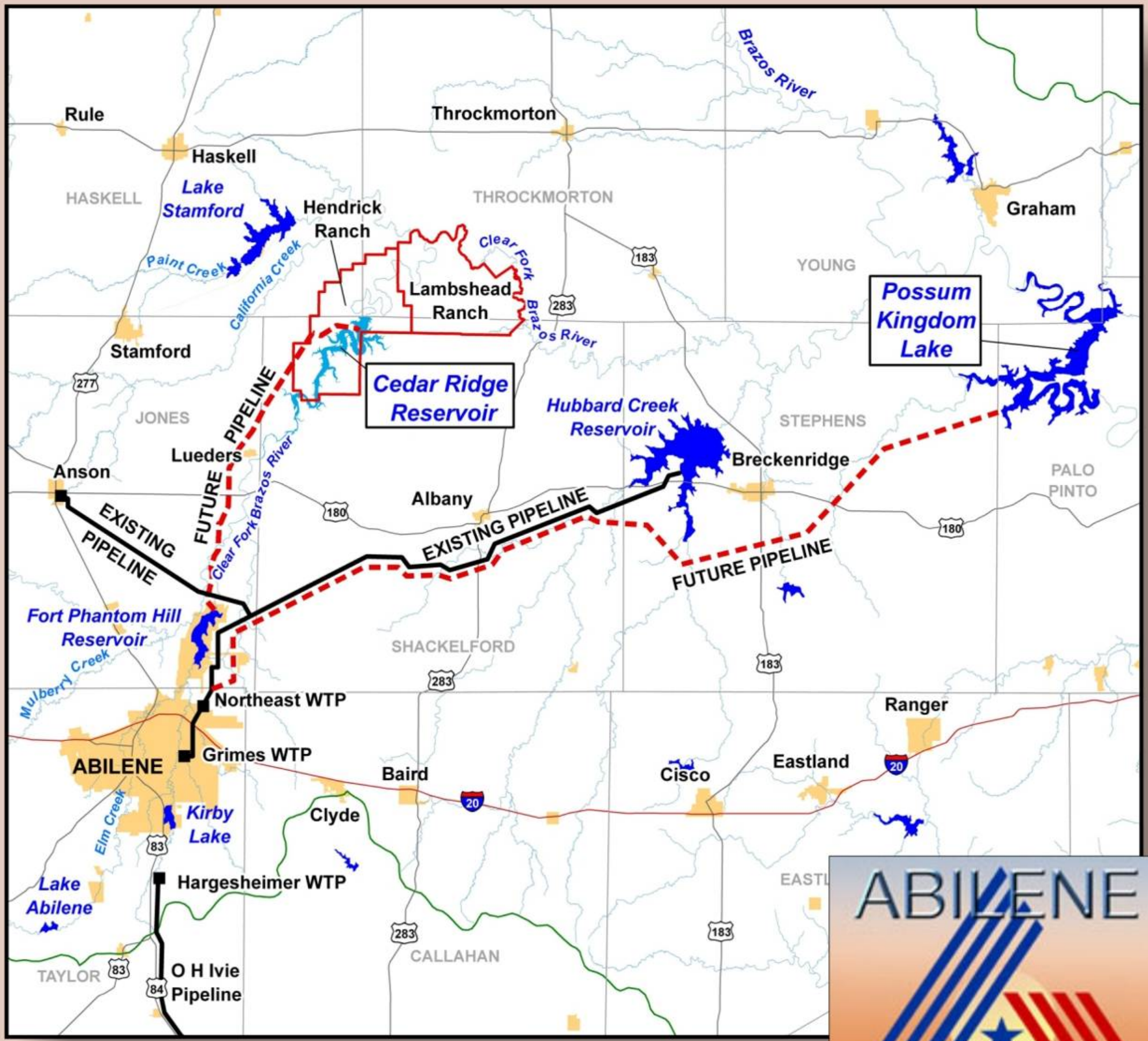
- Fugro to finalize Geotechnical Report (Site B)
- HDR to complete Environmental Report
- HDR to complete updated Yield and Cost Report
- HDR and eHT to finalize Scope of Work for FY 2010
- Environmental Report has following sections:
    - Executive Summary
    - Proposed Sampling and Monitoring Plan
    - Literature review – Appendix
    - Initial reconnaissance field trip – Appendix
    - Example shiner habitat in upper Brazos Basin – Attachment to Appendix
    - Brazos Water Snake Surveys – Appendix
    - Mussel Survey – Appendix
        - Choffel summarized Dr. Howells report. Concluded no threatened species present, identified species will live in a reservoir
    - Aquatic Life Monitoring (ALM) Surveys – Appendix

TASK 3

RESERVOIR YIELD AND COST REPORT

Summary Report

Updated Evaluations of Cedar Ridge Reservoir and Possum Kingdom Lake Water Supply Options for City of Abilene



ABILENE

November 2009

HDR | ONE COMPANY
Many Solutions℠

Enprotec / Hibbs & Todd

Summary Report

Updated Evaluations of Cedar Ridge Reservoir and Possum Kingdom Lake Water Supply Options for the City of Abilene

Prepared for:

ABILENE

Prepared by:

HDR | ONE COMPANY *Many Solutions*℠

Texas Registered Engineering Firm F-754

and

eHT
Enprotec / Hibbs & Todd

Texas Registered Engineering Firm F-1151

November 2009

Summary Report

Updated Evaluations of Cedar Ridge Reservoir and Possum Kingdom Lake Water Supply Options for the City of Abilene

Signature Page

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11/06/09

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Adam Cory Shockley 11/6/09

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RICHARD A. SHOEMAKER
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Richard A. Shoemaker

Richard A. Shoemaker, P.E.
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Firm Registration No. F-754

Enprotec/Hibbs & Todd, Inc.
Firm Registration No. F-1151

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Updated Evaluations of Cedar Ridge Reservoir and Possum Kingdom Lake Water Supply Options

1.0 Background on 2008 and 2009 Activities

In the spring of 2008, the City of Abilene (City) received a report entitled "Evaluation of Cedar Ridge Reservoir and Possum Kingdom Lake Water Supply Options for City of Abilene" (2008 report) prepared by HDR Engineering, Inc (HDR) and Enprotec/Hibbs & Todd, Inc. (eHT). The 2008 report recommended the City pursue the permitting and development of the Cedar Ridge Reservoir project to meet future water demands as it was the preferred option considering the total quantity of water supply provided and the unit cost of the supply (dollars per acre-foot). On June 26, 2008 the City passed Resolution No. 24-2008 (June resolution) to pursue, for permitting purposes, the evaluation and investigation of Cedar Ridge Reservoir as the recommended water management strategy to meet future water supply needs.

Subsequent to the June resolution, a geotechnical investigation[1] determined that gypsum, a soluble mineral, was present at the dam site identified in the 2008 report (original dam site) and that gypsum would be in direct contact with the reservoir water. The presence of gypsum at the original dam site effectively prevents the construction of a dam and reservoir at that site. This unexpected discovery resulted in the development of a 2009 Regional Geologic Study[2] (2009 geologic study) of alternative dam sites. The 2009 geologic study recommended that an alternate dam site located approximately 19 river miles upstream of the original dam site be investigated. This alternative dam site (new dam site) is shown in Figure 1 along with the location of the original dam site.

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[1] Fugro Consultants, Inc., "Phase 1 Geotechnical Investigations – Cedar Ridge Reservoir, Throckmorton County, Texas," dated February 2009.

[2] Fugro Consultants, Inc., "Regional Geologic Study – Cedar Ridge Reservoir Alternative Dam Sites, Haskell, Shackelford, and Throckmorton Counties," dated September 2009.

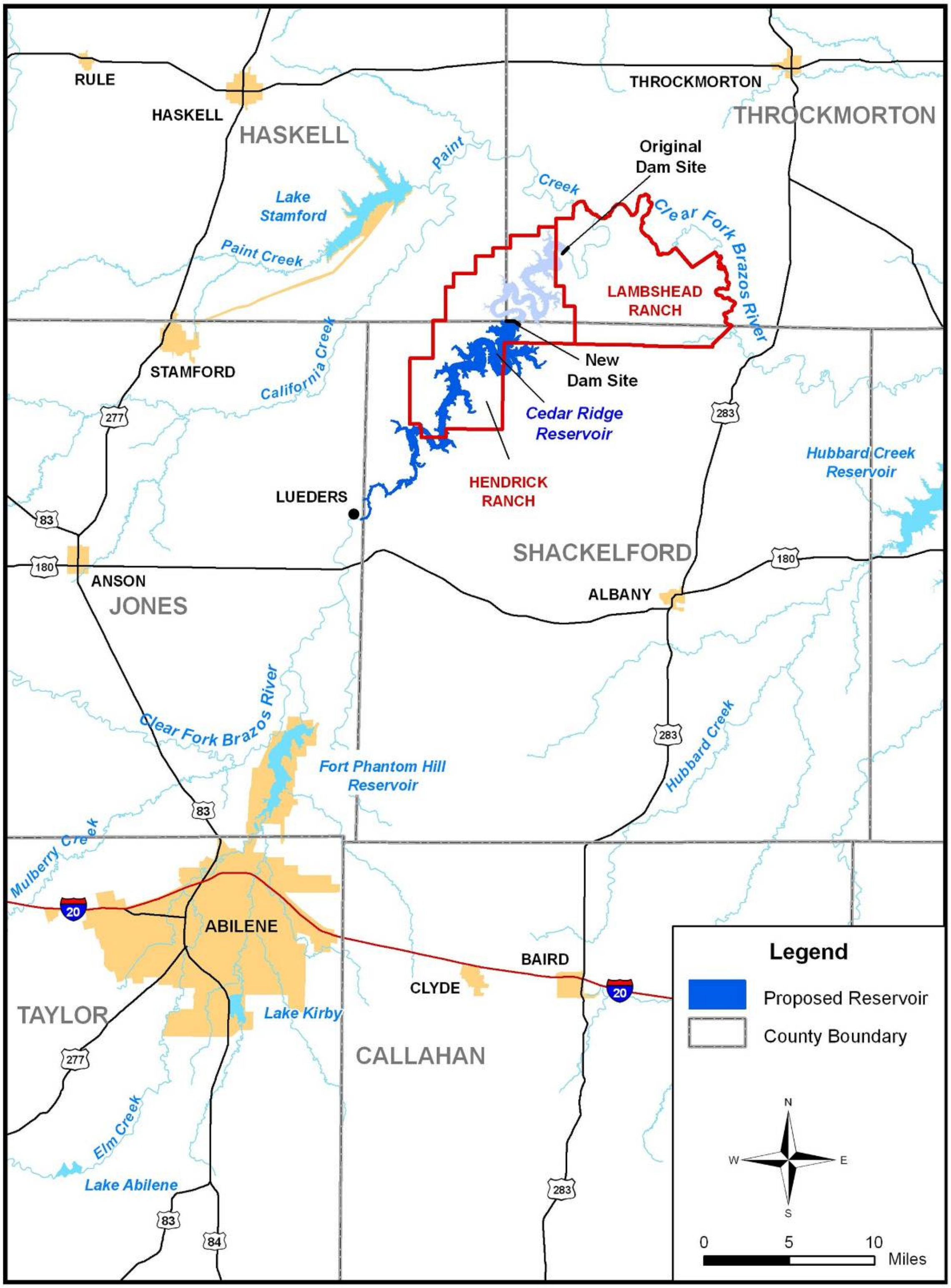

Figure 1. Cedar Ridge Reservoir (Original and New Dam Sites)

During the summer of 2009, a geotechnical investigation[3] was performed at the new dam site, which determined that this dam site was suitable for the construction of a dam and reservoir, as gypsum layers are sufficiently deep so as to not be in direct contact with the reservoir water. At the new dam site, the reservoir water will be separated from the gypsum by sufficiently thick layers of low permeability shale and limestone, which will serve to protect the integrity of the reservoir.

At the new dam site, Cedar Ridge Reservoir can be developed with a conservation pool elevation of 1,489 feet above mean sea level (ft-msl) which is 59 feet higher in elevation than the conservation pool elevation of the original dam site. The 1489 ft-msl level was selected to maximize the conservation capacity while minimizing increases in flood levels at the upper end of the reservoir near the City of Lueders. At the 1489 ft-msl conservation level, the reservoir will have a maximum depth of 130 feet and a surface area of 6,635 acres (as compared to 6,190 acres for the original dam site). The conservation pool will have a capacity of 227,127 acre-feet (as compared to 310,383 acre-feet for the original dam site). Cedar Ridge Reservoir impounded by the new dam site has an average depth of 34 feet, which is more than 1.5 times that of Hubbard Creek Reservoir (HCR) and over twice that of Fort Phantom Hill Reservoir (FPH), making it an efficient reservoir with respect to minimizing losses to evaporation. While the conservation storage capacity at the new dam site is 73 percent of the conservation storage at the original dam site, the initial 1-year safe yield of the project (as discussed in a subsequent section) is 78 percent of the original dam site.

2.0 New Drought of Record and Updated Yield Estimates

From 1993 through 2006, the region of Texas near Abilene experienced serious drought conditions. Streamflows in the Clear Fork of the Brazos River (Clear Fork) during this 14-year period were only 82 percent of the cumulative 14-year flows that occurred during the previous drought of record which occurred from 1943 through 1956. Cumulative streamflows for both droughts are shown on Figure 2. This recent drought is the new drought of record. Reservoir yield analyses performed for this report consider both the 1940/50's and recent drought periods.

Yield analyses for Cedar Ridge Reservoir using the new dam site were performed for three reservoir operating scenarios. These included the firm yield, the 1-year safe yield and the

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[3] Fugro Consultants, Inc., "Preliminary Geotechnical Investigation — Cedar Ridge Reservoir Alternative Dam Site, Throckmorton County, Texas," dated November 2009.

2-year safe yield. Firm yield is defined as the amount of water that could be diverted from the reservoir every year of the simulation period (January 1940 to June 2008 in this case) with the minimum volume of water remaining in storage during the worst month equal to zero. The safe yield of a reservoir is defined as the amount of water that could be diverted from the reservoir every year of the simulation period with the minimum volume of water in storage during the worst month equal to the annual diversion amount. For example, if a reservoir has a 1-year safe yield of 10,000 acre-feet per year (acft/yr), then the amount of water remaining in storage in the worst month would be 10,000 acre-feet (acft). If the 2-year safe yield of a reservoir is 10,000 acft/yr then the amount of water remaining in storage in the worst month would be 20,000 acft. Each of these progressively higher minimum storage volumes provides for a greater degree of security from running out of water in the event a future drought occurs which is worse than the previous drought of record.

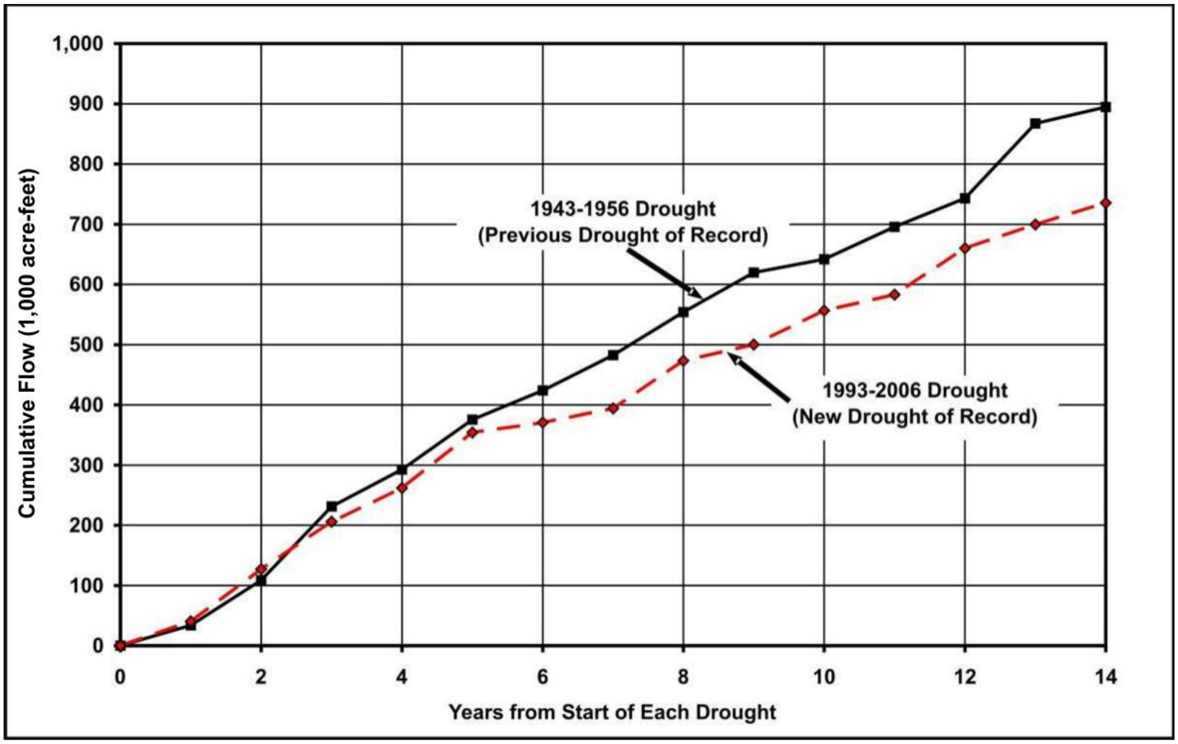

Figure 2. Comparison of Cumulative Drought Streamflows for Clear Fork of Brazos River at Nugent

The updated yields of Cedar Ridge Reservoir are summarized in Table 1. The initial firm yield of the reservoir is 29,380 acft/yr, the initial 1-year safe 25,180 acft/yr, and the initial 2-year safe yield is 22,220 acft/yr.

Table 1.
Summary of Yields for Cedar Ridge Reservoir
(New Dam Site)

Yield Scenario	Initial Yield[1] (acft/yr)	Estimated Yield after 50-years of Sediment[1,2] (acft/yr)
Firm Yield	29,380	28,680
1-Year Safe Yield	25,180	24,480
2-Year Safe Yield	22,220	21,520

[1] Based on the 2005 and 2007 agreements with BRA, Clear Fork scalping to FPH and no return flows.

[2] Estimated based on 700 acft/yr reduction of initial firm yield.

The effects of adding Abilene's return flows and 50 years of sediment to the reservoir can be estimated based on the findings of the 2008 report. The 2008 report indicated that when the City's recent volume of return flows are made available to Cedar Ridge, the 1-year safe yield of the reservoir is increased by 5,550 acft/y and the 2-year safe yield by 4,850 acft/yr. The 2008 report determined that when a 50-year estimate of sediment is included, yields are reduced by as much as 700 acft/yr depending on the volume of return flows. Therefore, reservoir yields using the new dam site after 50 years of sedimentation are estimated to all be reduced by 700 acft/yr as shown in Table 1.

Figure 3 demonstrates how the reservoir would perform during a repeat of hydrologic conditions which occurred for the 1940 to 2008 timeframe. Figure 3 compares reservoir time series elevation traces for the three yield scenarios and shows how the recent drought is more severe than the previous drought. Figure 4 compares reservoir elevation on a frequency basis for the same timeframe and shows that the reservoir will be above elevation 1,469 ft-msl (or 20 feet below its full conservation level of 1,489 ft-msl) about 70 percent of the time.

3.0 Cedar Ridge Reservoir Site Designated as Unique

As part of the Senate Bill 1 statewide water planning process, the 2006 Brazos G Regional Water Plan (2006 plan) and the 2007 State Water Plan both included Cedar Ridge Reservoir as a recommended water management strategy for the Abilene region to meet future

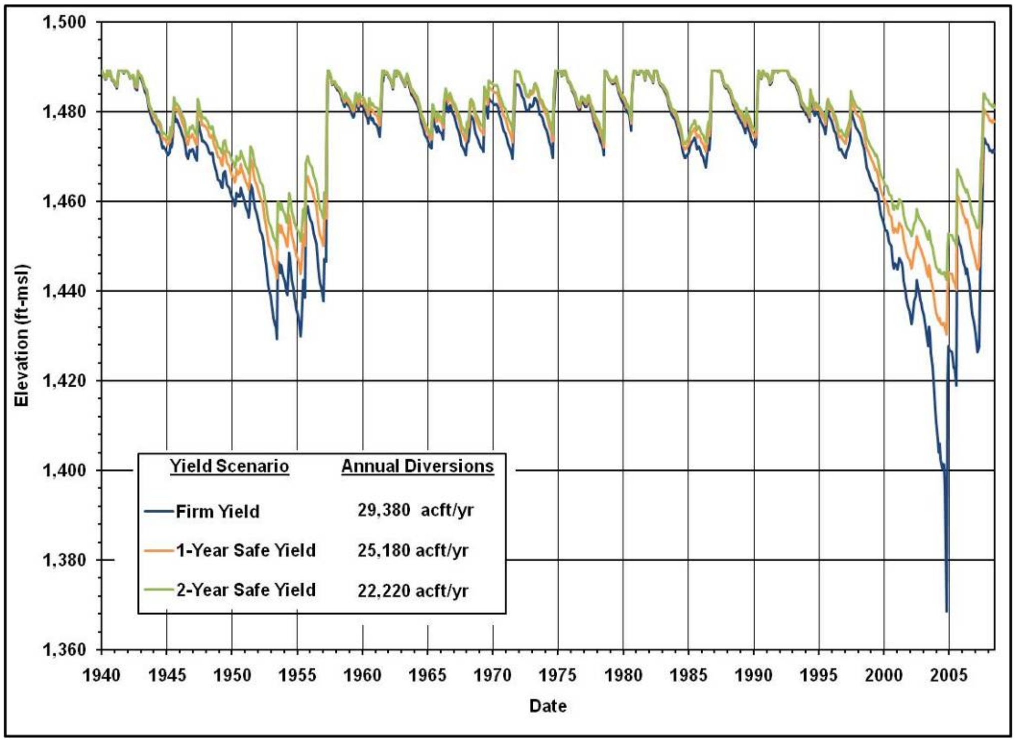

Figure 3. Comparison of Reservoir Levels for Cedar Ridge (New Dam Site) (1940 – 2008)

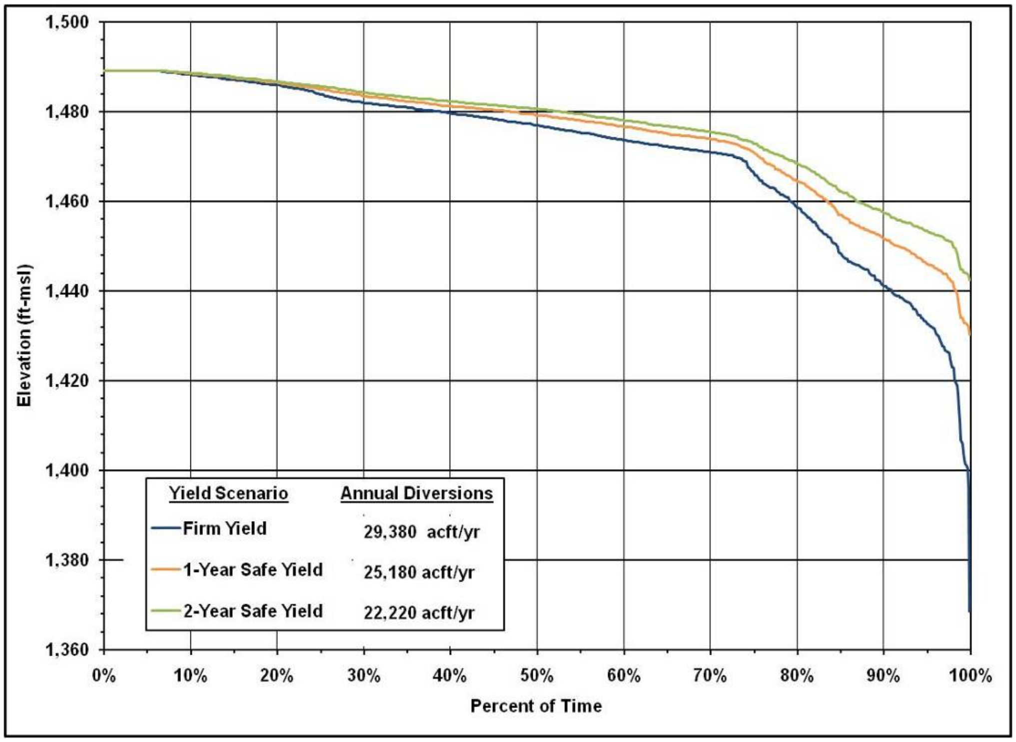

Figure 4. Percent of Time Using New Dam Site Cedar Ridge Reservoir Levels are Exceeded (1940 – 2008)

water demands. Additionally, during the 2007 Texas legislative session, the Legislature designated 19 sites that were previously included in the 2007 State Water Plan, including Cedar Ridge Reservoir, as unique for the construction of reservoirs.

4.0 Use of 2-year Safe Yield Approved by TWDB and Brazos G Planning Group

As part of the Senate Bill 1 statewide water planning process and at the request of the City of Abilene, in August and September of 2009, respectively, the Brazos G Regional Water Planning Group and the Texas Water Development Board (TWDB) approved the use of a 2-year safe yield for water supply planning purposes for the Abilene region. Previously 1-year safe yields were used to evaluate reservoir yields for the region. However, with the recent drought being worse than the 1950’s drought and the unknown impacts of future climate and watershed changes, using the more conservative 2-year safe yield criteria provides the Abilene region with an appropriate safety factor for planning purposes in the event a worse drought occurs. For comparison purposes, this report evaluates the use of both 1- and 2-year safe yields.

5.0 2005 and 2007 Interlocal Agreements Between the City, WCTMWD, and Brazos River Authority Significantly Enhance Region’s Water Supplies

In 2005 and 2007, the City of Abilene entered into several interlocal agreements (“2005/2007 agreements” or “agreements”) with the West Central Texas Municipal Water District (WCTMWD or District) and Brazos River Authority (BRA) regarding their respective water rights. These agreements effectively removed future obligations of the City and District to pass streamflow occurring at their respective water right locations to Possum Kingdom Lake.

The 2005/2007 agreements also apply to the City’s existing and future return flows and to the Cedar Ridge Reservoir project. The agreements include provisions that resulted in the safe yields of Cedar Ridge Reservoir increasing by about 50 percent. This increase in yield occurs as a result of inflows to Cedar Ridge Reservoir not having to be released to Possum Kingdom Lake which is a senior water right in exchange for an annual payment to BRA. Additionally, these agreements included an option for the City and/or District to purchase up to 20,000 acft/yr from BRA for diversion from Possum Kingdom Lake (PK) for future water supply purposes. The 20,000 acft/yr of high salinity raw PK water could supply about 14,800 acft/yr of potable water after consideration of the brine reject produced in the treatment process.

6.0 Population and Water Demand Projections (TWDB/Brazos G Estimates)

As part of the Senate Bill 1 water planning process, the Texas Water Development Board (TWDB) has compiled historical population data for the City of Abilene, and has developed projections of future population through the year 2060 for the City, and for Taylor and Jones Counties (TWDB population projections). The TWDB population projections and the associated water demand projections were utilized by the Brazos G Regional Water Planning Group (Brazos G) to develop the 2006 Brazos G Regional Water Plan (2006 plan). Figure 5 presents these historical and projected population estimates as utilized by Brazos G for the 2006 plan. The TWDB population projections are based on demographic data and migration rates for the area which occurred between 1990 and 2000. The underlying assumption is that future migration patterns will occur at half the rate of the 1990’s.

As illustrated in Figure 5, the TWDB projects little overall growth for the City and counties in the region, and actually projects population declines after 2040. This pattern is exhibited by many of the smaller West Texas communities. However, larger communities like Abilene could see a reversal in this trend as corporations consider relocating operations outside of the larger metropolitan areas to avoid rising property taxes, air quality concerns, and congestion. Cities such as Abilene that are situated along major transportation corridors are likely candidates to attract new industry. This realistic future scenario is addressed as a part of this study.

Water demands for the City of Abilene as developed by Brazos G for years 2000, 2030, and 2060 were updated for the 2008 report and are shown in Table 2. These water demands include contract sales to surrounding communities, water utilities and industry. These projections assume that the City will continue to provide the majority of manufacturing water in Taylor County and steam-electric supply in Jones County.

Municipal water demands for Abilene are calculated by the TWDB using the projected populations and projected per capita water use. The per capita water use is an accumulation of the total raw water pumped by the City, less wholesale contract use, divided by population (this calculation was completed using year 2000 data to develop a base per capita water use). The per capita water use estimates and population projections for Abilene are also shown in Table 2 and

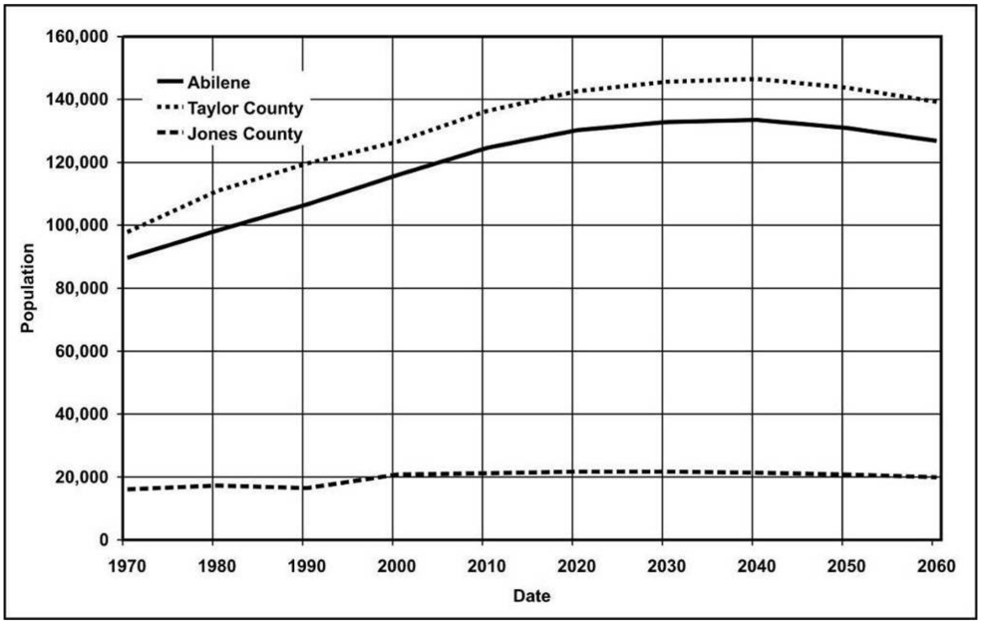

Figure 5. Brazos G Population of Abilene, and Jones and Taylor Counties

Table 2.
Updated Brazos G Projected Water Demands for Abilene

		2000	*2030*	*2060*
Abilene	**Brazos G Projected Populations for Abilene**	**115,926**	**132,820**	**126,835**
	Brazos G Projected Per Capita Water Demands (gallons per person per day)	**168**[1]	**158**	**154**
	Brazos G Municipal Demands for Abilene (all values in acft/yr)	**21,816**	**23,507**	**21,879**
	Current Water Supply Contracts[2] (all values in acft/yr)			
	Blair Water Supply Corp. (Taylor County-Other)	77	77	77
	City of Baird	77	77	77
	City of Clyde	307	307	307
	City of Lawn	77	77	77
	City of Merkel	353	353	353
	City of Tye	184	184	184
	Eula WSC (Callahan County-Other)	61	61	61
	Hamby Water Supply Corp. (Taylor County-Other)	307	307	307
	Hawley WSC	307	307	307
	Potosi Water Supply Corp.	307	307	307
	Steamboat Mountain WSC	307	307	307
	Sun Water Supply Corp. (Taylor County-Other)	230	230	230
	View-Caps Water Supply Corp. (Taylor County-Other)	199	199	199
	Contracts for Steam-Electric	11,837	11,837	11,837
	Total Contracts	**14,630**	**14,630**	**14,630**
	Other Brazos G Demands			
	Manufacturing (Taylor County)	789	1,177	1,462
	Steam-Electric (Jones County)	1,510	1,170	1,935
	Total Other Brazos G Demands	**2,299**	**2,347**	**3,397**
	Total Demands	**38,745**	**40,484**	**39,906**

[1] Estimated from City-provided data.

[2] Revised from Brazos G based on updated information provided by Abilene.

show that per capita water use in 2000 was 168 gallons per person per day and is projected to drop to 158 and 154 gallons per person per day by 2030 and 2060, respectively. As estimated by the TWDB and the Brazos G Planning Group for the 2006 plan, and updated for the 2008 report, water demands in Abilene are projected to increase from 38,745 acft/yr in 2000 to 39,906 acft/yr in 2060.

7.0 Alternative Population Projections for Abilene

The TWDB estimates of growth for the Abilene region are conservative and do not consider factors which could significantly affect the region's future water demands. Therefore, an alternative method for projecting Abilene's population was developed for the 2008 report. This alternative methodology uses growth patterns for a recent 30-year period. Between 1970 and 2000, Abilene experienced a very consistent growth rate, adding 876 persons per year on average, based on decadal census data as shown in Table 3.

Table 3.
Recent Historical Growth in Abilene

Census Year	Population	Change	Growth Rate (Persons/yr)
1970	89,653	—	—
1980	98,315	8,662	866
1990	106,654	8,339	834
2000	115,926	9,272	927
		Average	876

A straight-line extension of Abilene's population beginning with the City's year 2006 estimated population of 121,183[4] and assuming a constant growth of 876 persons per year results in the projection shown in Figure 6. This figure compares population projections developed using this alternative method with TWDB population projections. This alternative projection methodology provides a more realistic population projection for the City. Population estimates using this alternative method are shown in Table 4 and compared to the TWDB estimates. The alternative method has an additional 9,387 people in 2030 and an additional 41,652 in 2060 for the City of Abilene.

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[4] Source: Texas State Data Center

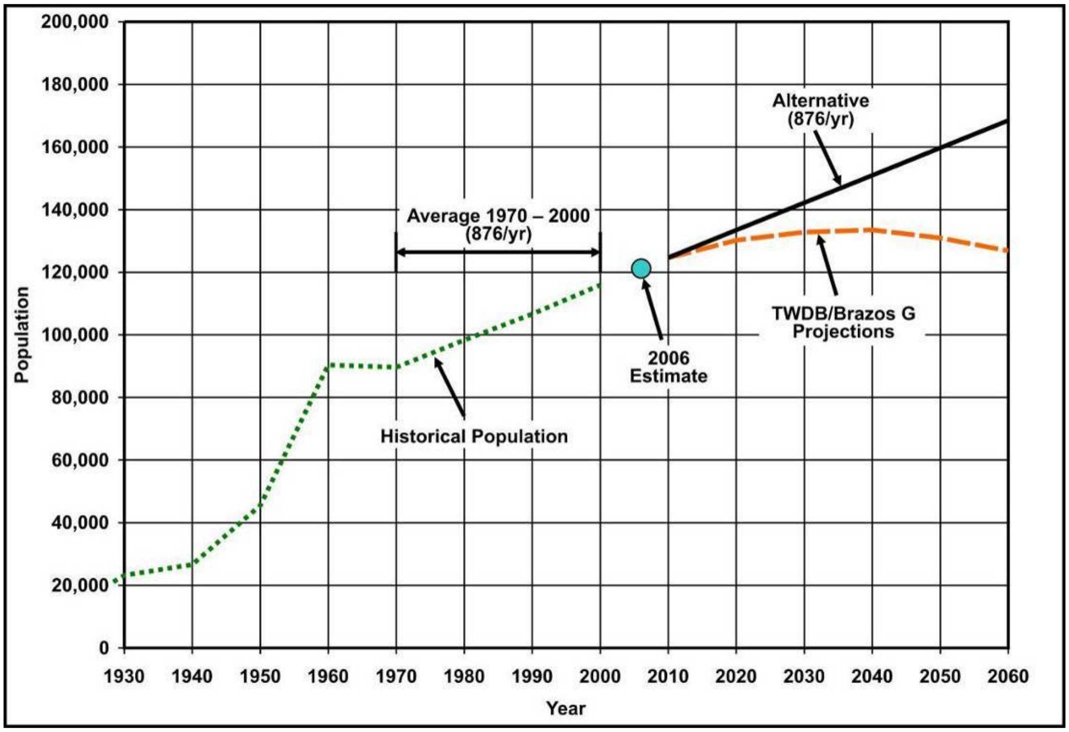

Figure 6. Historical, Alternative, and TWDB/Brazos G Population Projections for Abilene

Table 4.
Comparison of TWDB and Alternative Estimates of Future Population for the City of Abilene

Year	Population Estimates			Percent Difference
	TWDB/ Brazos G	Alternative	Difference	
2000	115,926	115,926	0	0
2030	132,820	142,207	9,387	+7.1
2060	126,835	168,487	41,652	+32.8

8.0 Alternative Water Demand Projections for Abilene

The alternative population projections prepared for the 2008 report result in additional municipal water demands for Abilene as compared to the demands in the 2006 Brazos G plan. The additional population increases the City’s municipal demands by 1,677 acft/yr in 2030 and by 7,254 acft/yr in 2060 above the updated TWDB/Brazos G projections as shown in Table 5.

**Table 5.
Alternative Water Demands for the City of Abilene (acft/yr)**

Year	Updated Brazos G Demands[1]	Additional Abilene Municipal Demand[2]	Sweetwater Needs[3]	Nolan County Steam-Electric[3]	Fisher County Man.[3]	Automobile Man.[4]	Other Man.[4]	Total
2000	38,745	0	0	0	0	0	0	38,745
2010	39,748	15	1,969	0	86	560	400	42,778
2020	40,197	587	2,022	700	114	560	400	44,580
2030	40,484	1,677	2,026	700	137	560	400	45,984
2040	40,457	3,059	1,969	1,100	164	560	400	47,709
2050	40,195	5,013	1,835	1,500	188	560	400	49,691
2060	39,906	7,254	1,693	2,000	212	560	400	52,025

Notes:

[1] Total of Abilene Municipal, Jones County Steam-Electric, and Taylor County Manufacturing demands, as presented in the 2006 Brazos G Regional Water Plan and updated by Abilene to reflect current contracts (refer to Table 2).

[2] Municipal demands based on alternative population projections in excess of those used in the 2006 Brazos G Regional Water Plan for Abilene (refer to Table 4).

[3] Demands identified to be met by water management strategies for the City of Sweetwater, as presented in the 2006 Brazos G Regional Water Plan.

[4] Quantities to be held in reserve in anticipation of additional manufacturing demands.

Additionally, the City is a regional supplier of water, and as such is a realistic provider to meet future water needs outside of Jones and Taylor Counties. Brazos G considers Abilene to be an alternative source of supply to meet the future needs for the City of Sweetwater, if water supply strategies identified for Sweetwater are ultimately not capable of providing the necessary supplies. These future demands are shown in Table 5 and include not only municipal needs within Sweetwater of up to 2,026 acft/yr, but also Steam-Electric demands in Nolan County and Manufacturing demands in Fisher County of 2,000 acft/yr and 212 acft/yr, respectively.[5]

In addition to the future water demands that have been identified by the TWDB and Brazos G, it is prudent for the City to retain supply reserves to meet additional water needs resulting from new or expanded manufacturers or industries. In order to estimate these reserve supplies, it was assumed in the 2008 report that a new manufacturing plant equivalent to an automobile assembly facility and a new beverage bottling plant (or expansion) would potentially be located in Abilene. A typical automobile assembly facility requires about 560 acft/yr of

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[5] "2006 Brazos G Regional Water Plan," HDR Engineering, Inc., January 2006.

supply, mostly related to painting processes. A new or expanded bottling plant is estimated to require about 400 acft/yr of supply.

In summary, the alternative water demand projections presented in Table 5 indicate that by 2060, water demands for Abilene could reach 52,025 acft/yr. This represents an increase of 13,280 acft/yr or 34 percent above the City's year 2000 demands of 38,745 acft/yr.

9.0 Water Demand Projections for Abilene for TWDB/Brazos G 2011 Plan (Pending)

The next update to the Brazos G Regional Water Plan will be finalized in 2011 (2011 plan). Water demand projections currently under consideration by Brazos G for use in the 2011 plan for the Abilene Region are significantly higher than those included in the 2006 plan due primarily to updated estimates of Steam-Electric demands. The 2060 water demands under consideration for the Abilene Region by Brazos G for the 2011 plan total 60,339 acft/yr, and are presented in Appendix A. This is 8,314 acft/yr more than the City's alternative 2060 demands of 52,025 acft/yr and 20,433 acft/yr more than the 2060 estimates in the 2006 Brazos G Regional Water Plan of 39,906 acft/yr. In the spring of 2010, Brazos G will publish its Initially Prepared 2011 Plan which is anticipated to include these new demand estimates. This report considers both the City's alternative 2060 demands of 52,025 acft/yr and the pending Brazos G 2011 plan demands of 60,339 acft/yr for purposes of evaluating the Cedar Ridge Reservoir and Possum Kingdom water supply options.

10.0 Summary of Water Available from Abilene's Existing Supply Sources

A summary of water supply available to Abilene from each of the City's existing water supply sources is included in Table 6. These estimates are from the 2008 report and based on long-term supplies (under year 2060 sediment conditions) from Fort Phantom Hill and Hubbard Creek Reservoirs as well as the existing potable water production capacity of the Hargesheimer water treatment plant. This table shows that year 2060 supplies from existing sources total 39,664 acft/yr for a 1-year safe yield and 31,982 acft/yr for a 2-year safe yield.

Traditionally, water supply planning in West Texas has been based on the 1-year safe yield of a reservoir. However, considering the severity and length of the recent drought and the uncertainties associated with future climate and watershed changes using a 2-year safe yield is appropriate. As an example, the initial planning for the O.H. Ivie Reservoir project would have needed to consider something in excess of a 2-year safe yield in order for that project to have yielded assured water supplies during the current drought cycle. The results of the 2008 report's safe yield analyses are summarized in Table 6, which shows the portions of the FPH and HCR yields and the volume of Ivie Reservoir water available to Abilene. The FPH yield available to Abilene is adjusted by 2,500 acft/yr to account for West Texas Utilities water rights. The HCR amounts available to Abilene are based on the City's existing contract with the WCTMWD.

Table 6.
Summary of Long-Term (2060) Water Supply Volumes
Available to Abilene from Existing Sources
(from 2008 report)

	Safe Yields for 2060 Sediment Conditions (acft/yr)	
Source	***1-year***	***2-year***
Fort Phantom Hill (Abilene Portion)	12,650[1]	8,372[1]
Hubbard Creek Reservoir (Abilene Portion)	20,294[2]	16,890[2]
Ivie/Hargesheimer WTP	6,720[3]	6,720[3]
Total Supply	39,664	31,982

[1] FPH safe yields are adjusted based on WTU's right to use 2,500 acft/yr.

[2] HCR yields available to Abilene are based on City's contract with WCTMWD.

[3] Based on current potable plant production capacity. Future (2060) potable water supply is limited to 6,720 acft/yr due to potential for additional reduction of safe yield of Ivie.

The Ivie Reservoir amount of 6,720 acft/yr is based on the current capacity of the Hargesheimer water treatment plant, rather than the City's contract amount with the Colorado River Municipal Water District (CRMWD), because the City's contract with CRMWD is for 16.54 percent of the 1-year safe yield of the Ivie project. Originally, in 1976, the safe yield of Ivie Reservoir was estimated to be 90,700 acft/yr. However, over the past two decades, inflows to Ivie have been seriously affected by drought conditions in the watershed and the 1-year safe yield has been revised three times between 1976 to 2006. The most recent safe yield study for the Ivie Reservoir (2006, Freese and Nichols, Inc.) indicates that the 1-year safe yield of the project is now 65,940 acft/yr, or 72.7 percent of the original estimate. This means that during the recent drought, if Ivie Reservoir had been utilized at its original safe yield amount of 90,700 acft/yr, the reservoir would have gone dry.

This reduction in the safe yield of Ivie Reservoir effectively limits the amount of raw water available to Abilene from Ivie to about 10,600 acft/yr, based on estimated year 2060 reservoir sediment conditions. Because the water quality in Ivie Reservoir does not meet secondary drinking water standards, it is treated using reverse osmosis at the City's Hargesheimer water treatment plant. In this treatment process, about 15 percent of the raw water from Ivie ends up in a waste stream (brine), which is currently disposed of in evaporation ponds or discharged to the City's wastewater system. Currently, the capacity of the Hargesheimer water treatment plant to produce potable water is limited to 6,720 acft/yr. Because the continuing drought could further reduce the safe yield of the Ivie Reservoir, future use of Ivie water in this study is limited to the current treatment plant capacity of 6,720 acft/yr of potable supply.

11.0 Comparison of Future Water Demand Projections and Existing Supply Sources

A comparison of future water demands to existing water supplies is shown in Figure 7 and Table 7. Table 7 shows that by 2060 under the 1-year safe yield scenario, the City will need an additional supply of 12,361 acft/yr (or 12,400 acft/yr when rounded), and that under the 2-year safe yield scenario an additional supply of 20,043 acft/yr (or 20,000 acft/yr when rounded) is needed. Both of these additional supply requirements are based on the City's alternative 2060 demand projections of 52,025 acft/yr. If the pending Brazos G 2011 plan demand projections for 2060 conditions of 60,339 acft/yr are accepted, then the 2060 additional supply requirement increases to 28,357 acft/yr (or 28,400 acft/yr when rounded) as shown in Table 7.

12.0 Evaluation of Water Supply Options

Two water supply options were evaluated with respect to safe yield and updated costs to meet future needs. These options include:

- Cedar Ridge Reservoir with delivery to Fort Phantom Hill Reservoir, and
- Purchase of Possum Kingdom Lake water from the BRA with delivery to Abilene.

For this report both options were evaluated for supplying 12,400 acft/yr to meet year 2060 projected additional supply requirements as shown in Table 7 and Figure 8 using

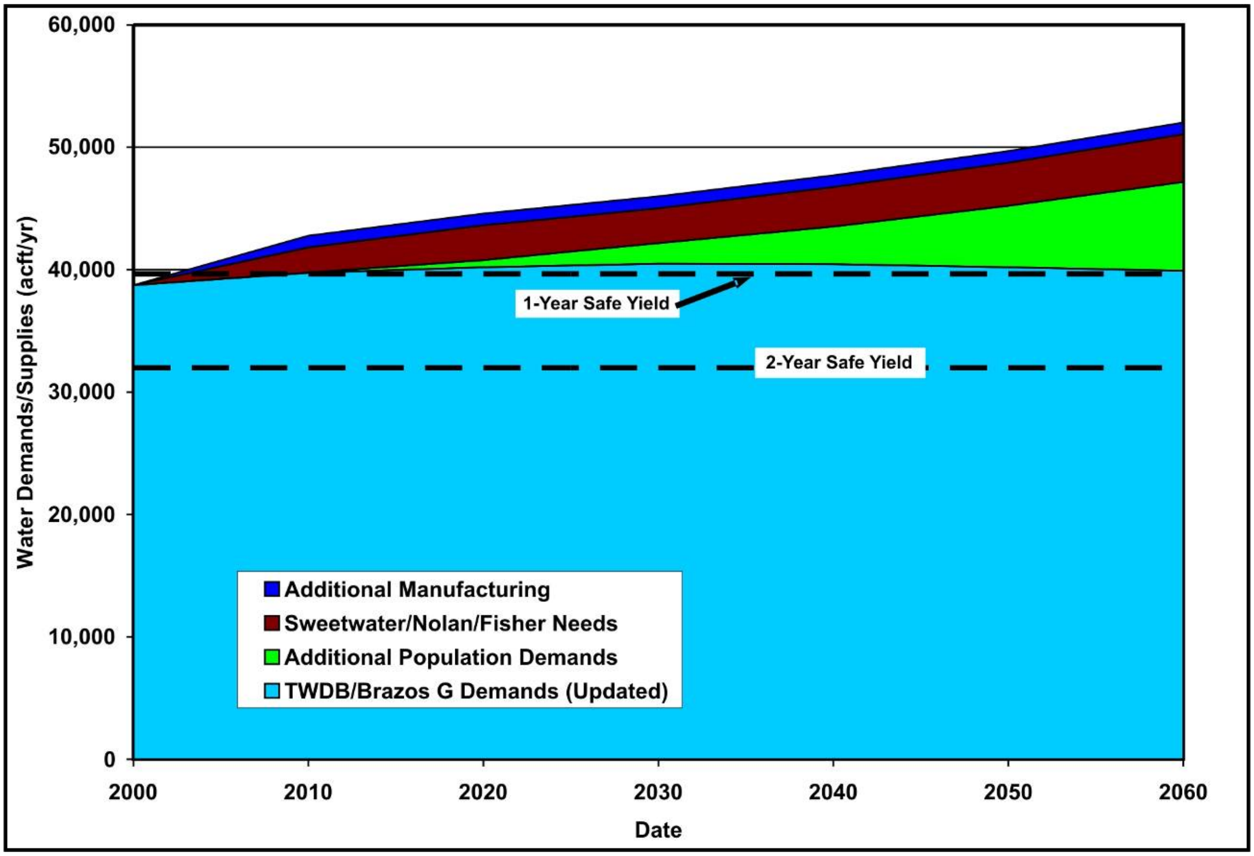

Figure 7. Comparison of Updated Brazos G 2006 Plan and City's Alternative Demands with Existing Water Supplies

Table 7.
Comparison of Future Demands with Current Supplies for 2060 Conditions

Existing Supply Based on This Safe Yield	***2060 Supply from Existing Sources (acft/yr)***	***2060 Demands (acft/yr)***	***2060 Additional Supply Requirements (acft/yr) (Rounded Amounts)***
1-Year	39,664	52,025 (City's Alternative)	12,361 (12,400)
2-Year	31,982	52,025 (City's Alternative)	20,043 (20,000)
2-Year	31,982	60,339 (Region G 2011 Plan Pending)	28,357 (28,400)

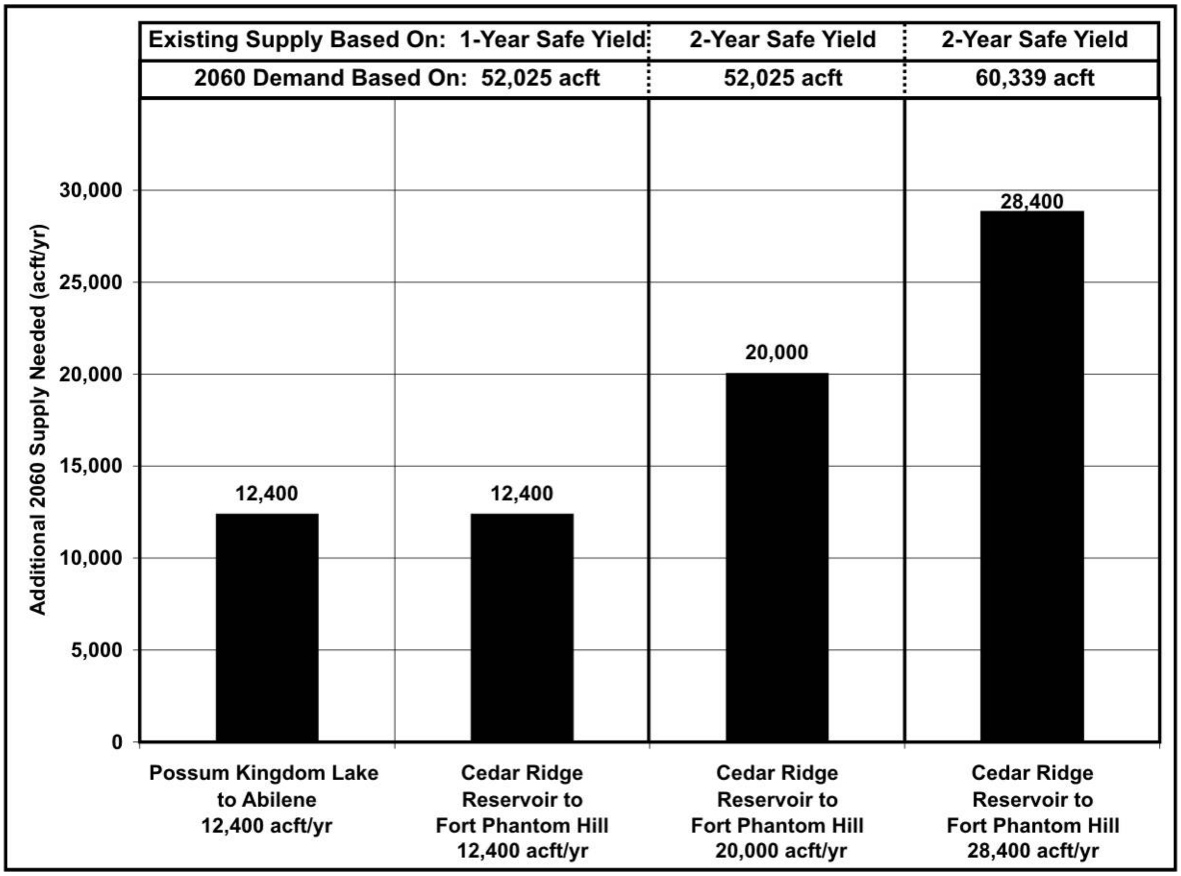

Figure 8. Comparison of Additional 2060 Water Supply Requirements

1-year safe yields from existing sources. Cedar Ridge Reservoir was also evaluated for two other scenarios based on meeting year 2060 projected additional water supply requirements using 2-year safe yields from existing sources as shown in Table 7 and Figure 8. One scenario includes the use of the City's alternative 2060 demands of 52,025 acft/yr and results in a 2060 additional water supply requirement of about 20,000 acft/yr. The other scenario includes the use of the pending Brazos G 2011 plan 2060 water demands of 60,339 acft/yr and results in a 2060 additional water supply requirement of about 28,400 acft/yr. This last scenario requires Cedar Ridge Reservoir to be operated on a firm yield basis as it requires the use of almost the entire 2060 firm yield of Cedar Ridge Reservoir of 28,680 acft/yr.

Of the two options considered, Cedar Ridge Reservoir is the only option able to meet the City's 2060 water demands if future planning is based on 2-year reservoir safe yields or if the pending Brazos G 2011 plan water demands for the Abilene Region are eventually adopted.

13.0 Comparison of Water Supply and Costs for Two Options

Total project costs, including transmission and treatment for both options, were updated for this study to September 2008 pricing to be consistent with the 2011 regional water plan costing timeframe. Total project costs are shown in Figure 9, average annual costs are shown in Figure 10, and unit costs of water are shown in Figure 11.

For the Possum Kingdom option (which includes a new pipeline to deliver, on average, 12,400 acft/yr), total project costs increased from $166,283,000 (2008 report) to $175,876,000 an increase of $9,593,000 or 5.8 percent. All of this increase in cost was due to inflation. Total annual costs for this option increased from $20,975,000 to $21,969,000 an increase of $994,000 or 4.7 percent. The increase in annual cost was not as significant as the increase in project costs due to power costs remaining the same at $0.09 per kilowatt hour (kWh). Unit cost of water for this option increased from $1,692 per acft to $1,772 per acft an increase of 4.7 percent.

For the Cedar Ridge Reservoir option (which includes a pipeline to deliver 12,400 acft/yr to Fort Phantom Hill Reservoir), total project costs increased from $192,420,000 (2008 report) to $215,166,000 an increase of $22,746,000 or 11.8 percent. About half of this increase in cost is due to inflation (5.8%) with the other portion being attributable primarily to a larger capacity spillway than was associated with the original dam site, so as to minimize flood levels in the reservoir. Total annual costs for this option increased from $18,019,000 to $19,206,000 an increase of $1,187,000 or 6.6 percent. The increase in annual costs were not as significant as the increase in project costs due, in part, to a shorter pipeline and reduced pumping costs. Unit cost of water for this option increased from $1,453 per acft to $1,549 per acft an increase of 6.6 percent. The two other Cedar Ridge options (i.e. delivery of 20,000 and 28,400 acft/yr), resulted in unit costs of $1,022 per acft for the 20,000 acft/yr option and $775 per acft for the 28,400 acft/yr option. As shown in Figure 11, all Cedar Ridge options have unit costs which are less than the Possum Kingdom option.

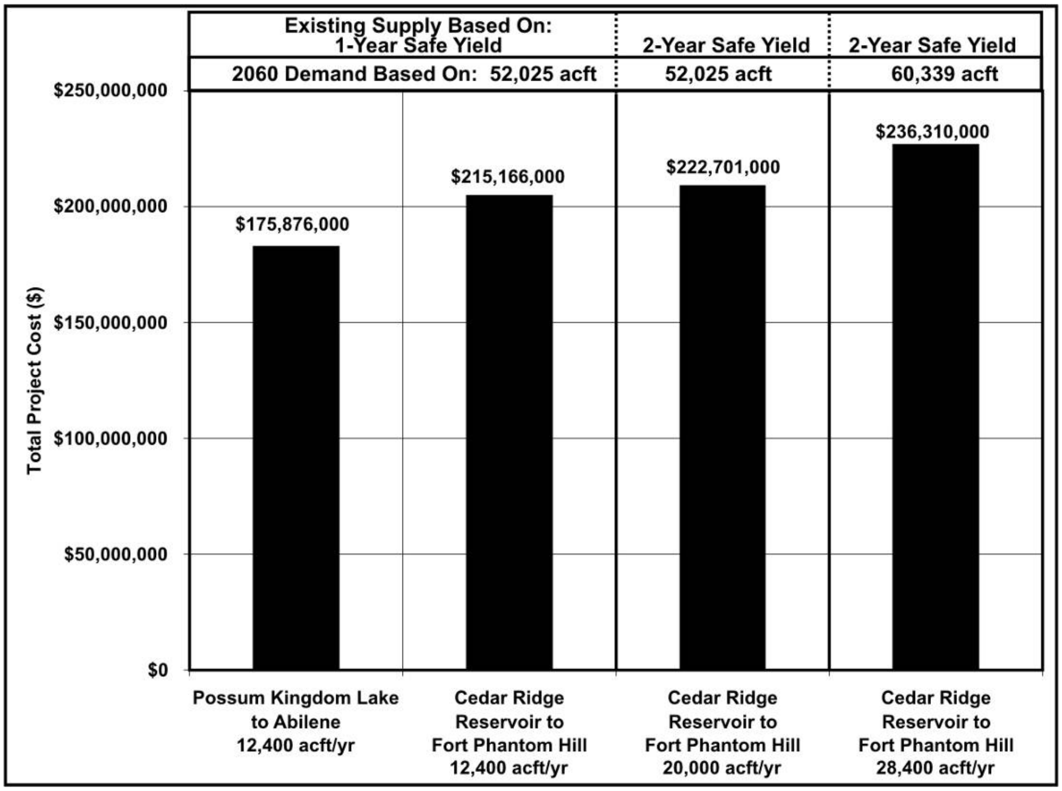

Figure 9. Comparison of Total Project Costs

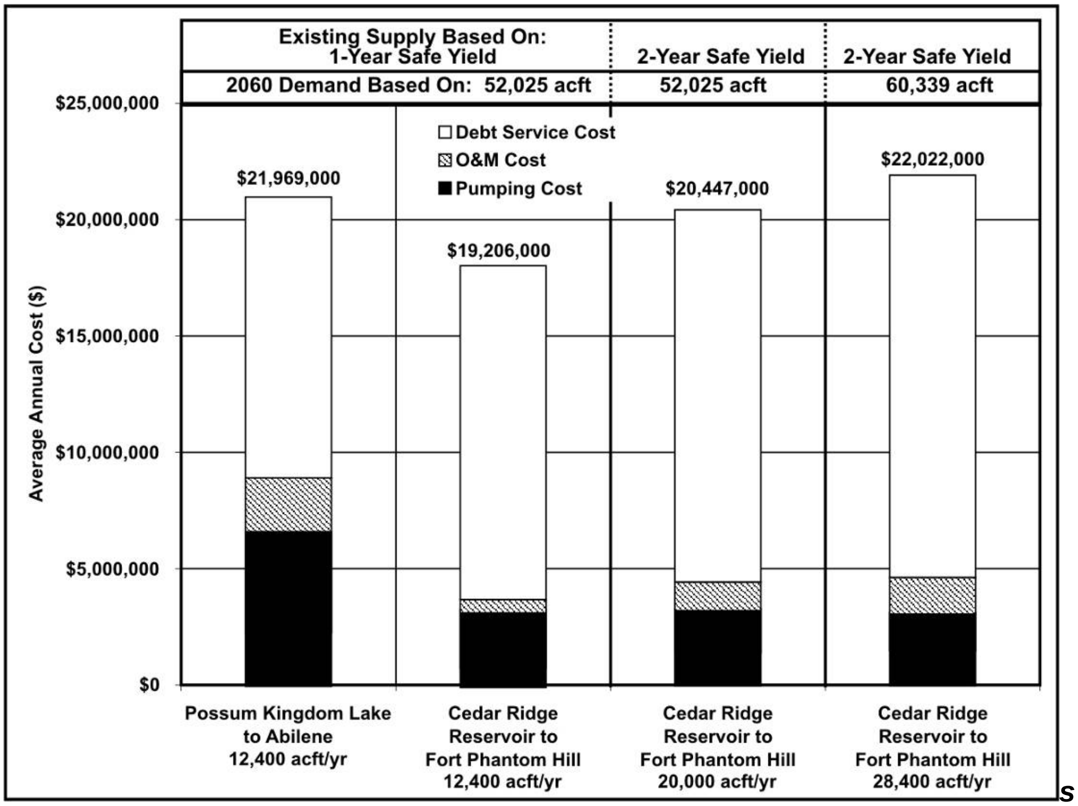

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Figure 10. Comparison of Average Annual Costs

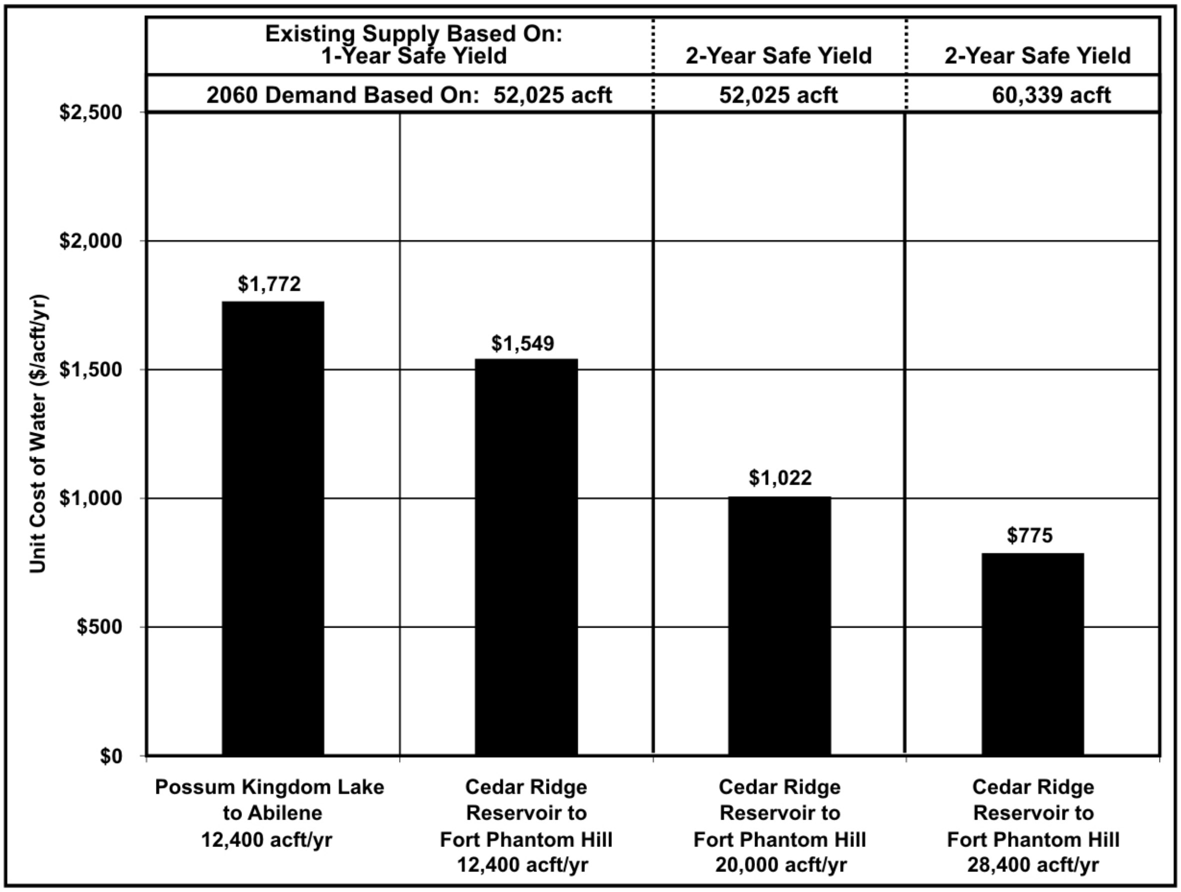

Figure 11. Comparison of Unit Costs of Water

14.0 Summary of Significant Findings

Significant findings of this study and the 2008 study include:

(1) Recent drought conditions have significantly reduced water supplies from Ivie and streamflows on the Clear Fork of the Brazos River and bring into question the adequacy of relying upon traditional 1-year safe yield methods to determine reservoir supplies in West Texas. Pursuant to a request by the City of Abilene to use 2-year estimates of safe yield for Fort Phantom Hill Reservoir, in August and September of 2009 the Brazos G Planning Group and the TWDB approved the use of the 2-year safe yield in planning for water supplies from this reservoir. A similar request from the WCTMWD for use of the 2-year safe yield of Hubbard Creek Reservoir was also approved.

(2) Water Supply from Ivie Reservoir should be limited to 6,720 acft/yr which is the existing plant capacity.

(3) Water demand projections prepared for the City (2008 report) indicate a projected supply shortage in 2060 of 12,400 acft based on 1-year safe yield estimates. When 2-year safe yield estimates are considered, supply shortages in 2060 are estimated at 20,000 acft. If the pending water demands proposed by the 2011 Brazos G plan are considered, estimated 2060 water shortages increase by 8,314 acft/yr to 28,400 acft/yr.

(4) The Possum Kingdom Lake (PK) option can supply a maximum quantity of 14,800 acft/yr of potable supply based on full utilization of the full 20,000 acft/yr of BRA raw water available. This option meets the City’s 2060 shortage of 12,400 acft/yr only if planning is based on using the 1-year safe yield of existing supply reservoirs. This option can not, on its own, meet the 2060 needs of the City if planning is based on using 2-year safe yields of existing supply reservoirs.

(5) The Cedar Ridge Reservoir option can supply the full 2060 shortage of 12,400, 20,000 or 28,400 acft/yr based on the 1- or 2-year safe yield scenarios and all water demand projections. Cedar Ridge is the only option that can meet Abilene's future needs if the region's existing water supplies are reduced by future droughts to what their 2-year safe yields can provide or if the pending 2011 Brazos G water demand projections are approved.

(6) The 2005/2007 agreements include these significant provisions:

   (a) Removal of future obligations of the City and District to release water to Possum Kingdom Lake, ensuring existing reservoir yields.

   (b) Opportunity for the City and/or District to obtain up to 20,000 acft/yr of raw water from Possum Kingdom Lake.

   (c) Opportunity for the City to pursue permitting of Cedar Ridge Reservoir with the Brazos River Authority’s agreement to not protest the City’s water rights application.

(7) Unit costs of delivering potable water to Abilene for all Cedar Ridge options are less than the unit cost of the Possum Kingdom option.

(8) City's outstanding debt service requirements associated with the Ivie project[6] will be reduced by about $5,290,000 per annum beginning in 2022 as shown in Figure 12.

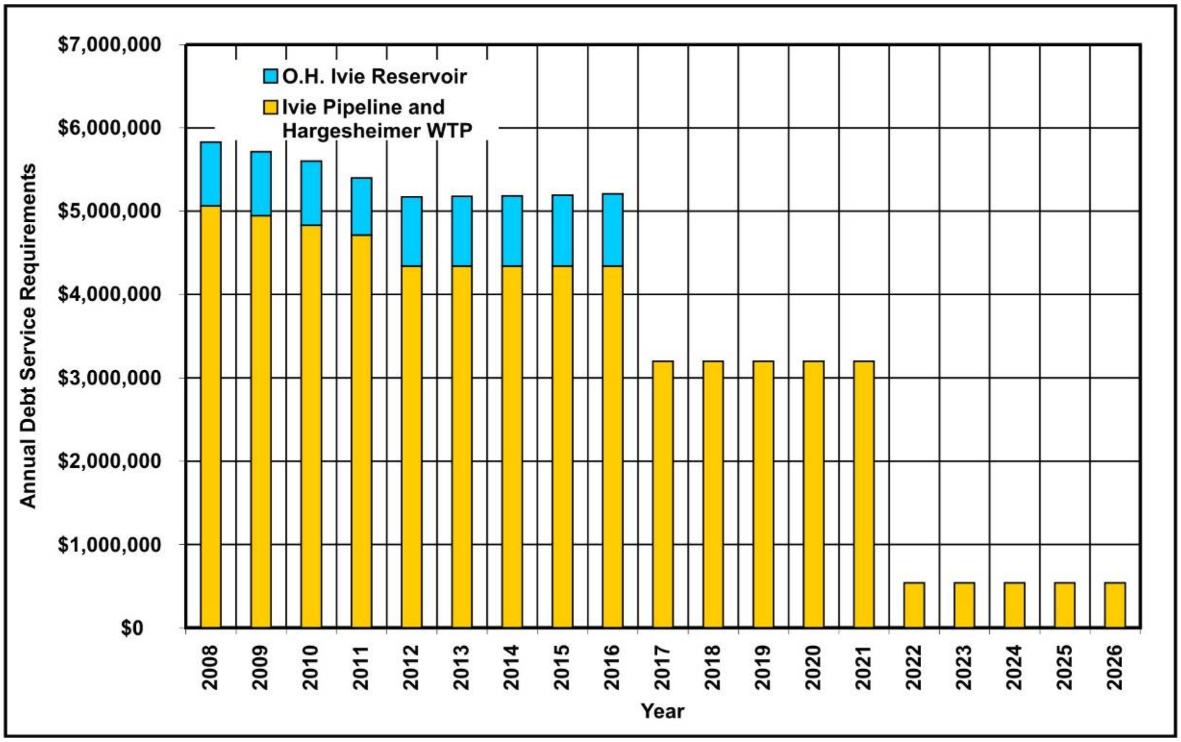

Figure 12. Abilene's Current Debt Service Requirements for Ivie Reservoir, Pipeline, Treatment Plant, and Associated Facilities

15.0 Summary of Additional Findings with Respect to Cedar Ridge Reservoir

Additional findings with respect to Cedar Ridge Reservoir include:

(1) Cedar Ridge Reservoir will store 227,127 acft at a conservation pool elevation of 1,489 feet above mean sea level (ft-msl). With a conservation pool area of 6,635 acres, the reservoir has an average depth of 34 feet, thus minimizing evaporation losses resulting in an efficient reservoir site.

(2) Cedar Ridge Reservoir is expected have an initial 1-year safe yield of between 25,180 acft/yr and 30,730 acft/yr based on hydrologic conditions occurring for the 1940 to 2008 period and various other assumptions regarding water rights, environmental flows, and use of Abilene's existing return flows.

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[6] Source: City of Abilene Finance Data.

(3) Geologic and geotechnical investigations performed at the new dam site revealed suitable characteristics to construct a safe dam and reservoir.

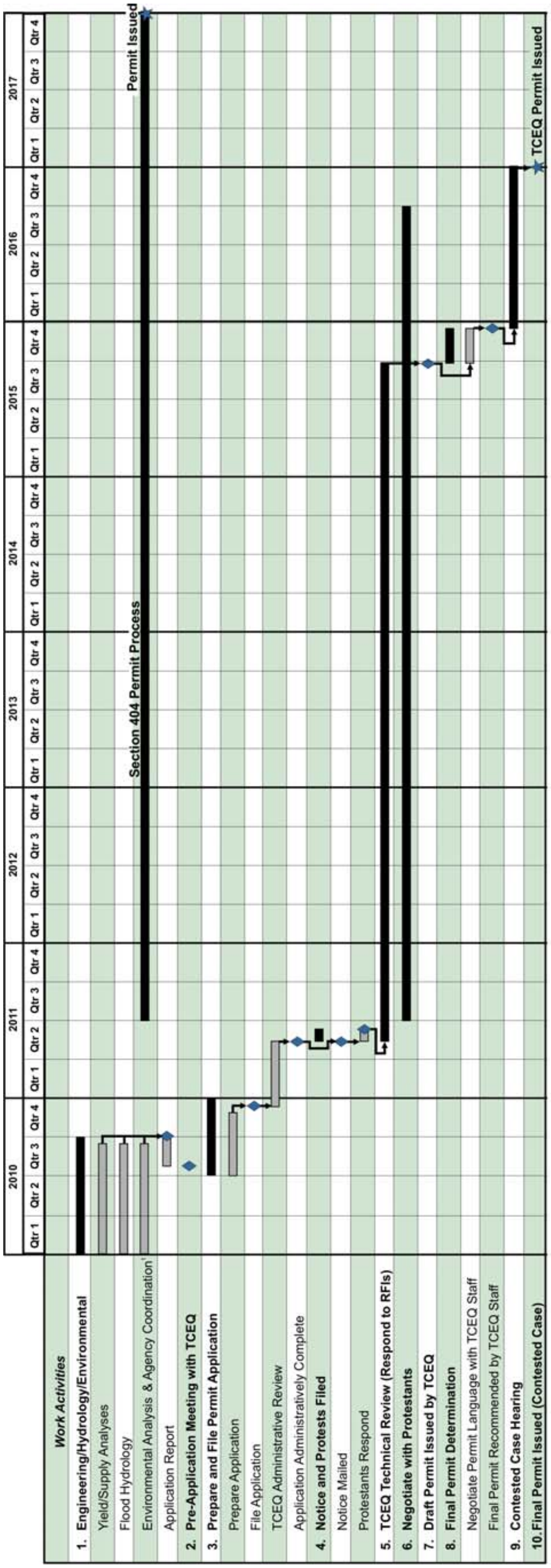
(4) Obtaining a State water right permit and Federal section 404 permit for the Cedar Ridge Reservoir project could take between 5 and 10 years to complete. An updated permitting schedule is shown in Figure 13.

(5) Construction and filling of Cedar Ridge Reservoir at the new dam site will result in the flooding of approximately 430 acres of lotic (river) habitat (as compared to about 500 acres at the original dam site), which includes the narrow riparian corridor flanking the river.

(6) Based on environmental sampling and numerous site visits in 2009 and prior years, no endangered species are likely to be affected by the construction of the reservoir. However, there is one threatened species likely to be an issue at the Cedar Ridge site and that is the Brazos water snake, Nerodia harteri. Although this snake is presently only state-listed, it is of restricted distribution as is its sister species, the Concho water snake (N. paucimaculata). The Concho water snake was listed as endangered by the U.S. Fish and Wildlife Service (USFWS) when the Stacy Reservoir project (now O.H. Ivie Reservoir) was announced, and USFWS could choose to do the same for the Brazos water snake in this case. Recently the USFWS has initiated efforts for the potential de-listing of the Concho water snake from the endangered species list and the result of this effort should continue to be monitored.

(7) Water quality in Cedar Ridge Reservoir is estimated to meet primary and secondary drinking water standards for chloride, sulfate, and total dissolved solids more than 90 percent of the time. Mixing the raw water with water in Fort Phantom Hill Reservoir should not be a problem; however, a more rigorous analysis of water quality resulting from delivery of Cedar Ridge water into FPH is recommended as more data becomes available.

(8) Provided that obstacles associated with permitting and threatened species can be overcome, the Cedar Ridge Reservoir project, as compared to other options, provides the largest quantity of water supply to the region at a reasonable unit cost, and provides the most protection to the region in the event that future droughts are more severe than previous droughts.



¹Includes coordination with TCEQ, TPWD, USFWS, and USACE for Section 404 permit.

Figure 13. Cedar Ridge Reservoir — Permtting Schedule

16.0 Recommendations

The following recommendations are presented based on the findings of this study and the 2008 report:

(1) City should proceed with applying for a water rights permit for Cedar Ridge Reservoir in 2010. The 2005/2007 agreements specify that the City must have a water rights permit filed and declared administratively complete by TCEQ by March 10, 2015 and the permit issued by March 10, 2018 in order for specific provisions of the agreements to remain in effect (i.e., that BRA will not protest the water right application). Because Cedar Ridge Reservoir will be perceived to be a significant project in a river basin with many downstream water rights, there will be an opportunity for potential protests of the permit and this permitting effort could take up to 10 years. Concurrent with the State water rights permitting effort, the City should continue on-going environmental studies necessary to file for and `secure a Federal Section 404 permit in the near future.

(2) The Brazos G Planning Group should be requested to continue to include Cedar Ridge Reservoir as a Unique Reservoir Site and a Recommended Water Management Strategy and also be requested to include the Possum Kingdom Lake option as an Alternative Water Management Strategy.

(3) City should continue to operate their reservoirs on a 1-year safe yield basis but should use 2-year safe yields in planning for future supplies.

(4) City should evaluate trends in regional streamflows at about 3 to 5 year intervals to determine if streamflows are declining over time as a result of changes in climate and/or watershed conditions.

(5) City should maintain their option with BRA to purchase up to 20,000 acft of raw water from Possum Kingdom Lake until the Cedar Ridge Reservoir project is permitted, and even longer if streamflows in the region continue to decline. The 2005/2007 agreements specify that this option to purchase is available to the City at no cost until March 10, 2015. At such time, the City will have the opportunity to either exercise the option or maintain the option at a rate to be established by BRA for at least an additional 10 years.

(6) Considering the uncertainties associated with developing estimates of future water needs for the next 50 years in a region of the State as diverse as the Abilene region, the City should continue to investigate alternative water management strategies available to increase its water supply.

(7) A more rigorous analysis of the expected water quality from mixing Cedar Ridge Reservoir water with FPH water should be performed to ensure that water quality standards in FPH will not be exceeded.

(8) An alternative analysis of intake locations and pipeline routes to deliver Cedar Ridge water to FPH should be completed prior to the City selecting the most favorable intake site and pipeline route.

(9) To better define streamflows and water quality at the Cedar Ridge Reservoir site, the City should work with the TWDB and the U.S. Geological Survey (USGS) to install a new stream gage and water quality monitoring station upstream of Cedar Ridge Reservoir on the Clear Fork near the City of Lueders.

Appendix A
Water Demand Projections for the Abilene Region (Pending Brazos G Demands for 2011 Plan)

Existing Water Contracts and Potential Water Users	*Year (acft/yr)*					
	2010	*2020*	*2030*	*2040*	*2050*	*2060*
City of Abilene	22,891	23,485	23,507	23,181	22,588	21,879
Blair WSC (Taylor C-O)	77	77	77	77	77	77
City of Baird	77	77	77	77	77	77
City of Clyde	307	307	307	307	307	307
City of Lawn	77	77	77	77	77	77
City of Merkel	353	353	353	353	353	353
City of Tye	184	184	184	184	184	184
Eula WSC (Callahan C-O)	61	61	61	61	61	61
Hamby WSC (Taylor C-O)	308	308	308	308	308	308
Hawley WSC	307	307	307	307	307	307
Potosi WSC	307	307	307	307	307	307
Steamboat Mountain WSC	307	307	307	307	307	307
Sun WSC (Taylor C-O)	230	230	230	230	230	230
View Caps WSC (Taylor C-O)	199	199	199	199	199	199
West Texas Utilities	11,837	11,837	11,837	11,837	11,837	11,837
Taylor County Manufacturing	972	1,081	1,177	1,270	1,349	1,462
Pending: Nolan County Steam Electric	807	11,311	20,000	20,000	20,000	20,000
Pending: City of Sweetwater	2,597	2,660	2,673	2,626	2,501	2,368
Total Demand	41,898	53,167	61,987	61,707	61,068	60,339

TASK 4

PRESENTATION TO ABILENE CITY COUNCIL

CITY COUNCIL MEETING
November 19th, 2009, 8:30 a.m.

CITY COUNCIL OF THE CITY OF ABILENE, TEXAS
COUNCIL CHAMBERS, CITY HALL

The City Council of the City of Abilene, Texas, met in Regular Session on November 19th, at 8:30 a.m. in the Council Chambers at 555 Walnut Street. Mayor Archibald was present and presiding with Councilmen Shane Price, Joe Spano, Anthony Williams, Robert O. Briley, Stormy Higgins and Councilwoman Laura Moore. Also present were City Manager Larry Gilley, City Attorney Dan Santee, City Secretary Danette Dunlap, and various members of the City staff.

Councilman Higgins gave the invocation.

Mayor Archibald introduced Jacob Hovey attends Allie Ward Elementary and is a 5th grader. Jacob led the Pledge of Allegiance to the Flags of the United States of America and the State of Texas.

PROCLAMATION

Mayor Archibald presented the following proclamation:

November 2009
National Adoption Month
Bit Whitaker and Tiffani Smith with Child Protective Services accepted the proclamation.

DISPOSITION OF MINUTES

5.0 Mayor Archibald stated Council has been given the minutes from the Regular Meeting on November 5th there being no deletions, no additions, and no corrections, Councilman Williams made a motion to approve the minutes as presented. Councilman Price seconded the motion, the motion carried.

AYES: Councilmen Price, Spano, Williams, Briley, Higgins, Councilwoman Moore and Mayor Archibald
NAYS: None

CONSENT AGENDA

Mayor Archibald announced that item 6.12 is pulled to be considered separately. Councilman Price pulled item 6.8. Councilwoman Moore made the motion to approve consent items 6.1 through 6.11 with the exception of 6.8 as presented. Councilman Spano seconded the motion, the motion carried.

AYES: Councilmen Price, Spano, Williams, Briley, Higgins, Councilwoman Moore and Mayor Archibald
NAYS: None
ABSTENTION: Councilman Williams on item 6.10

Ordinances:

6.1 (First Reading) Replacing Chapter 2, "Administration", Article IV "Records and Information management Program" of the Abilene Code of Ordinances in its entirety as set out; and setting a public hearing for December 3, 2009.

AN ORDINANCE OF THE CITY COUNCIL OF THE CITY OF ABILENE REPLACING CHAPTER 2, "ADMINISTRATION" ARTICLE IV "RECORDS AND INFORMATION MANAGEMENT PROGRAM" OF THE ABILENE CODE OF ORDINANCES IN ITS ENTIRETY AS SET OUT BELOW; PROVIDING A SEVERABILITY CLAUSE; AND CALLING FOR A PUBLIC HEARING.

6.2 (First Reading) Ordinance for Case No. **Z-2009-16**, a request from the Landmarks Commission to rezone property from RM-3 (Multi Family residential) to RM-3/H (Multi Family residential with Historic Overlay) zoning, located at 702 Meander Street; and setting a public hearing for December 3, 2009.

AN ORDINANCE OF THE CITY OF ABILENE, TEXAS, AMENDING CHAPTER 23, SUBPART E, "ZONING," OF THE ABILENE MUNICIPAL CODE, BY CHANGING THE ZONING DISTRICT BOUNDARIES AFFECTING CERTAIN PROPERTIES; CALLING A PUBLIC HEARING; PROVIDING A PENALTY AND AN EFFECTIVE DATE.

Location: 702 Meander Street

6.3 (First Reading) Ordinance for Case No. **Z-2009-17**, a request from Aaron Waldrop to rezone property from AO (Agricultural Open Space) to RS-6 (Single Family Residential) zoning, located adjacent to the west side of Indian Wells Subdivision and south of Dakota Springs Section1; and setting a public hearing for December 3, 2009.

AN ORDINANCE OF THE CITY OF ABILENE, TEXAS, AMENDING CHAPTER 23, SUBPART E, "ZONING," OF THE ABILENE MUNICIPAL CODE, BY CHANGING THE ZONING DISTRICT BOUNDARIES AFFECTING CERTAIN PROPERTIES; CALLING A PUBLIC HEARING; PROVIDING A PENALTY AND AN EFFECTIVE DATE.

Location: Adjacent to the west side of Indian Wells Subdivision and south of Dakota Springs Section1

6.4 (First Reading) Ordinance for Case No. **Z-2009-18**, a request from Charles Barbee to rezone property from RS-6 (Single Family Residential) to MH (Mobile Home) zoning, located at 6009 Pueblo Dr. and 933 Baker Street; and setting a public hearing for December 3, 2009.

AN ORDINANCE OF THE CITY OF ABILENE, TEXAS, AMENDING CHAPTER 23, SUBPART E, "ZONING," OF THE ABILENE MUNICIPAL CODE, BY CHANGING THE ZONING DISTRICT BOUNDARIES AFFECTING CERTAIN PROPERTIES; CALLING A PUBLIC HEARING; PROVIDING A PENALTY AND AN EFFECTIVE DATE.

Location: 6009 Pueblo Drive and 933 Baker Street

6.5 (First Reading) Ordinance for Case No. **TC-2009-03**, a request from the City of Abilene to abandon Rose Street beginning at the north right of way of S. 3rd Street and extending approximately 328 ft to the north; and setting a public hearing for December 3, 2009.

AN ORDINANCE PROVIDING FOR THE ABANDONMENT OF A PORTION OF PUBLIC RIGHT OF WAY; PROVIDING FOR THE TERMS AND CONDITIONS OF SUCH ABANDONMENT, AND CALLING A PUBLIC HEARING.

Location: Rose Street partial

6.6 Oral Resolution approving amendments to the Thoroughfare Plan in an area generally described as being east of Potosi Road, north of Buckskin Road, and south of Old Elmdale Road at Hwy 36. Set a public hearing for December 3, 2009.

The amendment will shift the alignment of the future expressway to the south, to allow for development of the property. The alignment will shift the right-of-way of the expressway onto properties to the east and south that currently have no such obligation.

6.7 (First Reading) Ordinance setting out the City of Abilene's Standards of Care Program; and setting a public hearing for December 3, 2009.

AN ORDINANCE OF THE CITY OF ABILENE, TEXAS, ESTABLISHING STANDARDS OF CARE FOR CITY OF ABILENE, YOUTH PROGRAMS; REPEALING ALL ORDINANCES OF PARTS OF ORDINANCES IN CONFLICT HEREWITH; PROVIDING A SAVINGS CLAUSE; AND CALLING A PUBLIC HEARING.

6.8 Oral Resolution – Acceptance of Energy Efficiency and Conservation Block Grant (EECBG) Program Funds. *Item pulled by Councilman Price.*

6.9 **Oral Resolution** - Amend Contract between City of Abilene and Schneider Electric (formally TAC) to complete energy measures under the Energy Efficiency and Conservation Block Grant (EECBG).

Schneider Electric is currently completing phase I of the long term energy conservation plan developed for the City of Abilene. This amendment will allow them to continue the work to further improve the overall mechanical systems within the City.

6.10 **Resolution –** Supporting the award of funds through the Neighborhood Stabilization Program to Abilene Neighborhoods in Progress.

Abilene Neighborhoods In Progress has applied for funding through Texas Department of Housing and Community Affairs (TDHCA).

Resolution **#35-2009** and is captioned as follows:

A RESOLUTION OF THE CITY COUNCIL OF ABILENE, TEXAS TO AUTHORIZE ABILENE NEIGHBORHOODS IN PROGRESS, INC. TO SUBMIT AN APPLICATION FOR THE NEIGHBORHOOD STABILIZATION PROGRAM (NSP) TO THE TEXAS DEPARTMENT OF HOUSING AND COMMUNITY AFFAIRS.

6.11 Oral Resolution – Approved a request to advertise City owned land and an oil and gas lease. Property is 91.92 acre "Lake Tract #3"

ITEMS PULLED FROM CONSENT

6.8 Oral Resolution – Acceptance of Energy Efficiency and Conservation Block Grant (EECBG) Program Funds. *Item pulled by Councilman Price.*

Abilene submitted an application for a non-competitive stimulus grant on June 26th, 2009 in the amount of $1.132 million. The Energy Efficiency and Conservation Block Grant (EECBG) were approved by the Department of Energy on September 28th, 2009.

The projects funded through this grant program include two major initiatives:

1. City Facility Energy Efficiency Upgrades, Phase II.
2. Community Energy Efficiency Incentive Program.

Councilman Price asked about who would qualify for the community energy program. Jon James Director of Planning and Community Development explained that the city didn't have any rules in place currently for qualifications. The State is working on rules for the program and the City will piggyback on the state guidelines.

Councilman Price made the motion to approve the acceptance of the Energy Efficiency and Conservation Block Grant Program Funds. Councilman Williams seconded the motion, motion carried.

AYES: Councilmen Price, Spano, Williams, Briley, Higgins, Councilwoman Moore and Mayor Archibald
NAYS: None

6.12 Resolution – Supporting and Joining the City of Alpine, Texas in litigation to determine whether a local government officials free speech made pursuant to official duties enjoys the same Constitutional protections that the 1st amendment to the United States Constitution Grants to other speech. *Item pulled by Mayor for special consideration.*

Dan Santee, City Attorney briefed the Council on the background of this Resolution and how it relates to the Open Meetings Act. The City doesn't have to join in the litigation, but the outcome of the litigation will have an effect on council members/board members everywhere.

Council and Staff discussion included: 1) the current proposed litigation by the City of Alpine has only to do with the penalty portion of the open meetings act; 2) clarity in the law is very much needed – will have to happen on the State level; and 3) council members are not trying to dodge open meetings, they want to be able to hear from the citizens that voted for them into office and then be able to represent them.

Mayor Archibald opened up the meeting for comments and the council heard from:

- Keith Elkins with the Freedom of Information Foundation of Texas – who asked that the council not join the City of Alpine.
- Barton Cromeens – Abilene Reporter News – asked that council not join the City of Alpine.

Councilman Williams made the motion to TABLE this item. Councilman Spano seconded the motion, motion carried.

AYES: Councilmen Spano, Williams, Higgins, Mayor Archibald
NAYS: Councilmen Briley, Price and Councilwoman Moore

REGULAR AGENDA

7.1 Mindy Patterson, Director of Finance briefed the Council on the Ordinance authorizing issuance of General Obligation Refunding Bonds, Series 2009B.

The City has the potential opportunity to realize debt service savings from refunding (refinancing) callable maturities at a lower interest rate. These maturities include certificates of obligation Series 2001 and general obligation bonds Series 2001.

Pricing approval for the sale of the refunding issue would be delegated to the City Manager, subject to the parameters established by the ordinance.

Councilman Briley made the motion to approve the Ordinance Authorizing the Issuance of General Obligation Refunding Bonds, Series 2009B. Councilman Higgins seconded the motion, motion carried.

AYES: Councilmen Price, Spano, Williams, Briley, Higgins, Councilwoman Moore and Mayor Archibald
NAYS: None

Ordinance **#35-2009** and captioned as follows:

AUTHORIZING THE ISSUANCE OF CITY OF ABILENE, TEXAS, GENERAL OBLIGATION REFUNDING BONDS, SERIES 2009B; ESTABLISHING PROCEDURES FOR THE SALE AND DELIVERY OF THE BONDS; LEVYING AN ANNUAL AD VALOREM TAX FOR THE PAYMENT OF SAID BONDS; PROVIDING AN EFFECTIVE DATE; AND ENACTING OTHER PROVISIONS RELATING TO THE SUBJECT **($2,285,000)**

7.2 Richard Burdine, Assistant City Manager for Economic Development, briefed the Council on the Annual Report of Activities for the Development Corporation of Abilene, Inc.

Progress Made Toward Goals

1. The DCOA approved assistance for four different companies. Two are local companies: Run Energy and Coca-Cola. A total of 174 jobs are to be retained and 45 jobs created.
2. The DCOA approved funds for training as follows: a) up to $50,000 for the first four sessions of a wind tech pilot training program for Global Energy Services, b) $37,500 job training grant to Run Energy, and c) $60,000 to continue support of the Texas Manufacturing Assistance Center through FY2011.
3. The DCOA approved funds to begin construction of the Abilene Life Sciences Accelerator on Pine Street, which is an area near downtown that is very blighted and part of the Pine Street Corridor initiative. Space will be leased temporarily by the DCOA at 302 Pine Street to AISD for the newly created STEM high school.
4. The DCOA provides $195,000 annually to the Small Business Development Center for counseling services provided free of charge to Abilene residents and businesses. In addition, the SBDC can assist businesses desiring to sell products or services to any level of government. For the second year in a row, the DCOA approved a sponsorship of ACU's Springboard Idea Challenge competition designed to promote entrepreneurial drive and spirit in Abilene.
5. During the report period (10/1/08 through 9/30/09) the DCOA approved $2,417,000 in funding to assist companies with growth and retention in Abilene, anticipating new employment of 45 jobs and retained employment of 174 positions. The Abilene Life Sciences Accelerator is being constructed as part of a $10 million project to enhance Abilene's new biotech research industry sector.

Councilman Williams made the motion to accept by Oral Resolution the DCOA's FY2009 Annual Report. Councilman Price seconded the motion, motion carried.

AYES: Councilmen Price, Spano, Williams, Briley, Higgins, Councilwoman Moore and Mayor Archibald

NAYS: None

7.3 Tommy O'Brien, Director of Water Utilities, along with Scott Hibbs with Enprotec/Hibbs & Todd Inc. briefed the Council on the status of Cedar Ridge Reservoir permitting and Geologic Investigations.

Recommended Key
Water Management Strategies

I. **Develop Cedar Ridge Reservoir as the Recommended Water Management Strategy**
   - Proceed with Water Rights Permitting through the Texas Commission on Environmental Quality (TCEQ)
   - Proceed with Section 404 Permitting through the Corps of Engineers
   - Proceed with Supporting Activities (Geotechnical; Environmental Studies; Surveying; Mapping; etc.)

II. **Continue Planning for Alternative Water Management Strategies**
   - Purchase and Use of Water from Possum Kingdom Reservoir
   - Recycled (Reclaimed) Water into Lake Fort Phantom Hill

Future Key Dates

Interlocal Agreement dated March 10, 2005, between Abilene, the WCTMWD and the BRA establishes:

- **Cedar Ridge Reservoir**

March 10, 2015: Cedar Ridge Reservoir TCEQ Water Rights Permit deemed administratively complete with public notice issued.

March 10, 2018: Cedar Ridge Reservoir TCEQ Water Rights Permit issued.

- **Water Supply from Possum Kingdom Reservoir**

March 10, 2015: End of a preferential right and option to purchase 20,000 acre-feet per year of BRA system water from Possum Kingdom Reservoir. There is no cost to the City during this period for this option to purchase.

March 10, 2025: End of an extension of the preferential right and option to purchase 20,000 acre-feet per year of BRA system water from Possum Kingdom Reservoir. The cost of this extended option period will be at a Reservation Rate (i.e., a rate established by the BRA to reserve water prior to actual diversion and use of the water). Extensions to this date can be obtained by mutual agreement.

Council heard a report on Gypsum from Kenneth S. Johnson, Ph.D., Geologist. Gypsum was found at the original dam site.

Summary

Gypsum is soluble and typically contains cavities, sinkholes, and caves ("karst").

Dams built upon gypsum karst generally are not able to retain water.

Although not mentioned in the geologic literature, gypsum was discovered at original CR dam site.

Gypsum is present in the Clear Fork Valley from the original CR dam site upstream to borehole SB-4.

Best location for dam is upstream from SB-4.

Two alternative dam sites were considered.

Site A – top of gypsum is within 20 feet of bottom of reservoir
– two narrow ridges are additional concern for seepage

Site B – top of gypsum is more than 50 ft below reservoir bottom – no narrow ridges at site B

Council then heard a report in regards to the updated size of the Cedar Ridge Reservoir due to the alternate site B for the dam. Site B is located further south upstream and will change the capacity of the Reservoir.

Council then heard a report on the Water Demands of 2060 based on the Brazos G and the Texas Water Development Board 2011 Plan. These demands are not a City issue, these are set out by the State for our Region.

Cedar Ridge Reservoir
Upcoming Activities

- **Continued Coordination with Ranches / Property Owners**
- **Develop Project Management Plan with Corps of Engineers (COE)**
- **Continued Inter-agency Coordination (Water Development Board)**
- **Continued Coordination with Brazos G Planning Group**
- **Continued Environmental Analyses**
    - **Brazos Water Snake Surveys**
    - **Aquatic Life Monitoring Surveys**
    - **Vegetation Mapping**
    - **Wetlands Survey**
- **Water Rights Permit Application Submission to TCEQ**
- **Initial Cultural Resources Evaluation**
- **Federal Section 404 Permitting and Mitigation Plan Preparation**
- **Installation of New USGS Stream gage at Lueders**

This item was for discussion only no action needed on this item.

EXECUTIVE SESSION

Mayor Archibald recessed the Council into Executive Session at 11:21 a.m. pursuant to Sections 551.071, 551.074, 551.072 and 551.087 of the Open Meetings Act, to seek the advice of the City Attorney with respect to pending and contemplated litigation, to consider the appointment and evaluation of public officers, to consider the purchase, exchange, lease or value of real property, and to discuss contemplated business prospects and or economic development matters.

The Council reconvened from Executive Session at 12:21 p.m. and reported no votes or action was taken in Executive Session in regards to Section 551.071 Consultation with the City Attorney, Section 551.072 Real Property and Section 551.074 Personnel Matters.

10. **Resolution** casting votes for the Board of Directors of the Central Appraisal District in proportion to the City's tax levy.

Mayor Archibald made the motion to cast votes for the following: David Copeland 834, Yvonne Batts 28, Dr. Colleen Durrington 28, and Cecil Davis 347. Councilman Williams seconded the motion, motion carried.

AYES: Councilmen Price, Spano, Williams, Briley, Higgins, Councilwoman Moore and Mayor Archibald
NAYS: None

Resolution **#36-2009** and is captioned as follows:

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF ABILENE, TEXAS, VOTING FOR THE FOLLOWING INDIVIDUALS TO THE BOARD OF DIRECTORS OF THE CENTRAL APPRAISAL DISTRICT OF TAYLOR COUNTY FOR 2010-2011.

11 **Resolution** casting votes for the Board of Directors of the Jones County Appraisal District in proportion to the City's tax levy.

Mayor Archibald made the motion to cast all 81 votes for the following: Stormy Higgins Councilman Spano seconded the motion, motion carried.

Resolution **#37-2009** and is captioned as follows:

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF ABILENE, TEXAS, VOTING FOR THE FOLLOWING INDIVIDUALS TO THE BOARD OF DIRECTORS OF THE JONES COUNTY APPRAISAL DISTRICT OF JONES COUNTY FOR 2010-2011.

AYES: Councilmen Price, Spano, Williams, Briley, Councilwoman Moore and Mayor Archibald
NAYS: None
ABSTAINED: Councilman Higgins

12 Oral Resolution approving the appointment/reappointments to the following boards and commissions.

Abilene-Taylor County Public Health Advisory Board
3 Year Terms
Re-appoint:

- Peter K. Norton M.D.

Appoint:

- Maureen Trotter, M.D

Abilene-Taylor County Venue District Board
2 Year Terms
Re-appoint:

- Mayor Norm Archibald

Airport Development Board
3 Year Terms
Re-appoint:

- Stan Egger
- Woody Gilliland
- David Lynn

Animal Services Advisory Board
3 Year Terms
Re-appoint:

- Leah Herron
- Aaron Vannoy
- Tom Rigsby

Board of Adjustment
2 Year Terms
Re-appoint:

- Brad Carter
- Roger Huber
- Col. Morton Langholtz
- Bob Beerman (Alternate)

Board of Building Standards
2-Year Term
Re-appoint:

- Marvin Barber
- David Beard
- Lloyd Turner
- Matt Loudermilk

Appoint:

- Randy Halstead (Social Worker)

Civil Service Commission
3 Year Terms
Re-appoint:

- Hubert Pickett

Abilene Housing Authority
2 Year Terms
Re-appoint:

- Patricia Hippely

- Kiddy Boswell
- Vanessa Faz

Landmarks Commission
3 Year Terms
Re-appoint:
- Laura Waldroup
- Dr. Michael McClellan
- Phil Miller

Library Board
2-Year term
- Stan Chapman
- John Williams
- Robert Carleton
- Brian Scalf
- Joe Specht

Appoint
- Jim Potts

Office of Neighborhood Services Advisory Council
2-Year term
Re-appoint:
- Bill Culp

- Vanessa Roberts
- Linda Carleton (at-large)

Appoint:
- Doug McIntyre

Planning and Zoning Commission
3-Year term
Re-appoint:
- Clint Rosenbaum

Keep Abilene Beautiful Board
3-Year term
Re-appoint:
- Malcolm Bramlett
- Carolyn Cockrell
- Martin Garcia
- JoAnn Sczech

Child Advocacy Center
3-Year term
Appoint:
- Craig Shaw
- Anthony Williams
- Nikki Favors

Councilman Price made the motion to approve the Mayor's recommendation for the Boards and Commissions. Councilman Williams seconded the motion, motion carried.

AYES: Councilmen Price, Spano, Williams, Higgins, Briley, Councilwoman Moore and Mayor Archibald.
NAYS: None

There being no further business the meeting was adjourned at 12:25 p.m.

Danette Dunlap, TRMC
City Secretary

Norm Archibald
Mayor

TASK 4

PRESENTATION TO ABILENE CITY COUNCIL

CITY OF ABILENE

City Council of Abilene

UPDATE

CEDAR RIDGE RESERVOIR PROJECT

November 19, 2009

AGENDA

CEDAR RIDGE PROJECT UPDATE

1. Introduction
2. Background – Council Workshop Held May 1, 2008
3. Summary of Activities Since May, 2008
4. Siting of Cedar Ridge Dam
5. Cedar Ridge Reservoir New Dam Site
6. Updated Need for Future Water Supply
7. Updated Project Development Costs
8. Upcoming Activities
9. Questions and Discussion

ITEM #1

INTRODUCTION

WATER SUPPLIES TEAM

eHT

Enprotec / Hibbs & Todd

Enprotec / Hibbs & Todd, Inc. (eHT) is a civil, environmental and geotechnical engineering firm that is in the business of creating sustainable development, improving community infrastructure for future growth, and preserving some of our most prized natural resources. We are a forward-thinking and progressive team of engineers and scientists with deep industry expertise, knowledge and resources. Our success is based on enduring partnerships with our clients.

HDR | ONE COMPANY *Many Solutions*℠

HDR is an architectural, engineering and consulting firm that excels at managing complex projects and solving challenges for clients. As an integrated firm, HDR provides a total spectrum of services for our clients. Our staff professionals represent hundreds of disciplines and partner on blended teams nationwide to provide solutions beyond the scope of traditional A/E/C firms.

Since being founded as one of the first water, environment, and utility law firms in Texas, Lloyd Gosselink Rochelle & Townsend, P.C. has grown its practice to include business transactions, commercial litigation and employment law. Lloyd Gosselink is committed to its clients and their success and works hard to gain an in-depth understanding of their clients' operations. Lloyd Gosselink is trusted by both the public and private sectors to provide quality, cost-effective representation before legislatures, courts and regulatory agencies. The Firm's goal is to deliver top-quality, cost-effective legal representation and to work with our clients to find innovative solutions to legal problems.

ALAN PLUMMER ASSOCIATES, INC.

ENVIRONMENTAL ENGINEERS • DESIGNERS • SCIENTISTS

Alan Plummer Associates Inc., was founded in 1978 with a vision to balance environmental stewardship with technical excellence, serving clients with distinction and integrity. Today, with over 100 employees and five offices in Fort Worth, Dallas, Austin, Houston and San Antonio and a project office in Pascagoula, Mississippi, Alan Plummer Associates, Inc. continues that commitment. Dedicated to water resources and environmental engineering, our firm balances sound engineering principles with innovative technology tailored to our clients' needs. From initial project kick-off, through stringent QC review, to a completed project, our focus stays on developing cost-effective solutions.

GEOTECHNICAL/GEOLOGICAL CONSULTANTS

Fugro Consultants has provided geotechnical engineering, construction materials engineering and testing, pavement management, testing and materials research, and quality control/quality assurance services for 62 years. Our continuous growth is testament to our ability to work as a project team partner, bringing our clients the benefits of our reputation as an innovation leader in developing new methods, equipment and technologies into effective, practical and environmentally conscious state-of-the-art practice.

KENNETH S. JOHNSON, Ph.D., GEOLOGIST

Dr. Johnson has 48 years experience studying the geology of Oklahoma, Texas and the western United States. He earned a BS, MS and Ph.D. in Geology and a BS in Geological Engineering. A full-time employee with the Oklahoma Geological Survey (OGS) at The University of Oklahoma from 1961–2000, he was Associate Director at OGS from 1978–2000. He has also been a consultant since 1970. His major research is the study and evaluation of gypsum- and salt-related problems in Oklahoma and Texas, and he has published more than 250 books, reports, articles and abstracts. He is a Registered Professional Geologist in Texas and Arkansas.

CITY OF ABILENE

ITEM #2

BACKGROUND

COUNCIL WORKSHOP HELD MAY 1, 2008

RECOMMENDED KEY WATER MANAGEMENT STRATEGIES

I. **Develop Cedar Ridge Reservoir as the Recommended Water Management Strategy**

  - ➢ Proceed with Water Rights Permitting through the Texas Commission on Environmental Quality (TCEQ)
  - ➢ Proceed with Section 404 Permitting through the Corps of Engineers
  - ➢ Proceed with Supporting Activities (Geotechnical; Environmental Studies; Surveying; Mapping; etc.)

II. **Continue Planning for Alternative Water Management Strategies**

  - ➢ Purchase and Use of Water from Possum Kingdom Reservoir
  - ➢ Recycled (Reclaimed) Water into Lake Fort Phantom Hill

FUTURE KEY DATES

Interlocal Agreement dated March 10, 2005, between Abilene, the WCTMWD and the BRA establishes:

Cedar Ridge Reservoir

March 10, 2015: Cedar Ridge Reservoir TCEQ Water Rights Permit deemed administratively complete with public notice issued.

March 10, 2018: Cedar Ridge Reservoir TCEQ Water Rights Permit issued.

Water Supply from Possum Kingdom Reservoir

March 10, 2015: End of a preferential right and option to purchase 20,000 acre-feet per year of BRA system water from Possum Kingdom Reservoir. There is no cost to the City during this period for this option to purchase.

March 10, 2025: End of an extension of the preferential right and option to purchase 20,000 acre-feet per year of BRA system water from Possum Kingdom Reservoir. The cost of this extended option period will be at a Reservation Rate (i.e., a rate established by the BRA to reserve water prior to actual diversion and use of the water). Extensions to this date can be obtained by mutual agreement.

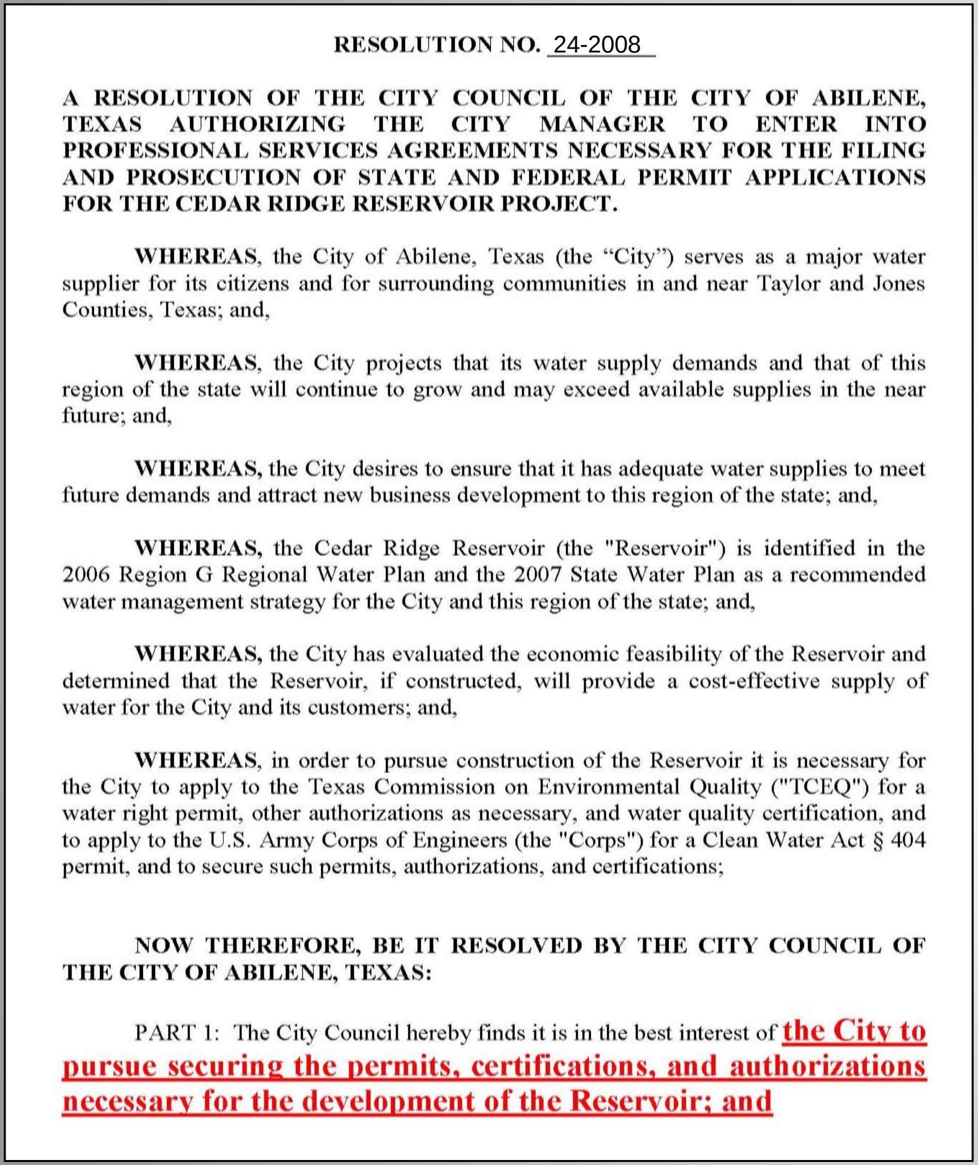
CITY OF ABILENE

ITEM #3

SUMMARY OF ACTIVITIES

SINCE MAY, 2008

COUNCIL RESOLUTION (Cedar Ridge Permits)



RESOLUTION NO. 24-2008

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF ABILENE, TEXAS AUTHORIZING THE CITY MANAGER TO ENTER INTO PROFESSIONAL SERVICES AGREEMENTS NECESSARY FOR THE FILING AND PROSECUTION OF STATE AND FEDERAL PERMIT APPLICATIONS FOR THE CEDAR RIDGE RESERVOIR PROJECT.

WHEREAS, the City of Abilene, Texas (the "City") serves as a major water supplier for its citizens and for surrounding communities in and near Taylor and Jones Counties, Texas; and,

WHEREAS, the City projects that its water supply demands and that of this region of the state will continue to grow and may exceed available supplies in the near future; and,

WHEREAS, the City desires to ensure that it has adequate water supplies to meet future demands and attract new business development to this region of the state; and,

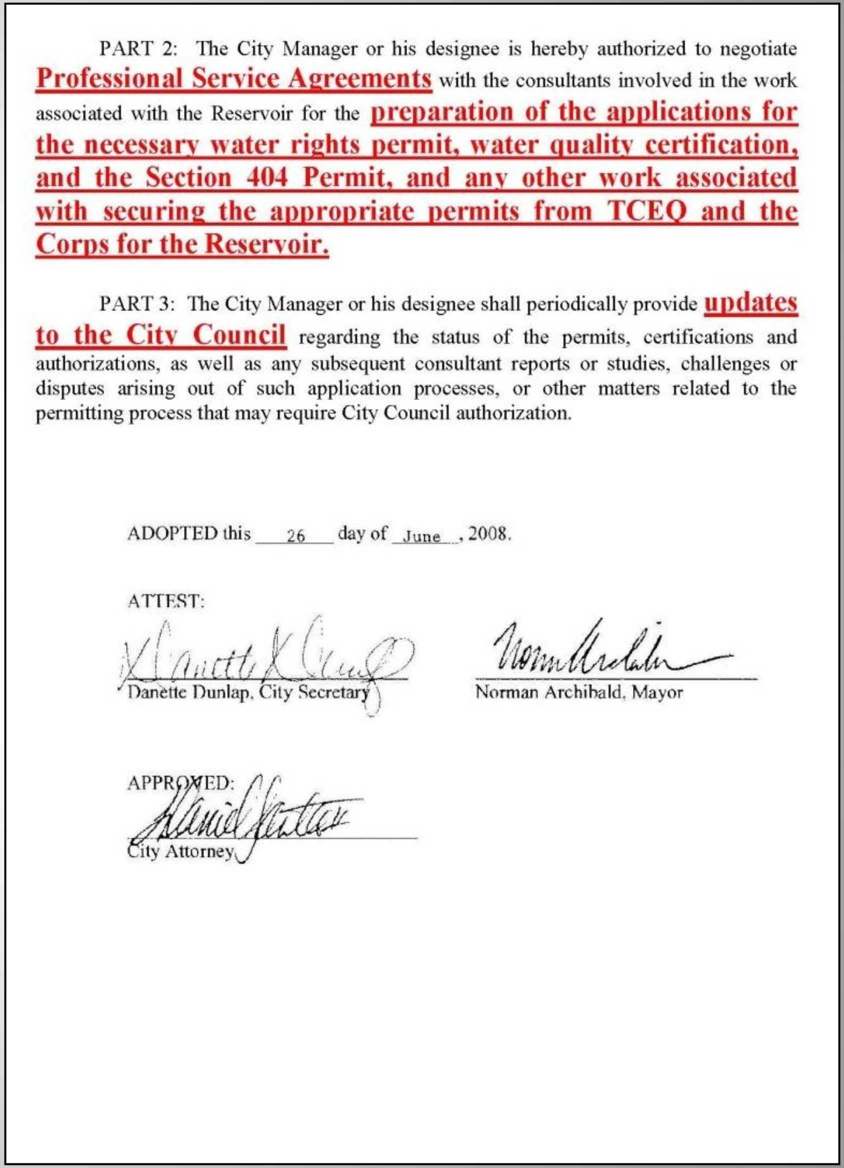
WHEREAS, the Cedar Ridge Reservoir (the "Reservoir") is identified in the 2006 Region G Regional Water Plan and the 2007 State Water Plan as a recommended water management strategy for the City and this region of the state; and,

WHEREAS, the City has evaluated the economic feasibility of the Reservoir and determined that the Reservoir, if constructed, will provide a cost-effective supply of water for the City and its customers; and,

WHEREAS, in order to pursue construction of the Reservoir it is necessary for the City to apply to the Texas Commission on Environmental Quality ("TCEQ") for a water right permit, other authorizations as necessary, and water quality certification, and to apply to the U.S. Army Corps of Engineers (the "Corps") for a Clean Water Act § 404 permit, and to secure such permits, authorizations, and certifications;

NOW THEREFORE, BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF ABILENE, TEXAS:

PART 1: The City Council hereby finds it is in the best interest of **the City to pursue securing the permits, certifications, and authorizations necessary for the development of the Reservoir; and**



PART 2: The City Manager or his designee is hereby authorized to negotiate **Professional Service Agreements** with the consultants involved in the work associated with the Reservoir for the **preparation of the applications for the necessary water rights permit, water quality certification, and the Section 404 Permit, and any other work associated with securing the appropriate permits from TCEQ and the Corps for the Reservoir.**

PART 3: The City Manager or his designee shall periodically provide **updates to the City Council** regarding the status of the permits, certifications and authorizations, as well as any subsequent consultant reports or studies, challenges or disputes arising out of such application processes, or other matters related to the permitting process that may require City Council authorization.

ADOPTED this 26 day of June, 2008.

ATTEST:

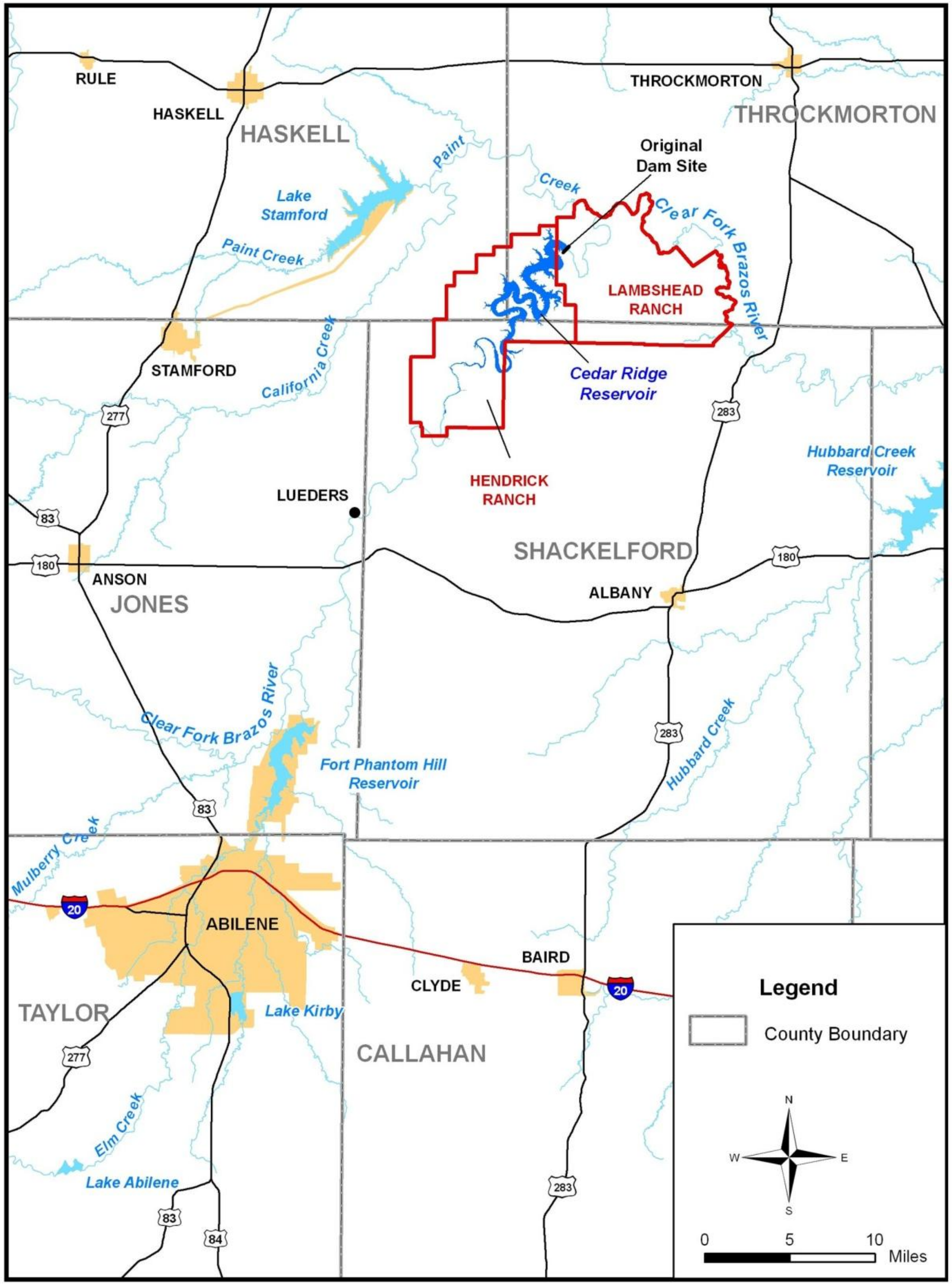
Danette Dunlap, City Secretary

Norman Archibald, Mayor

APPROVED:

City Attorney

CEDAR RIDGE RESERVOIR
(ORIGINAL DAM SITE)



PHASE I GEOTECHNICAL INVESTIGATION
AT ORIGINAL DAM SITE

- ➢ **Funded by the Texas Water Development Board (TWDB)**

- ➢ **Summer, 2008:** Field core drilling and geotechnical investigation. Finding of Gypsum.

- ➢ **February 16, 2009:** Fugro Consultants, Inc. issues report, "Phase I Geotechnical Investigations – Cedar Ridge Reservoir, Throckmorton County, Texas"

- ➢ **Geotechnical Advisory Group formed to determine a path forward considering the Gypsum issue**
  - Core eHT/HDR/Fugro Team with the addition of key personnel from HDR/Fugro
  - Dr. Kenneth S. Johnson

ENVIRONMENTAL ANALYSES

- **Literature Review**
  - Identified species of concern
  - Established appropriate survey methodologies
- **Brazos Water Snake Survey Report** (May, 2009)
- **Field Reconnaissance Trip** (March, 2009)
  - Preliminary documentation of vegetation, terrestrial and aquatic wildlife, freshwater mussels and the Brazos River Snake
- **Mussel Survey** (August, 2009)
- **Preliminary Aquatic Life Monitoring** (September, 2009)

ITEM #4

SITING OF CEDAR RIDGE DAM

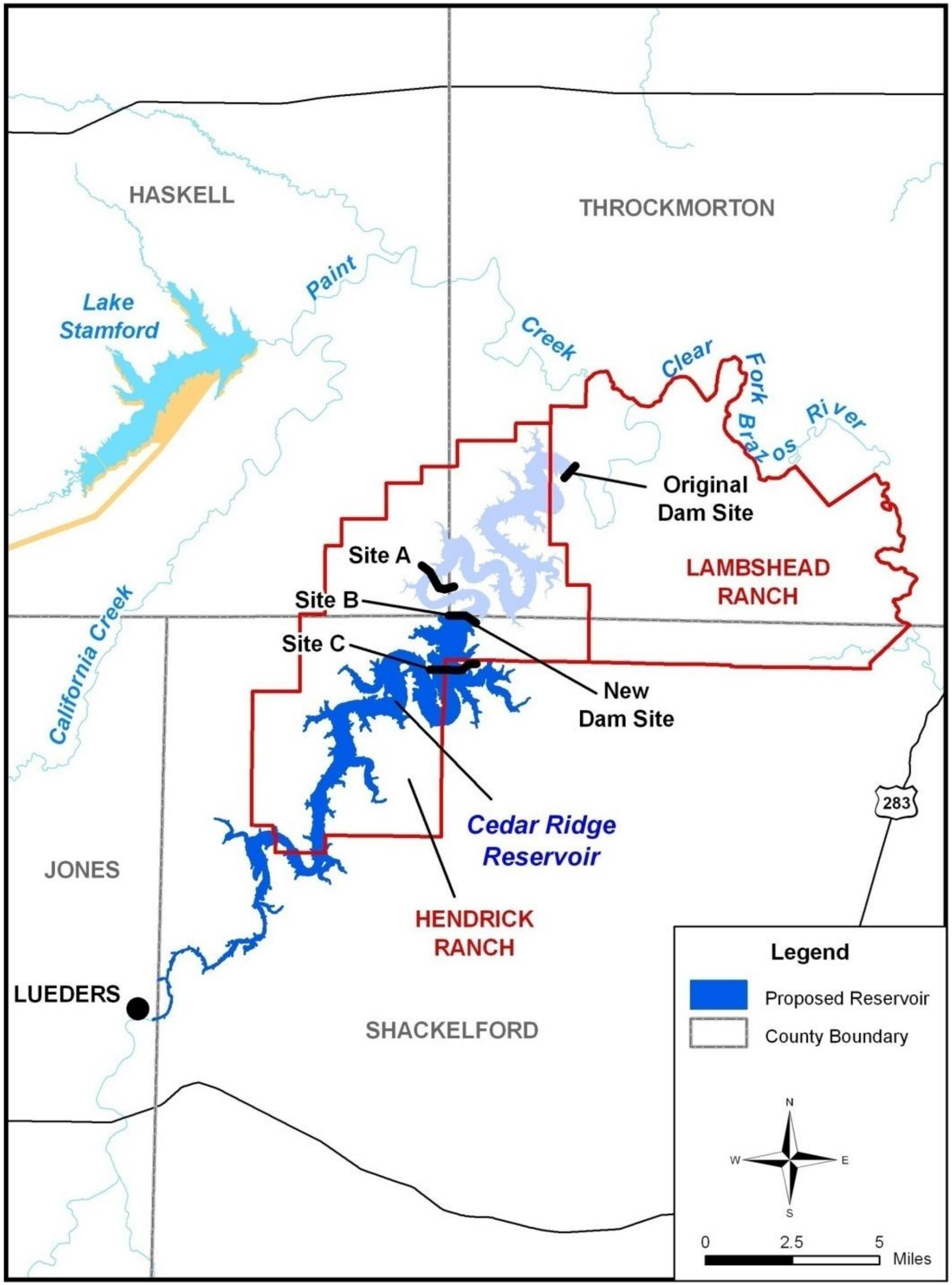
GEOTECHNICAL ADVISORY GROUP

Initiated Regional Geologic Study to aid in identifying alternative dam sites along the Clear Fork of the Brazos River

- Geologic Literature Review
- Geologic Structure Contour Map and Report
- Helicopter Flyover Reconnaissance
- Geologic Field Mapping and Report
- Geotechnical Core Borings for Geology Mapping

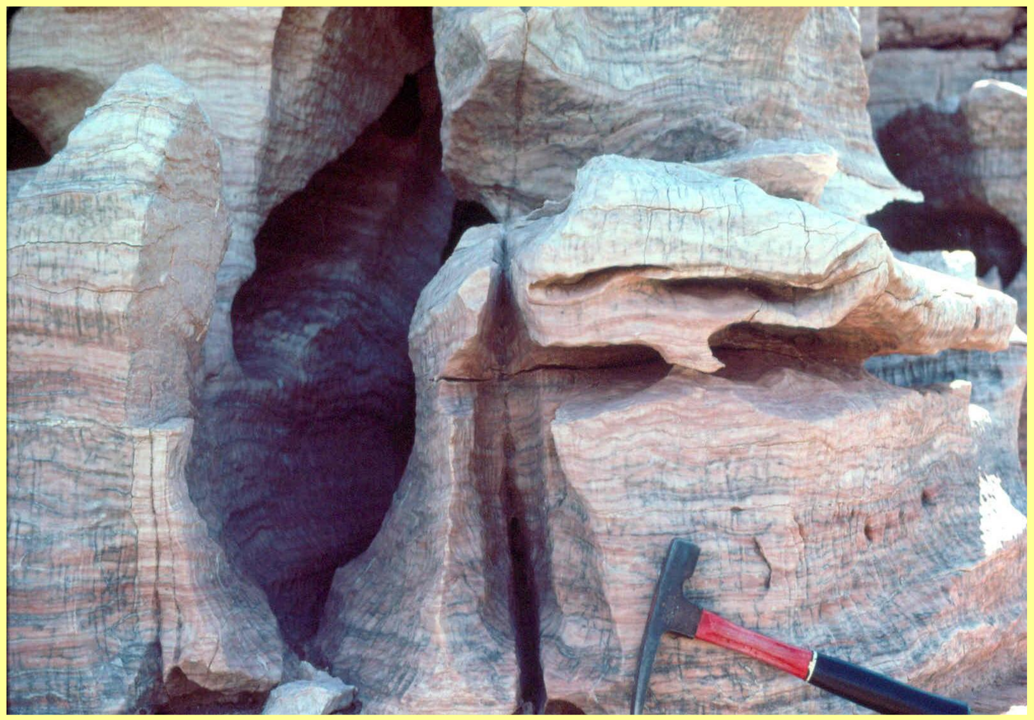
CEDAR RIDGE RESERVOIR

(ALTERNATIVE DAM SITES)



Gypsum-Karst Problems and the Siting of Cedar Ridge Dam

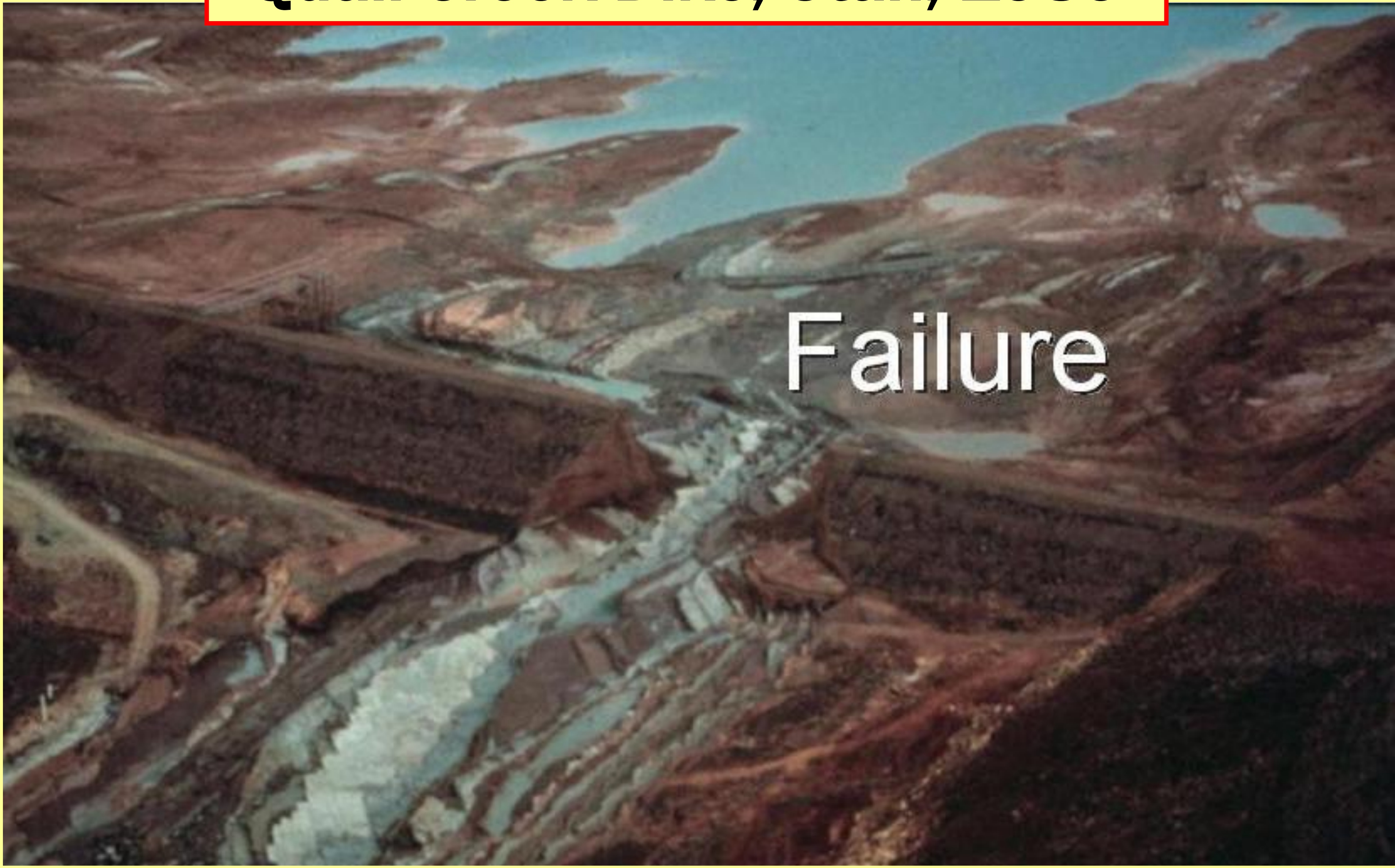
Kenneth S. Johnson



Karst Features: caves, sinkholes, disappearing streams, springs, and underground water courses; resulting from dissolution of relatively soluble rock (limestone, dolomite, and gypsum)

Karst development in gypsum

Quail Creek Dike, Utah, 1989



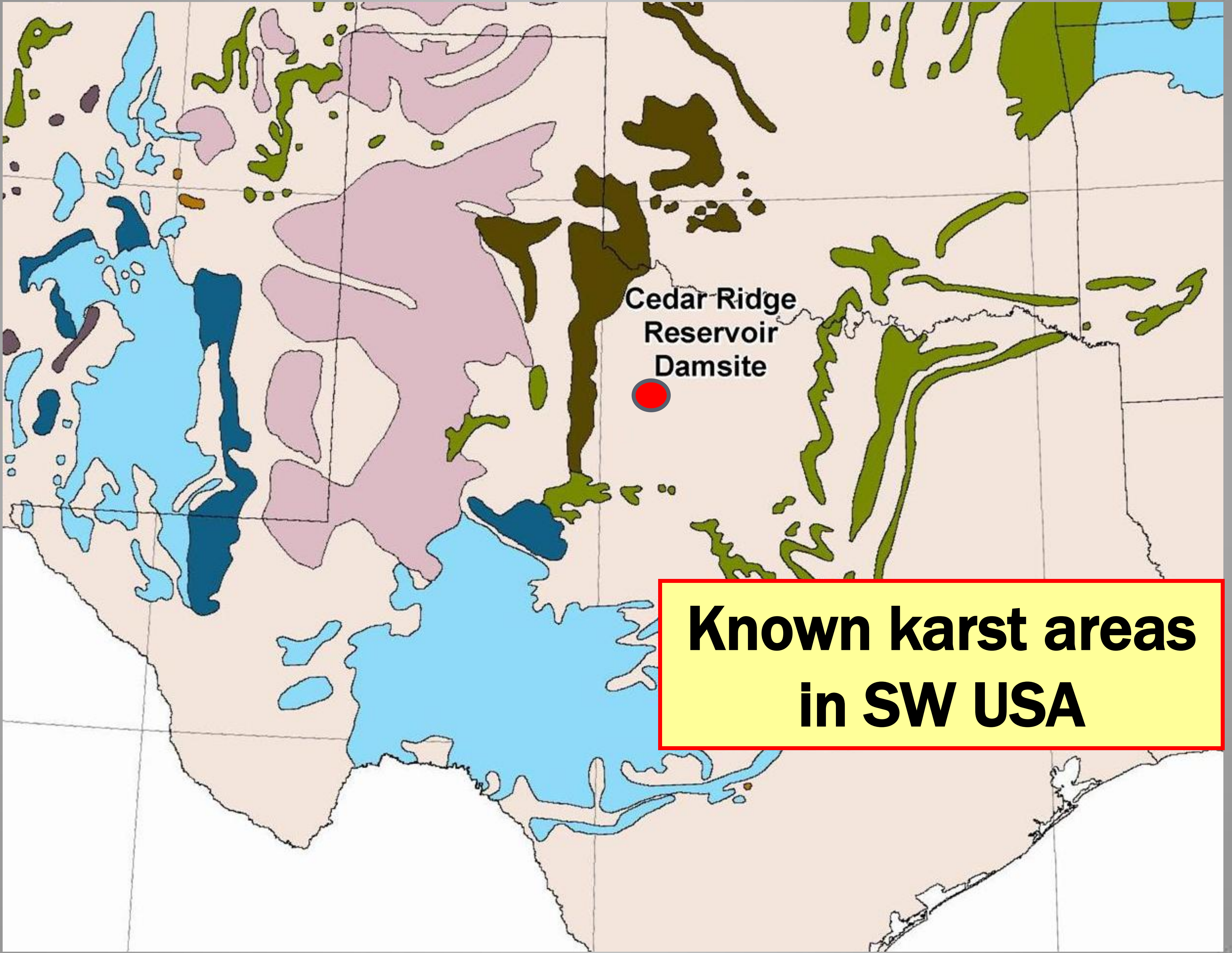
Requirements for Dissolution of Gypsum:

1. Deposit of gypsum against which, or through which, water can flow.

2. Water unsaturated with $CaSO_{4.}$

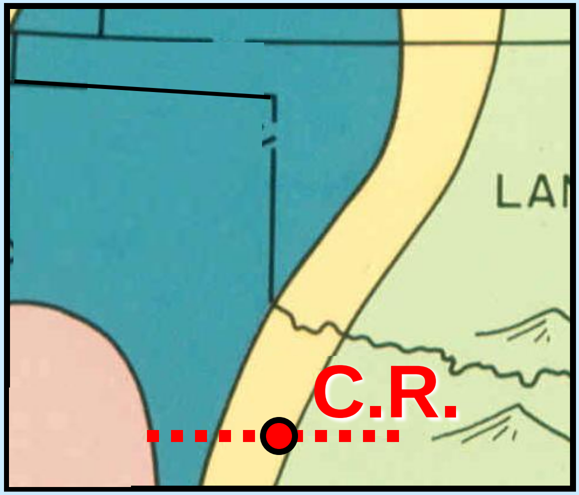
3. An outlet that allows resulting solution to escape.

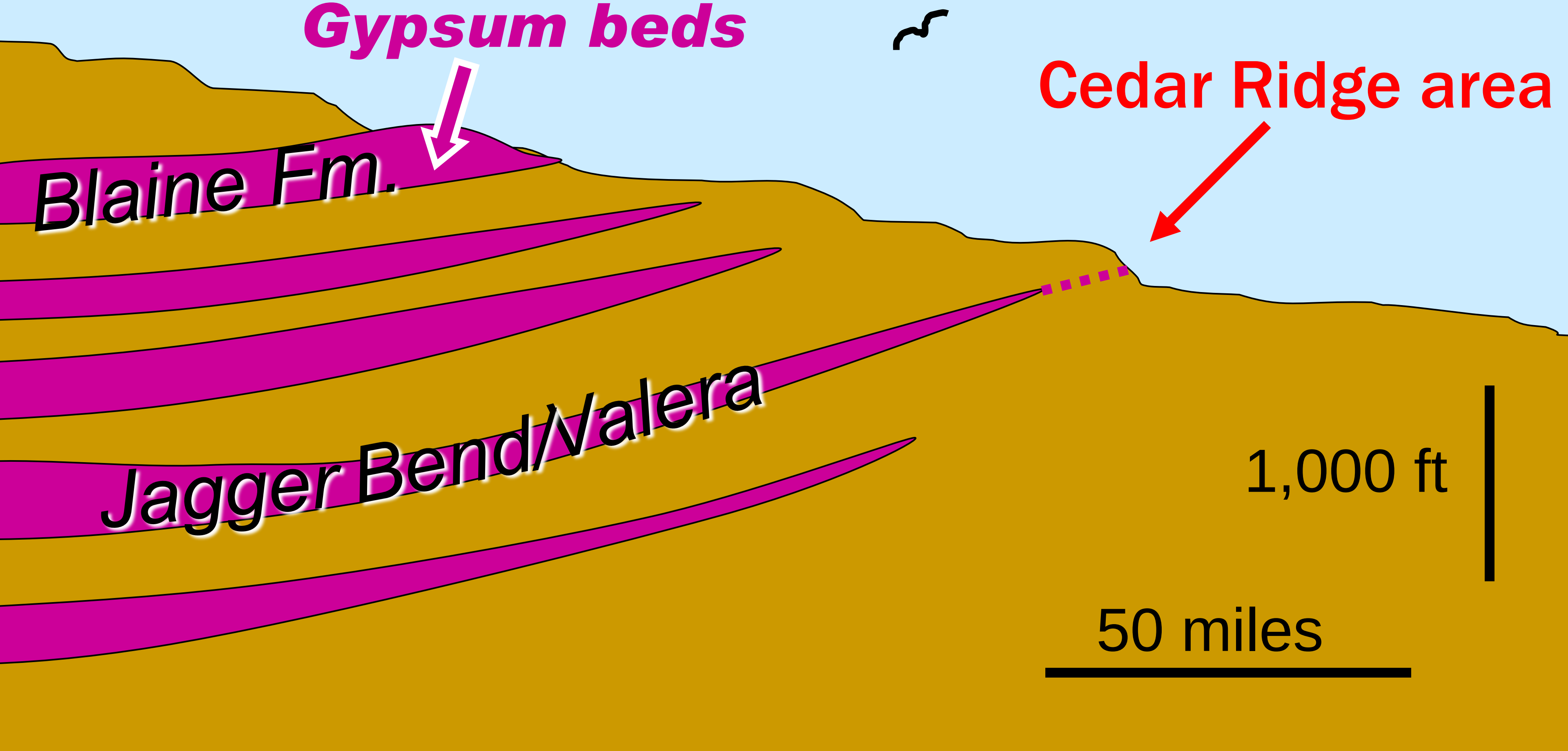
4. Energy, such as a hydrostatic head, that causes water to flow through the system.



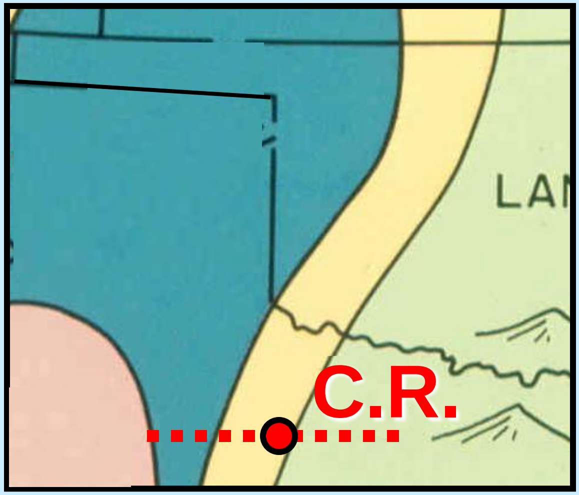
Known karst areas in SW USA

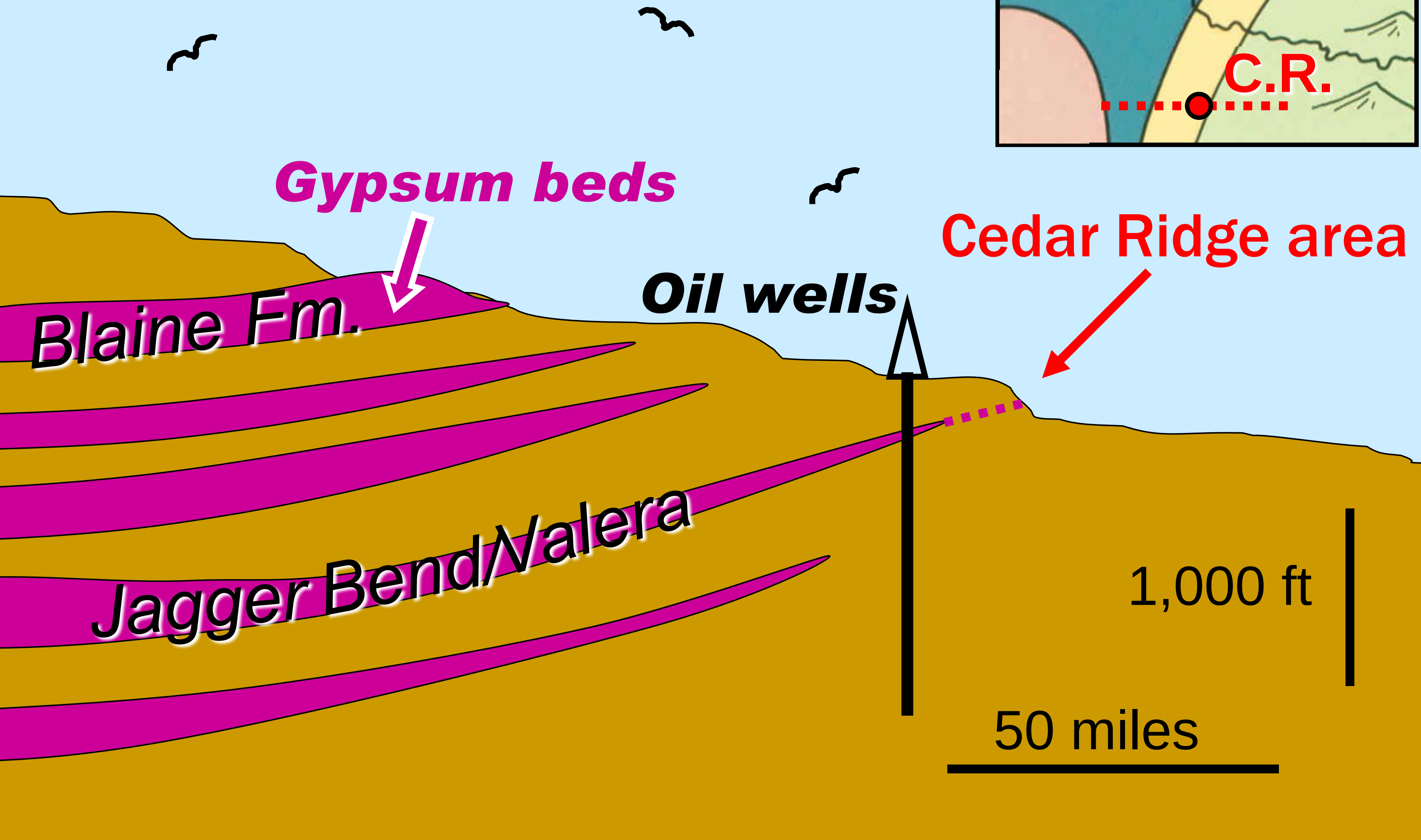
Generalized cross section through Cedar Ridge region



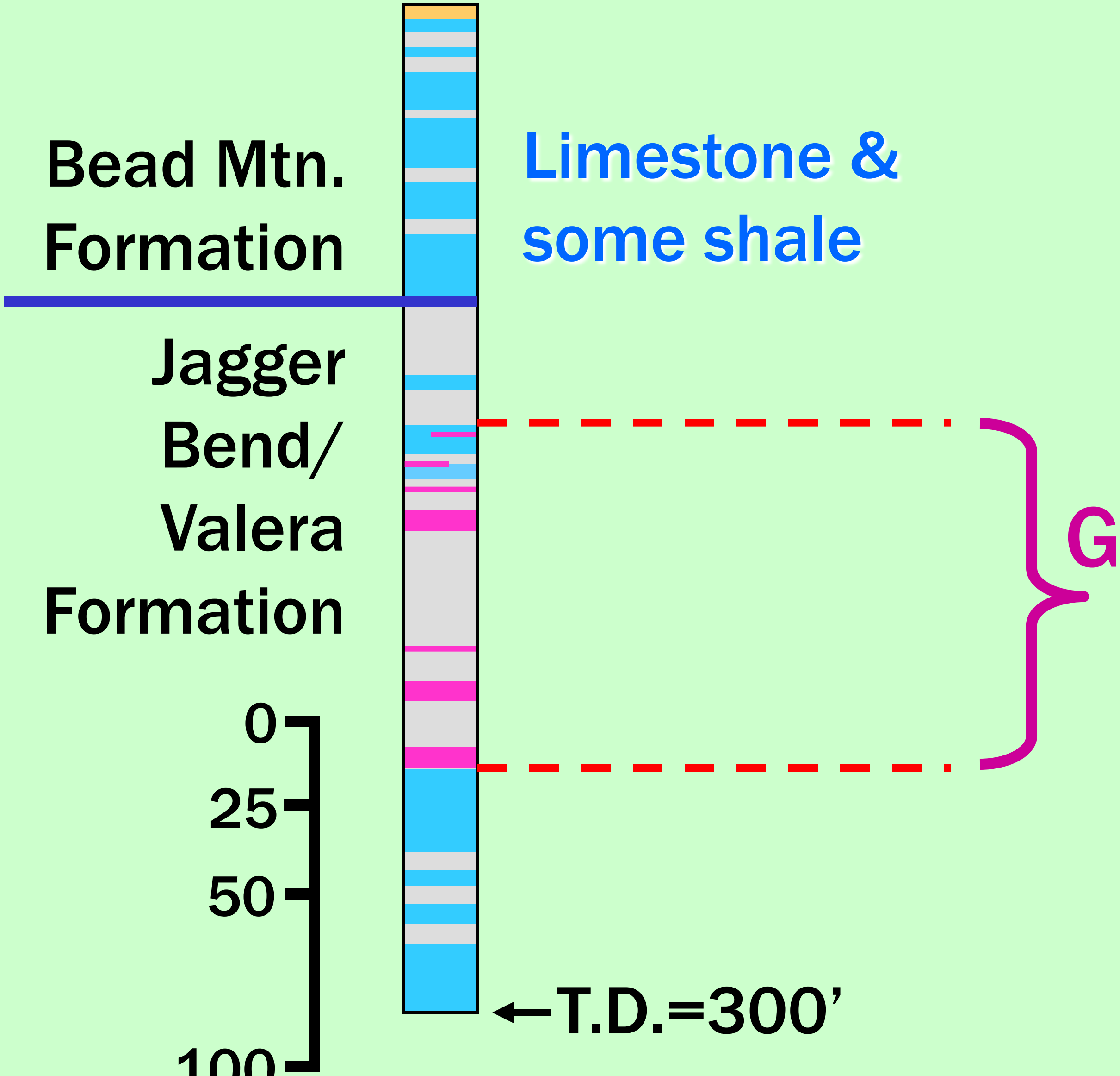


Generalized cross section through Cedar Ridge region





Core B-3 at CR



Bead Mtn.
Formation

Limestone &
some shale

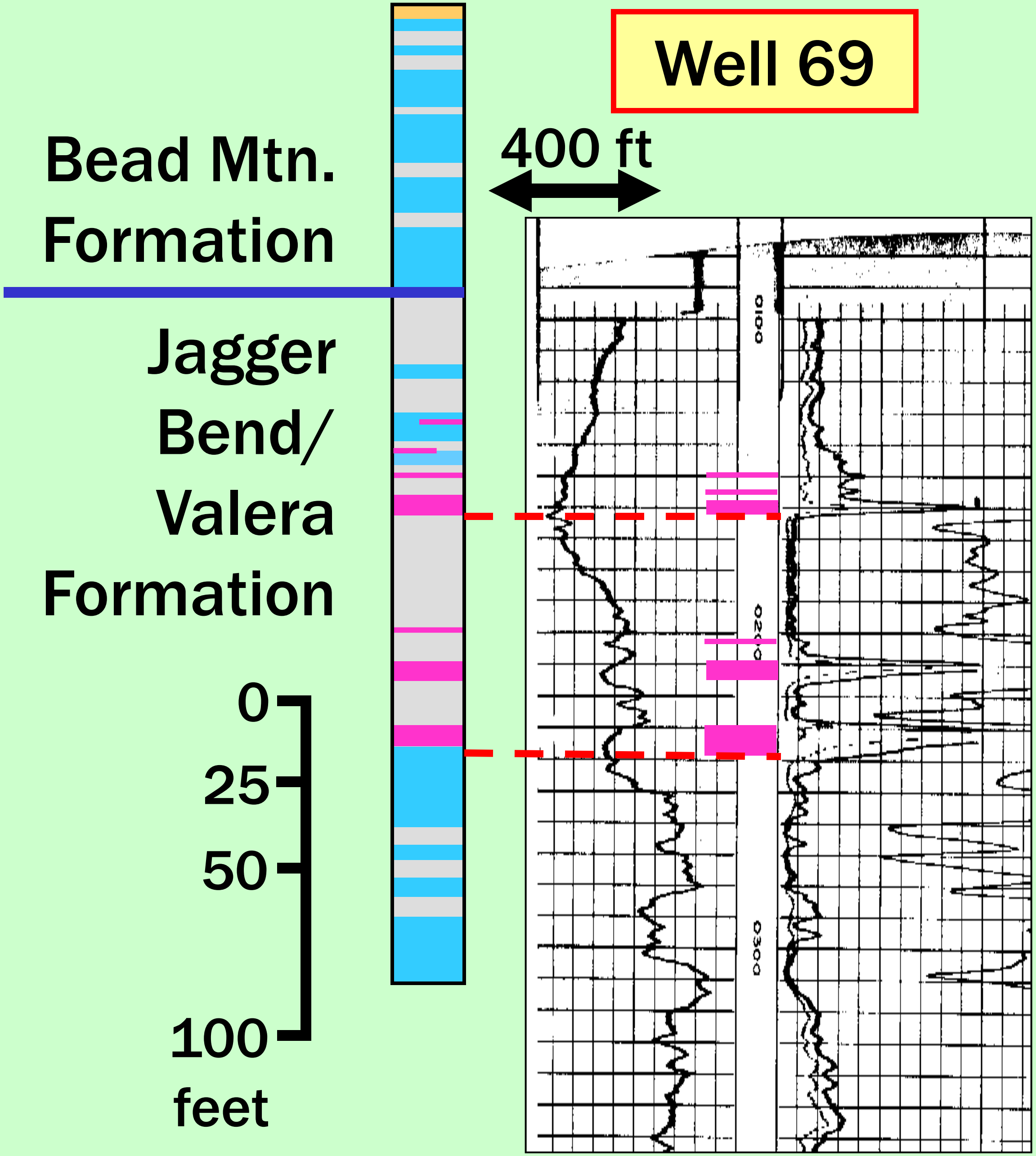
Jagger
Bend/
Valera
Formation

Gypsum
beds

←T.D.=300’

Core B-3 at CR

Well 69



Bead Mtn. Formation

Jagger Bend/ Valera Formation

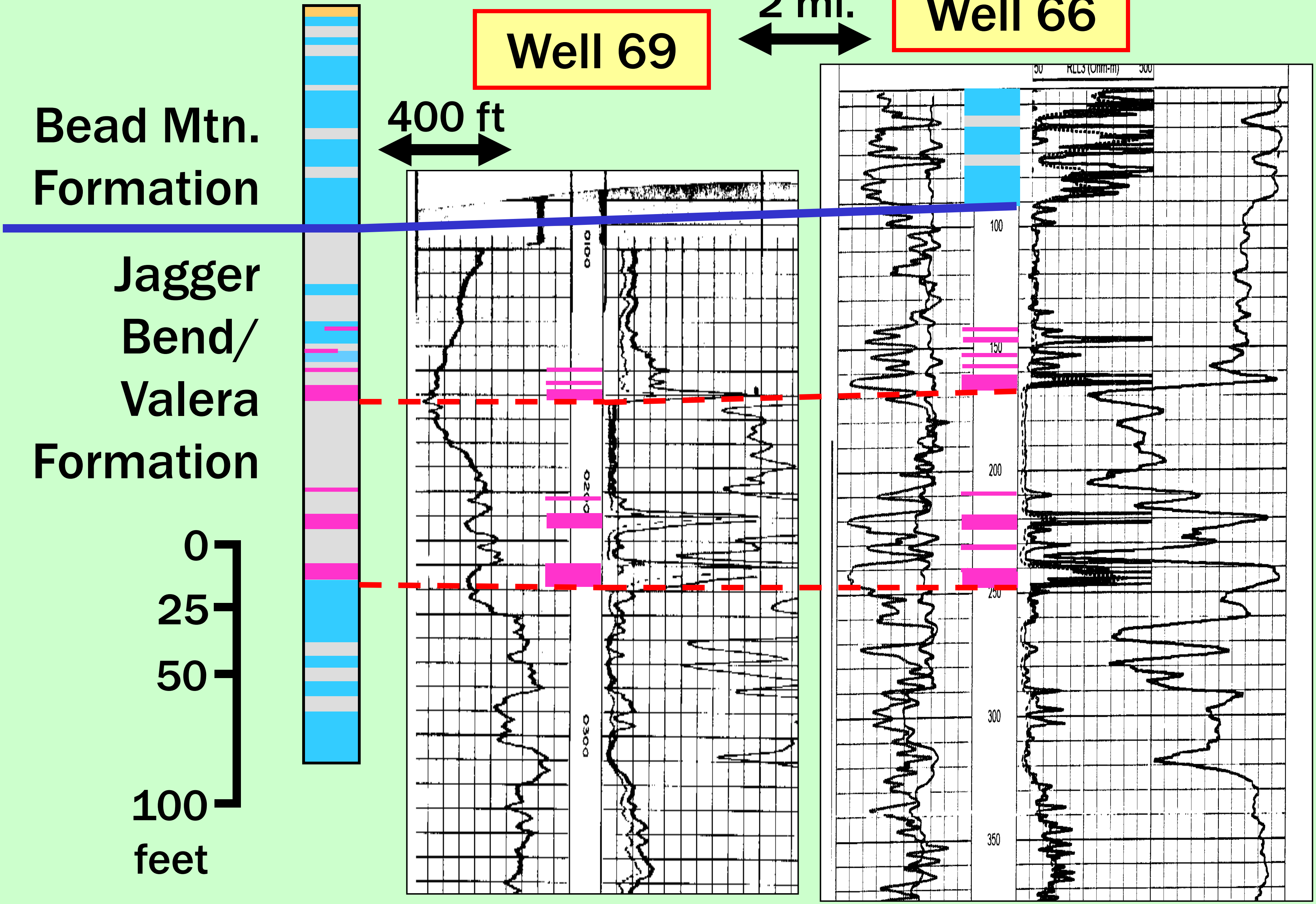
Core B-3 at CR

Well 69

Well 66

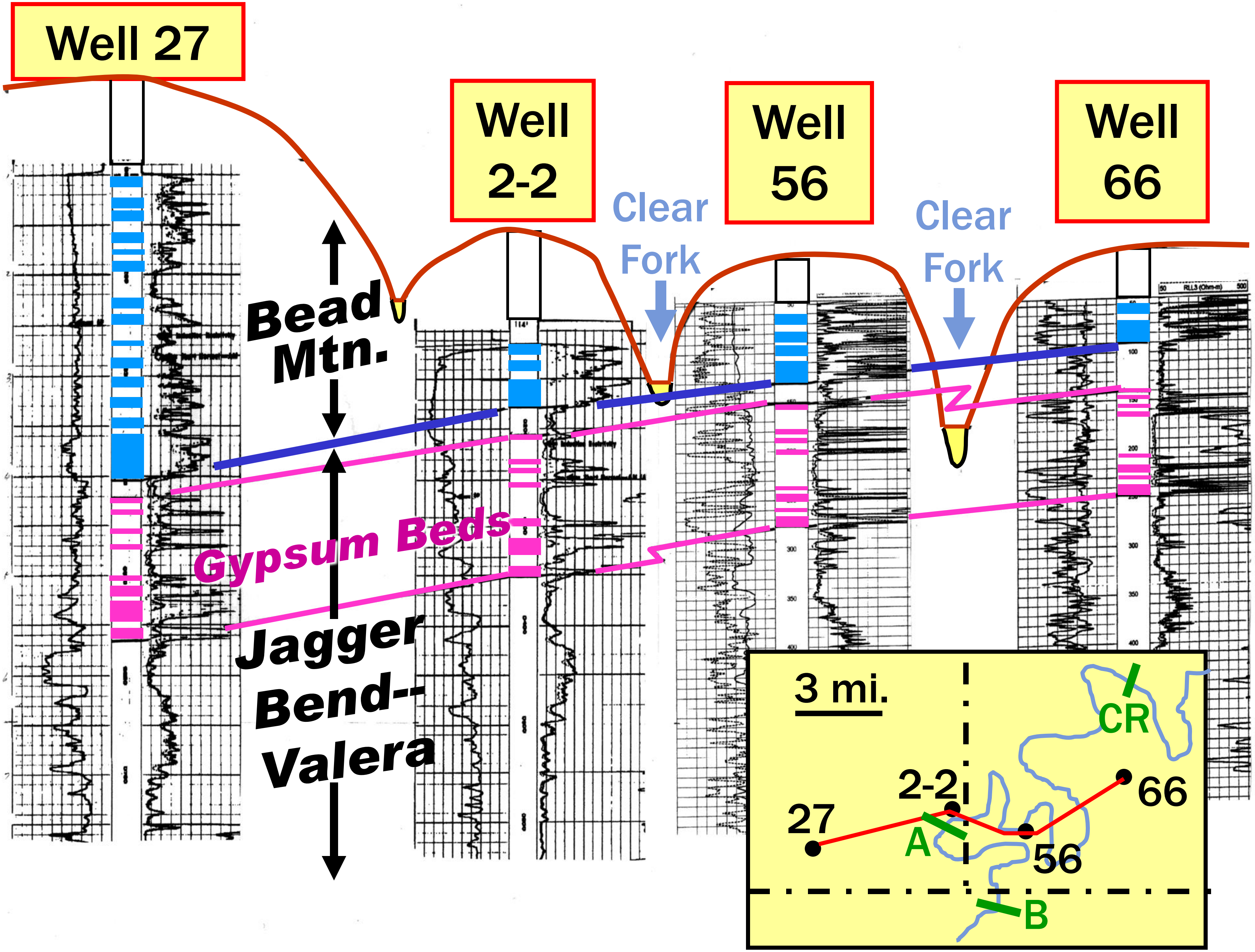
2 mi.

400 ft

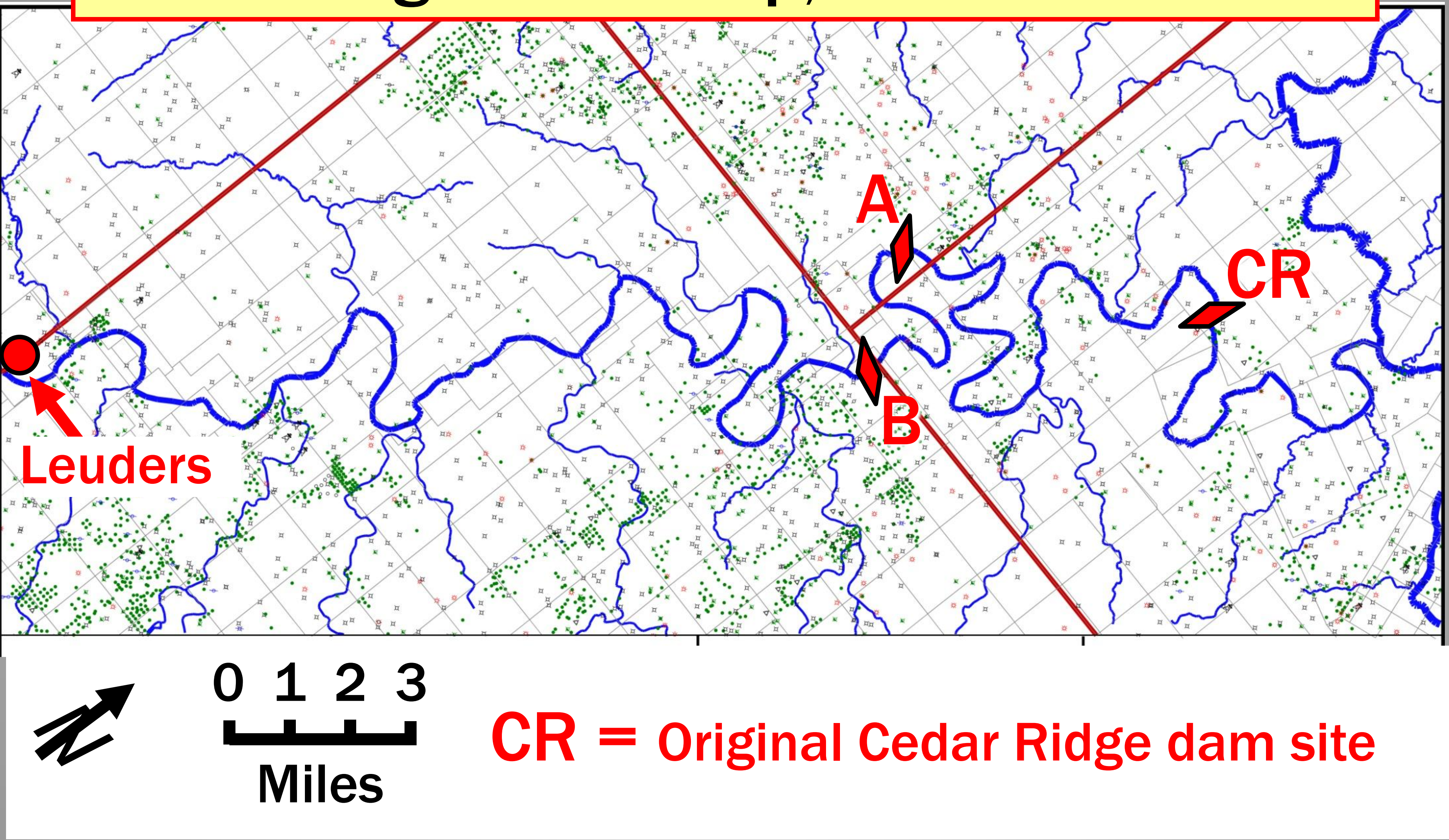


Bead Mtn. Formation

Jagger Bend/ Valera Formation


Well 27
Well 2-2
Clear Fork
Well 56
Clear Fork
Well 66
Bead Mtn.
Gypsum Beds
Jagger Bend--Valera
3 mi.
CR
2-2
27
66
A
56
B

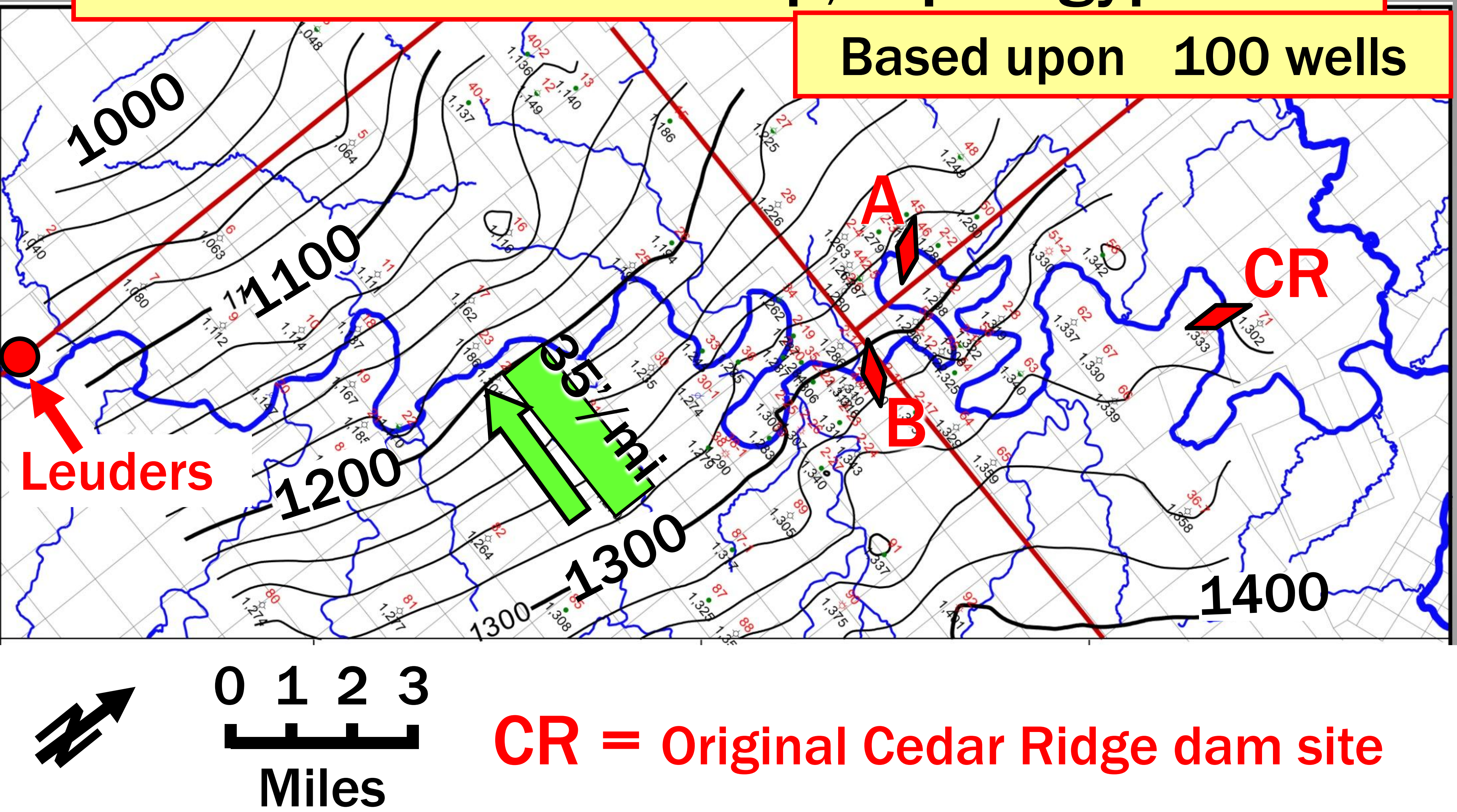
Oil- and gas-well map, Clear Fork area



CR = Original Cedar Ridge dam site

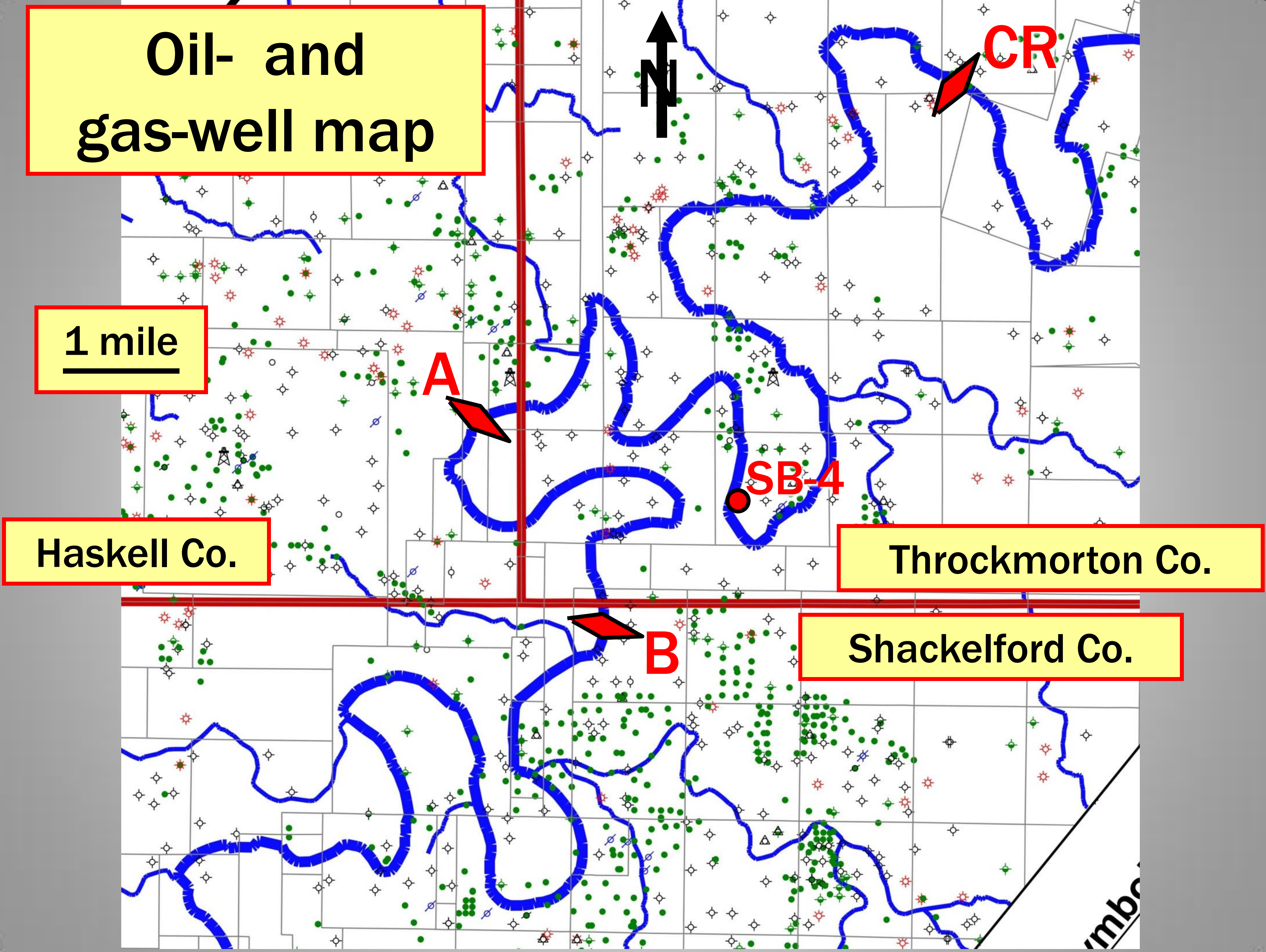
Structure-contour map, top of gypsums

Based upon 100 wells

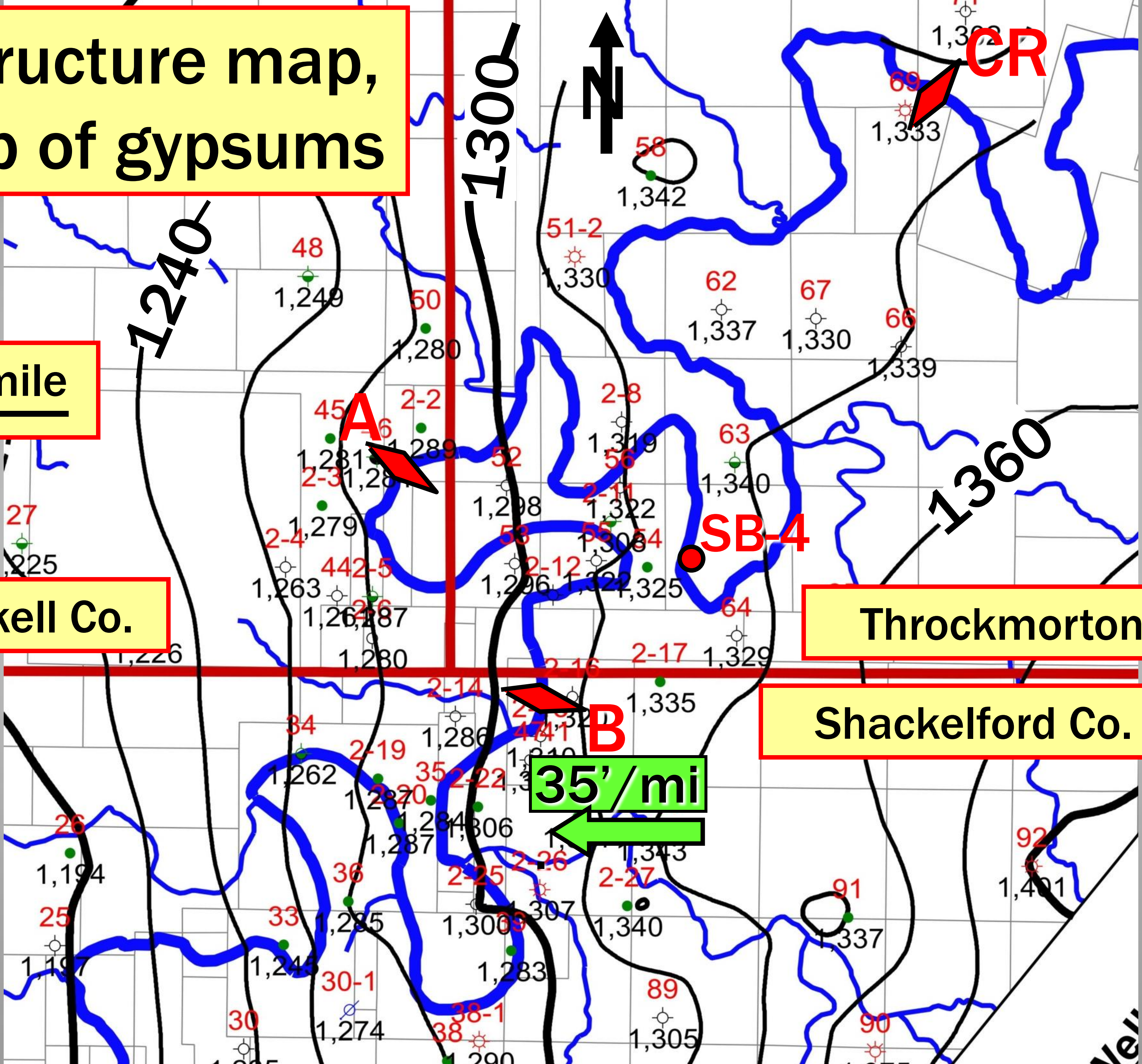


CR = Original Cedar Ridge dam site

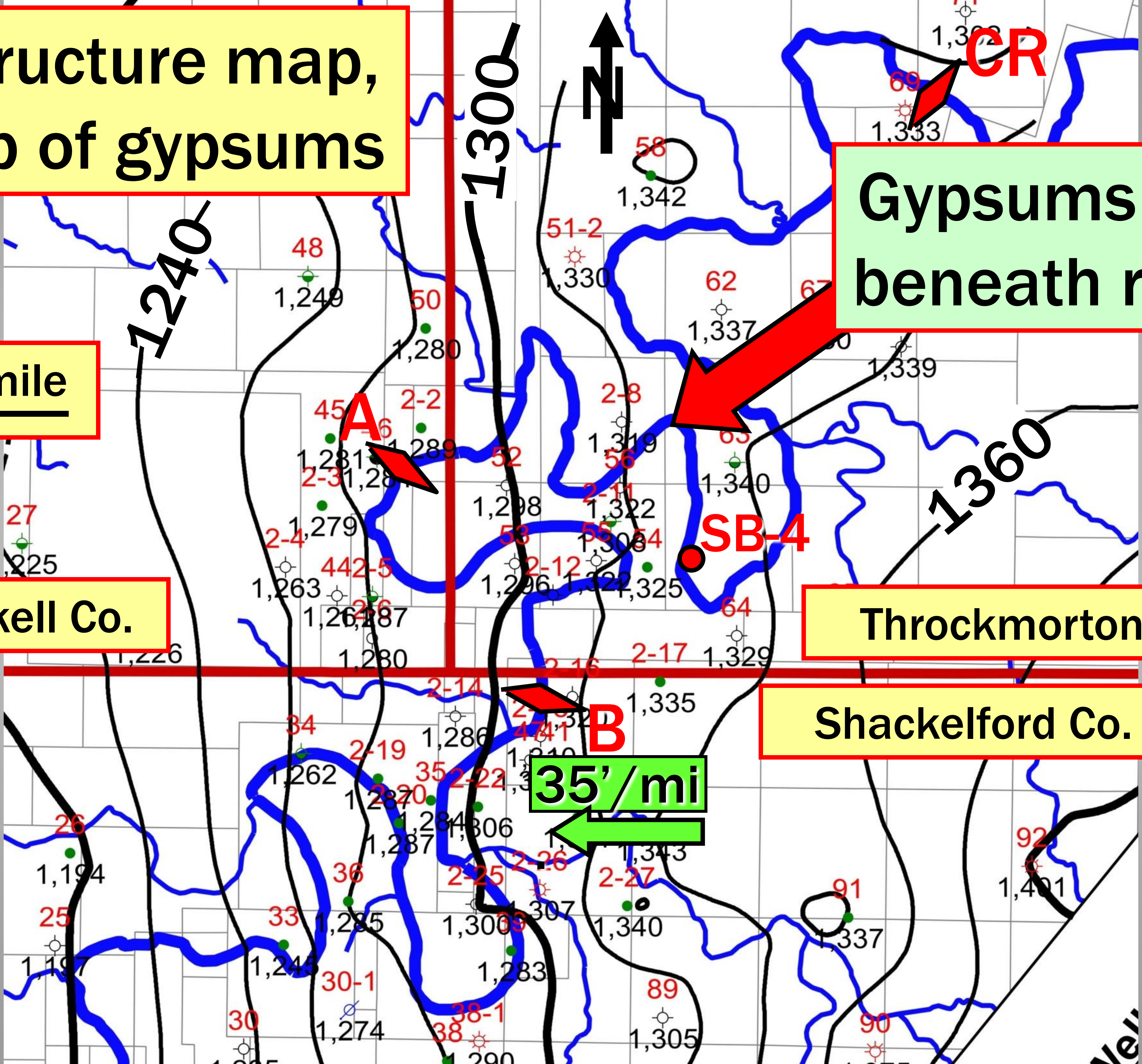
Oil- and gas-well map



Structure map, top of gypsums



Structure map, top of gypsums



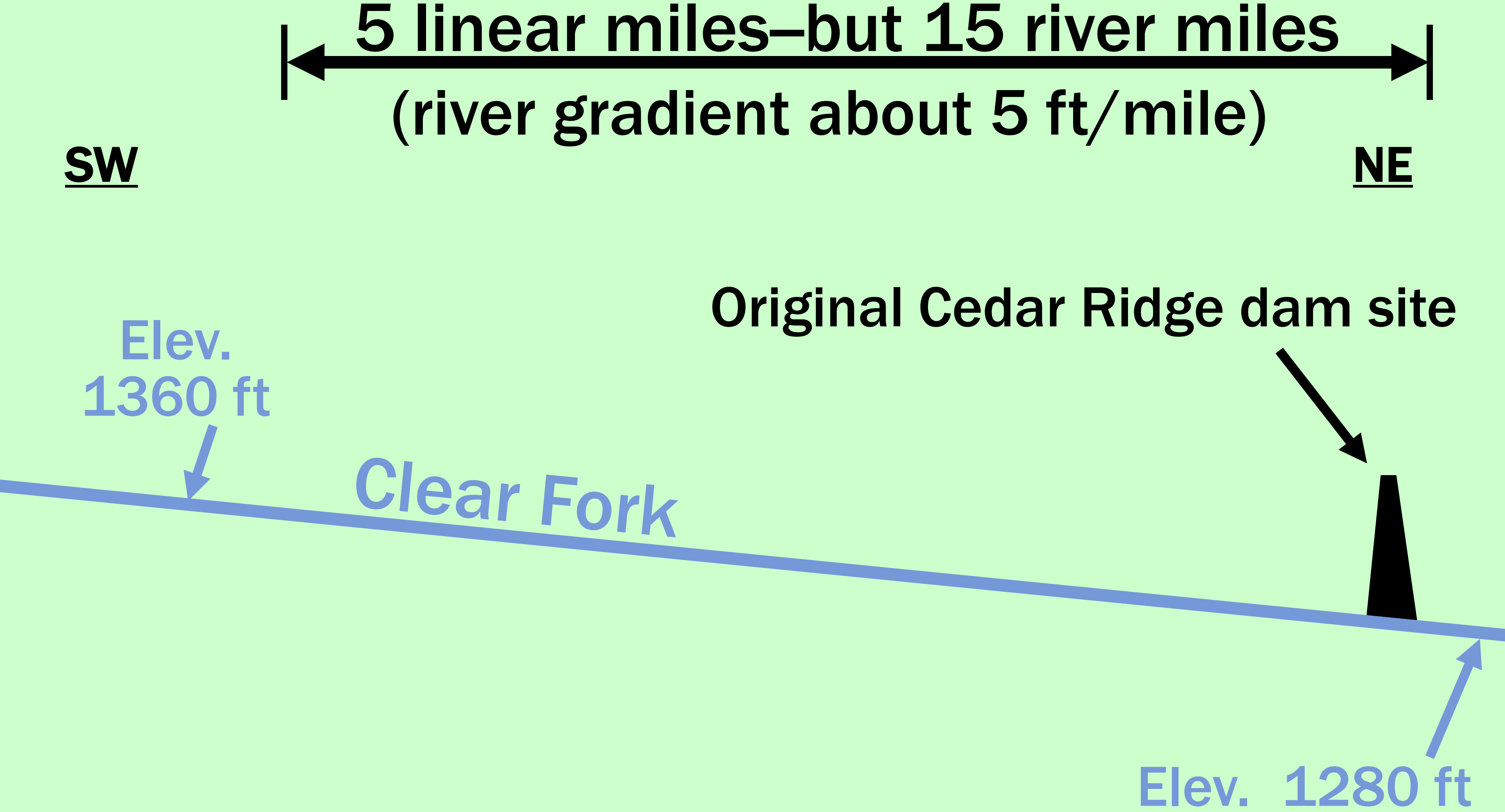
Gypsums dip beneath river

1 mile

Haskell Co.

Throckmorton Co.

Shackelford Co.



5 linear miles–but 15 river miles

(river gradient about 5 ft/mile)

SW

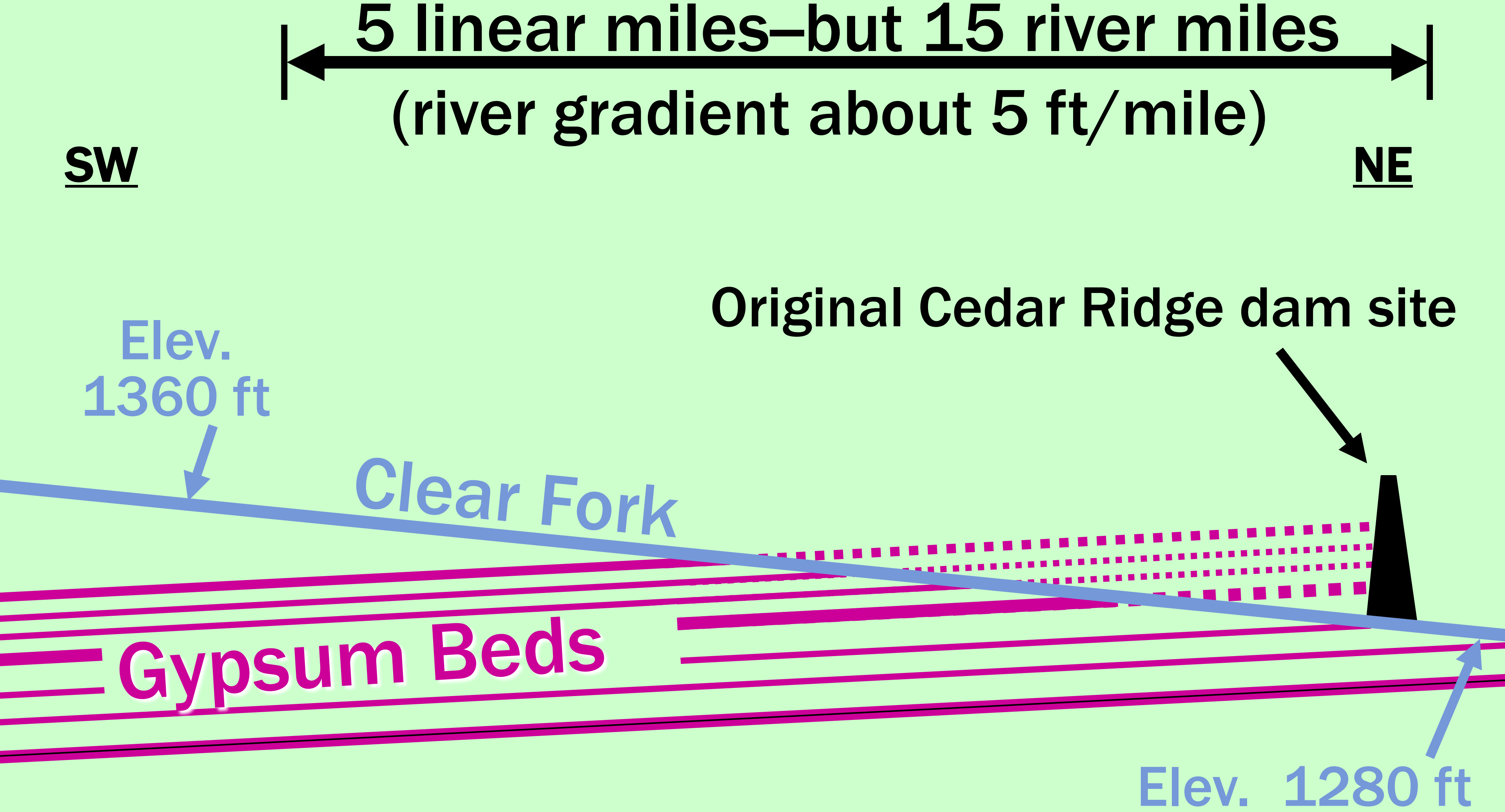
NE

Original Cedar Ridge dam site

Elev. 1360 ft

Clear Fork

Elev. 1280 ft



5 linear miles—but 15 river miles

(river gradient about 5 ft/mile)

SW

NE

Original Cedar Ridge dam site

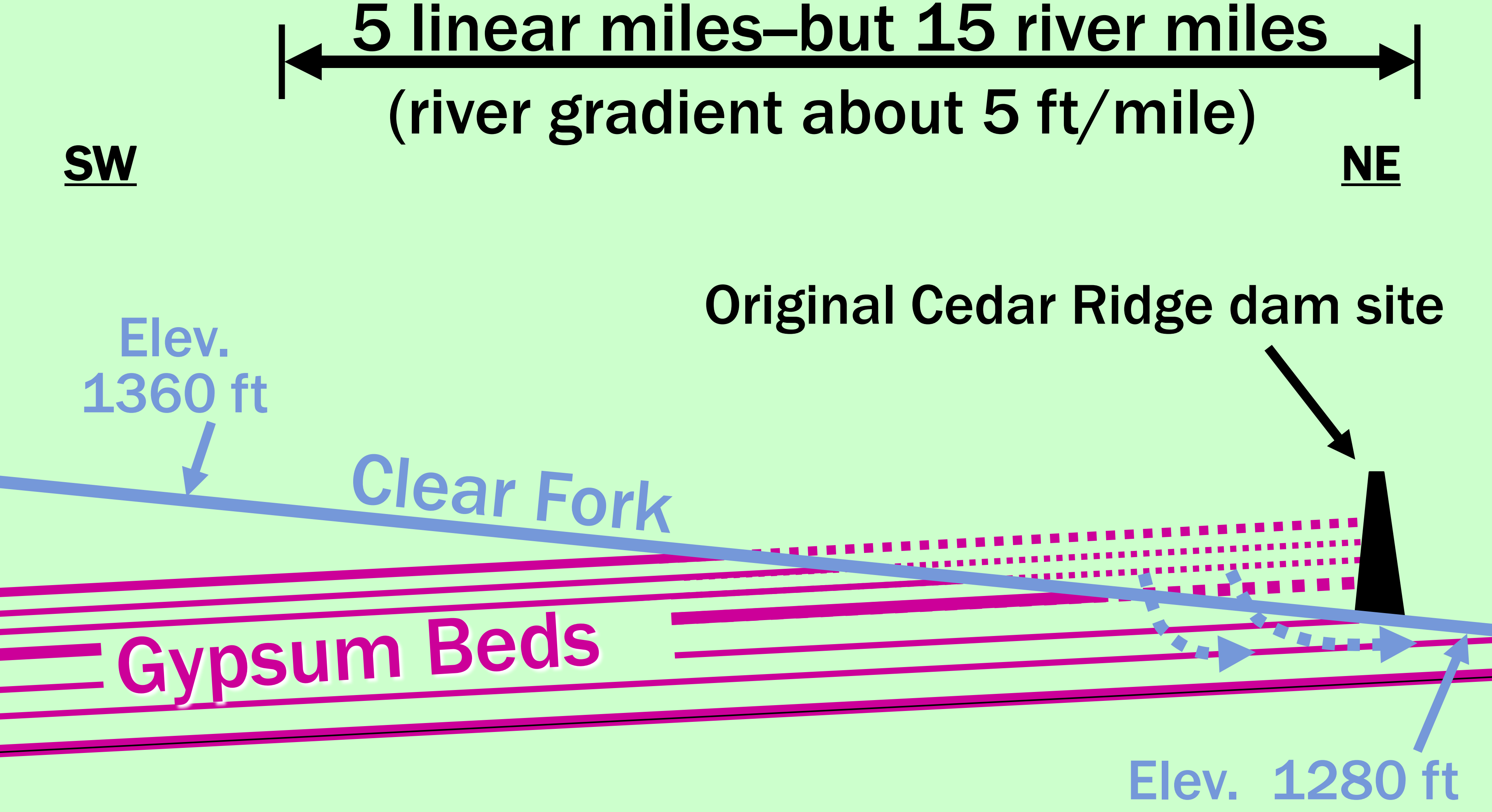
Elev. 1360 ft

Clear Fork

Gypsum Beds

Elev. 1280 ft

(Gypsum beds dip to the West at 35 ft/mile)



5 linear miles–but 15 river miles

(river gradient about 5 ft/mile)

SW

NE

Original Cedar Ridge dam site

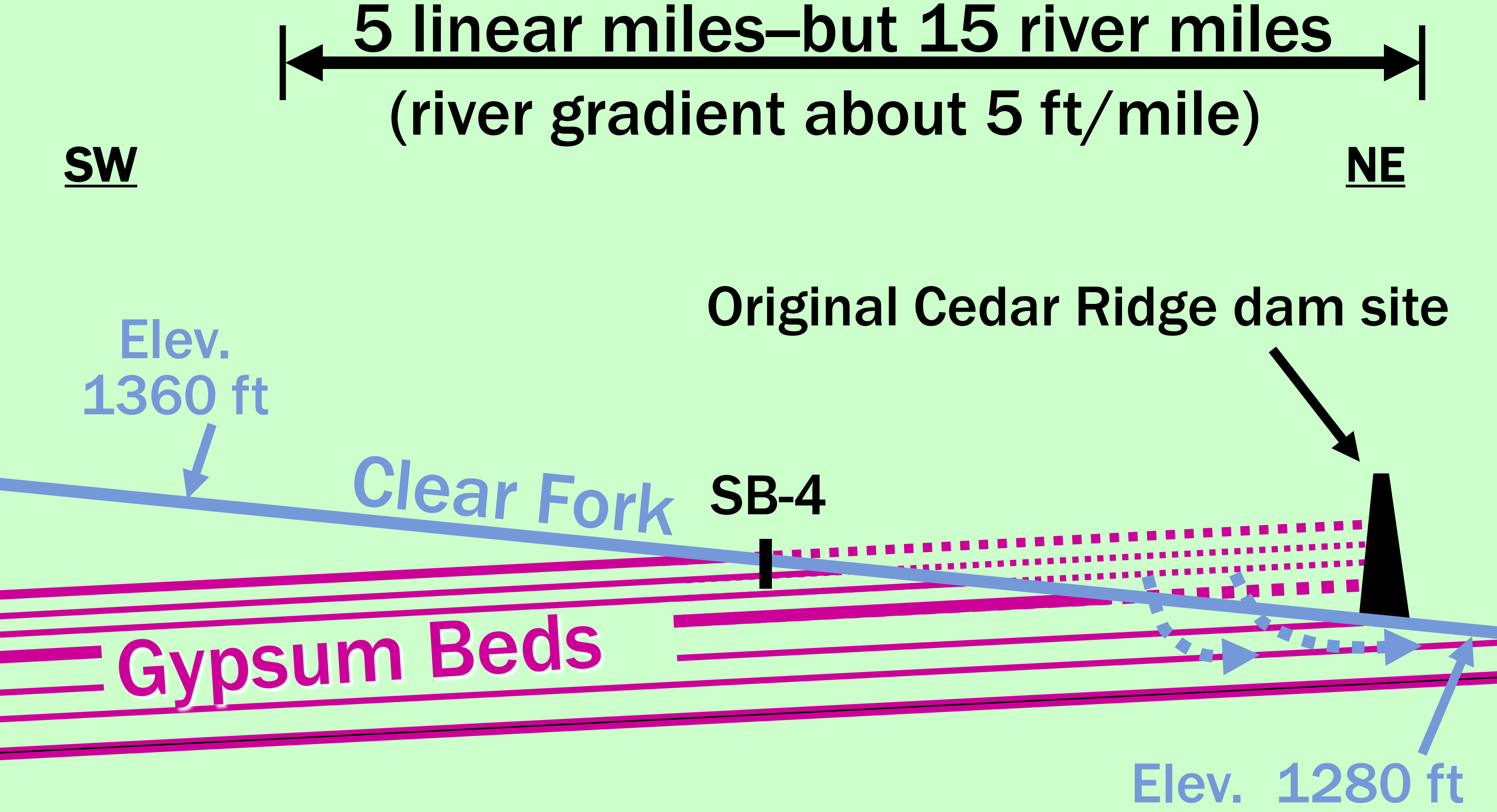
Elev. 1360 ft

Clear Fork

Gypsum Beds

Elev. 1280 ft

(Gypsum beds dip to the West at 35 ft/mile)



5 linear miles–but 15 river miles

(river gradient about 5 ft/mile)

SW

NE

Original Cedar Ridge dam site

Elev. 1360 ft

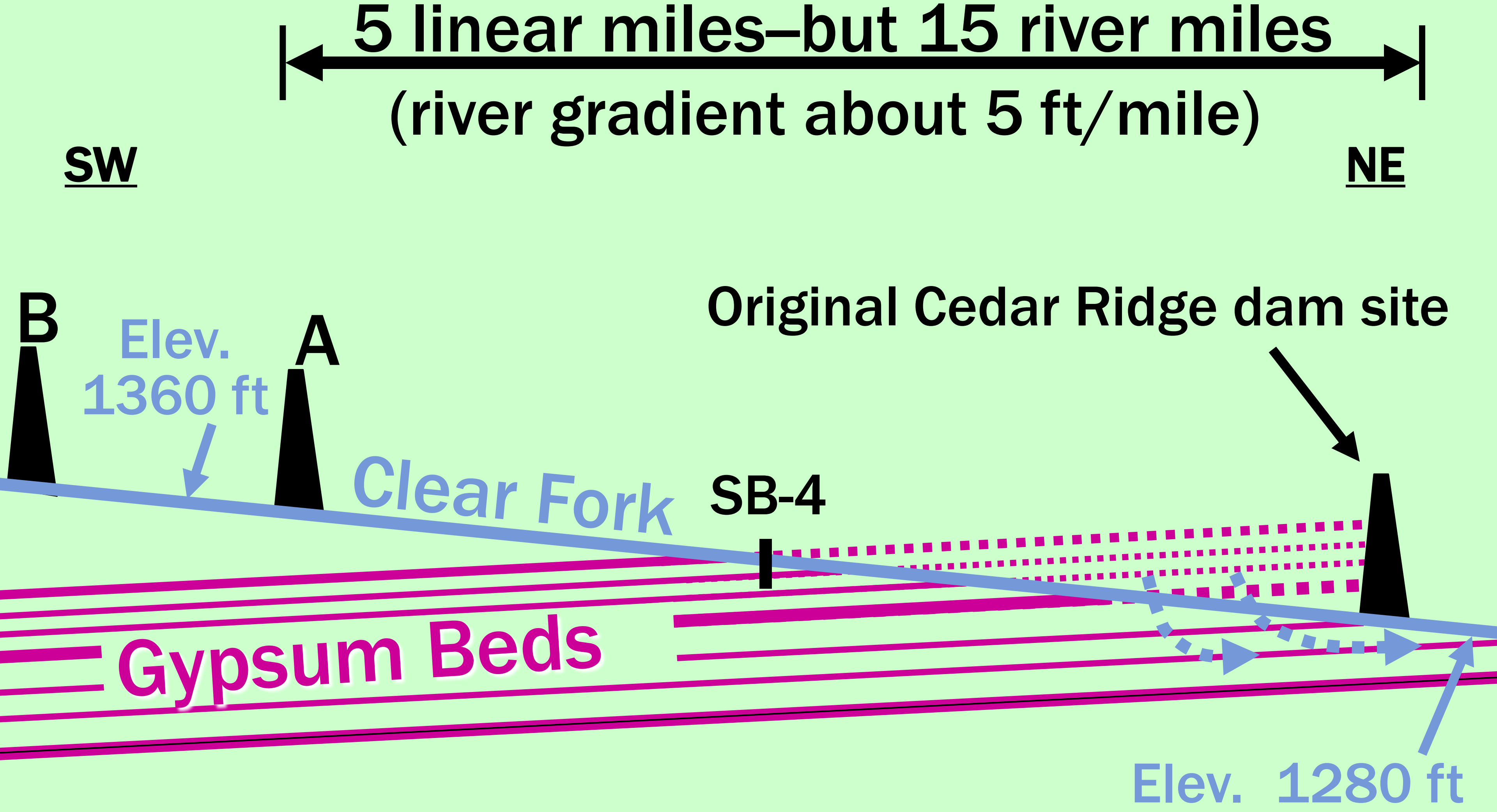
Clear Fork

SB-4

Gypsum Beds

Elev. 1280 ft

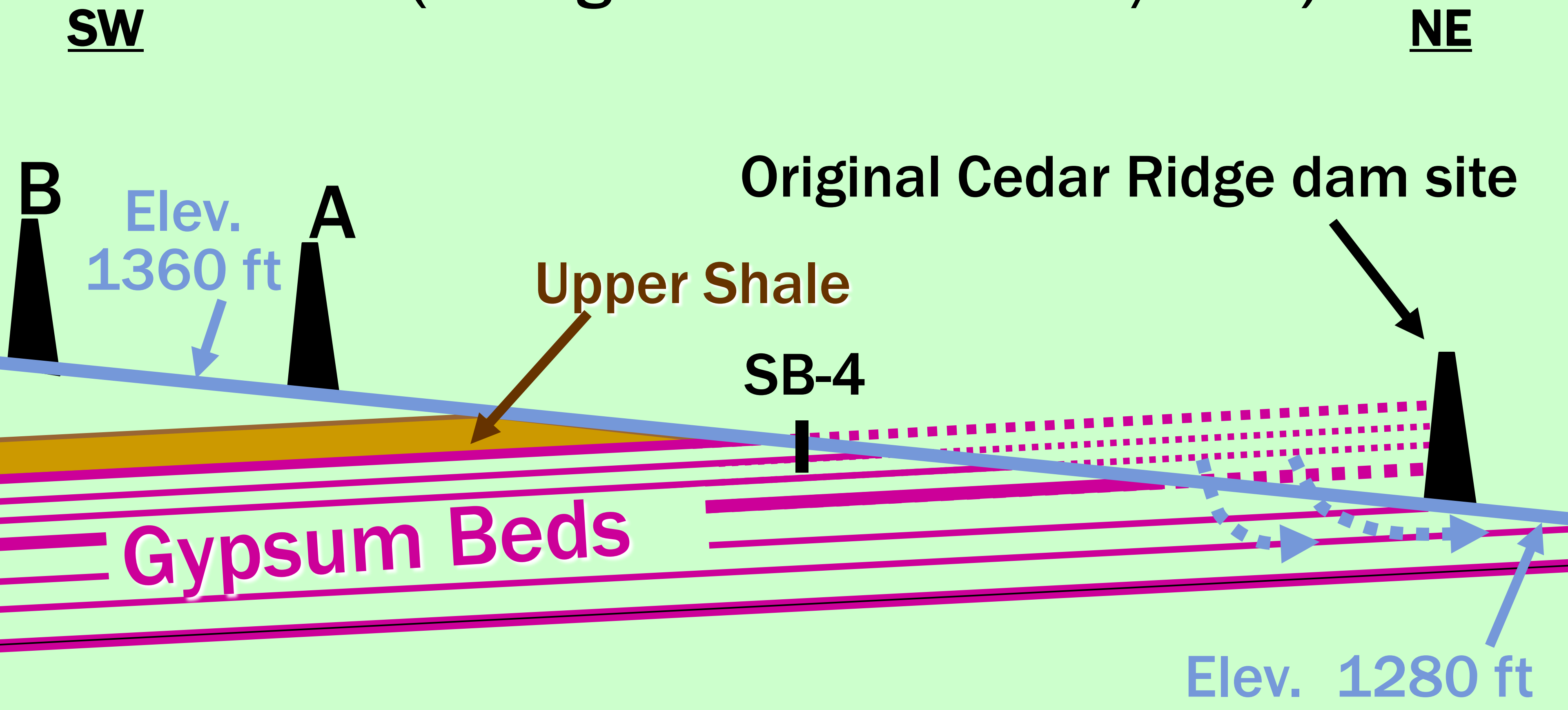
(Gypsum beds dip to the West at 35 ft/mile)



(Gypsum beds dip to the West at 35 ft/mile)

5 linear miles–but 15 river miles

(river gradient about 5 ft/mile)



(Gypsum beds dip to the West at 35 ft/mile)

Summary

Gypsum is soluble and typically contains cavities, sinkholes, and caves ("karst").

Dams built upon gypsum karst generally are not able to retain water.

Although not mentioned in the geologic literature, gypsum was discovered at original CR dam site.

Gypsum is present in the Clear Fork Valley from the original CR dam site upstream to borehole SB-4.

Best location for dam is upstream from SB-4.

Two alternative dam sites were considered.

Site A – top of gypsum is within 20 feet of bottom of reservoir – two narrow ridges are additional concern for seepage

Site B – top of gypsum is more than 50 ft below reservoir bottom – no narrow ridges at site B

ITEM #5

CEDAR RIDGE RESERVOIR

NEW DAM SITE

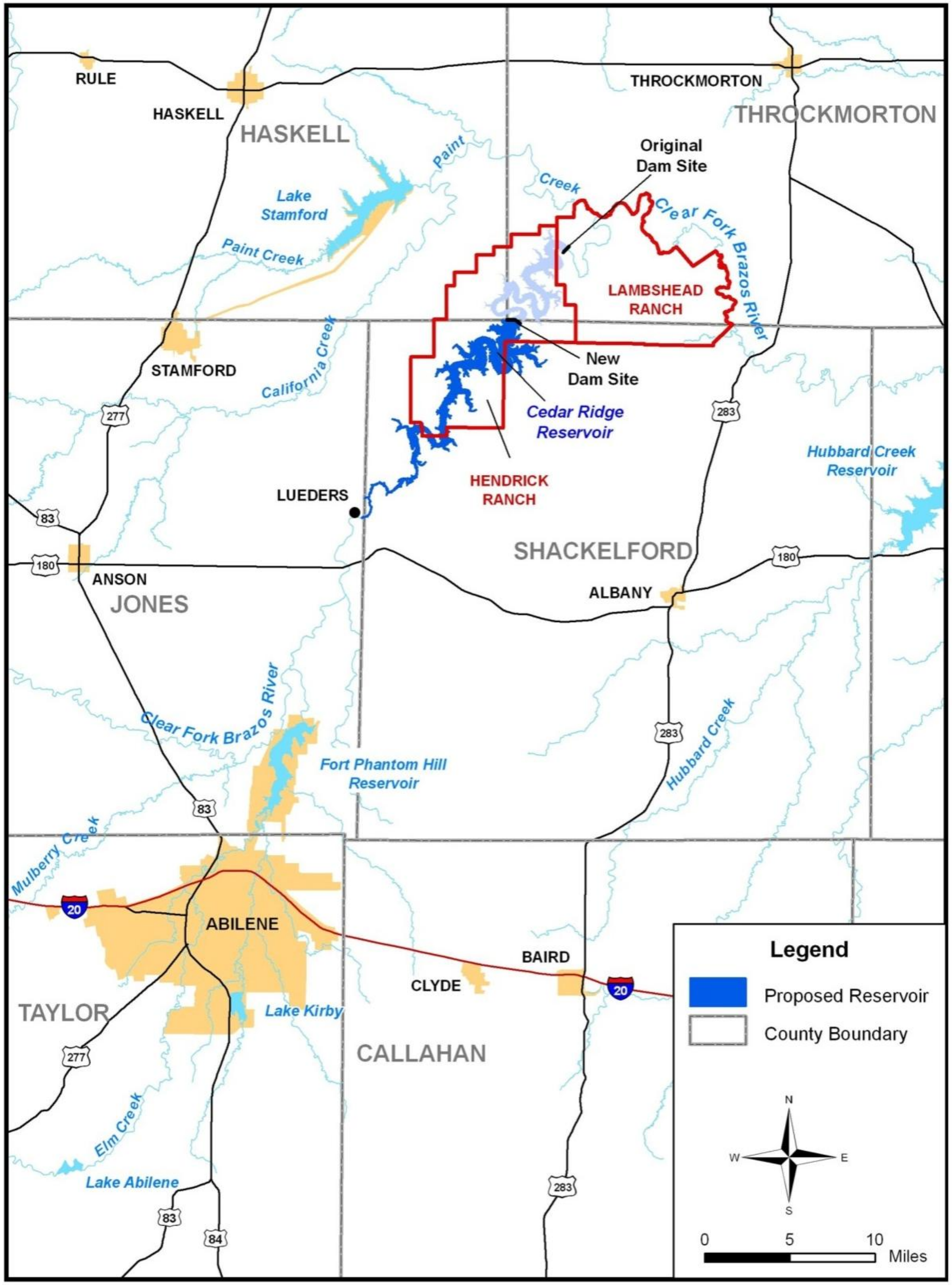
GEOTECHNICAL ADVISORY GROUP

June, 2009:	Alternative dam site selected
July, 2009:	Field core drilling and geotechnical investigation of alternative dam site
September 4, 2009:	Fugro Consultants, Inc. issues report, “Regional Geologic Study – Cedar Ridge Reservoir Alternative Dam Sites, Haskell, Shackelford and Throckmorton Counties”
November 6, 2009:	Fugro Consultants, Inc. issues report, “Preliminary Geotechnical Investigation – Cedar Ridge Reservoir Alternative Dam Site, Throckmorton County, Texas”

- **“...the alternative dam site under consideration is suitable for the planned project.”**

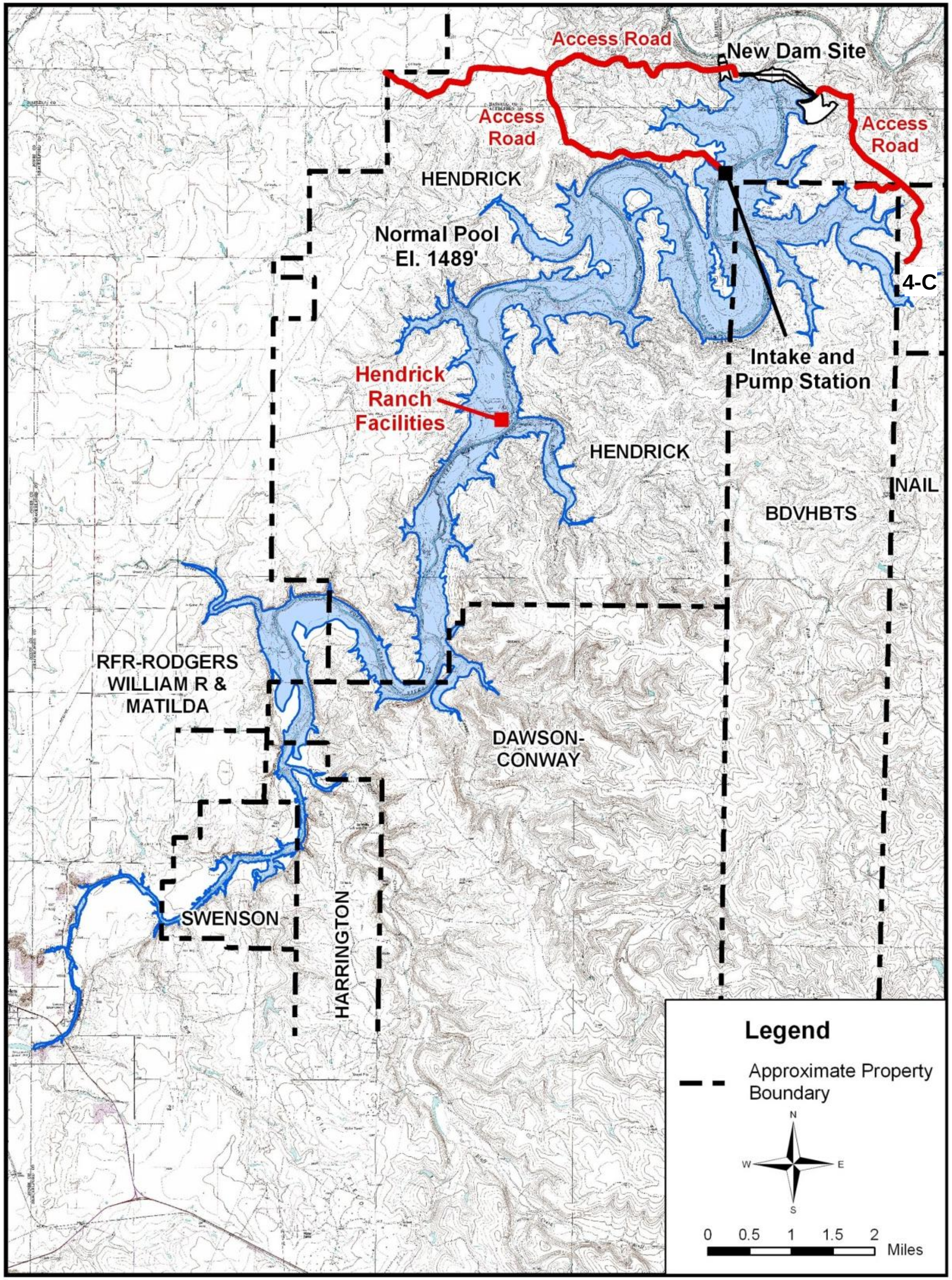
CEDAR RIDGE RESERVOIR

(NEW DAM SITE)



CEDAR RIDGE RESERVOIR

(NEW DAM SITE)



UPDATED SIZE
OF CEDAR RIDGE RESERVOIR

	Conservation Pool Elevation (ft-msl)	Surface Area (acres)	Capacity (ac-ft)	Average Depth (ft)
Original Dam Site	1,430	6,190	310,383	50
New Dam Site	1,489	6,635	227,127	34

- Conservation Pool Elevation at new dam site based on not significantly increasing flood levels in the Lueders area.

UPDATED YIELDS
FOR CEDAR RIDGE RESERVOIR

Yield Scenario	Estimated 2060 Yield (ac-ft / yr)		% Reduction
	Original Dam Site	New Dam Site	
Firm	35,660	28,680	20%
1-Year	31,660	24,480	23%
2-Year	28,877	21,520	25%

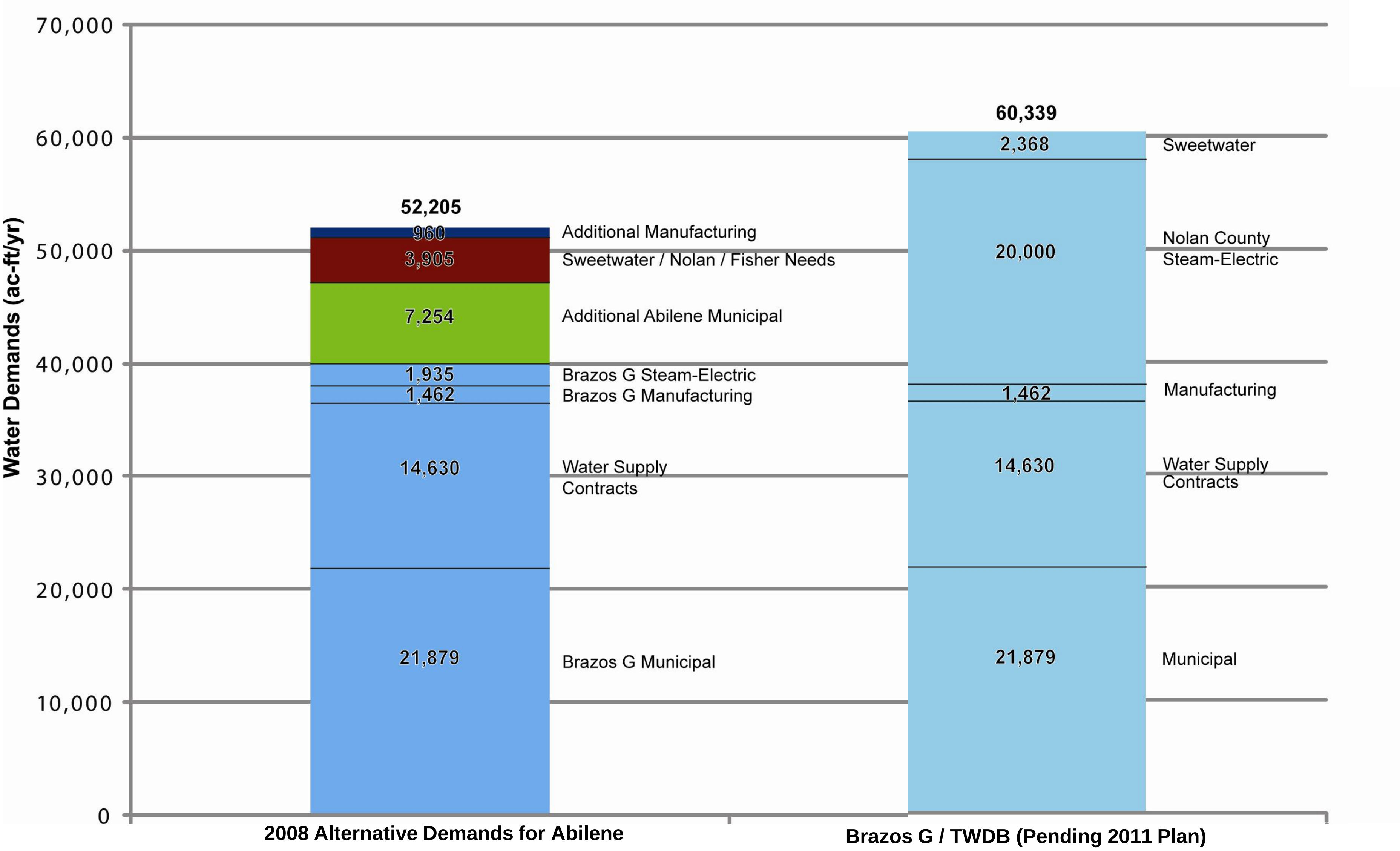
- ➢ Abilene return flows are not included in the yields presented.

CITY OF ABILENE

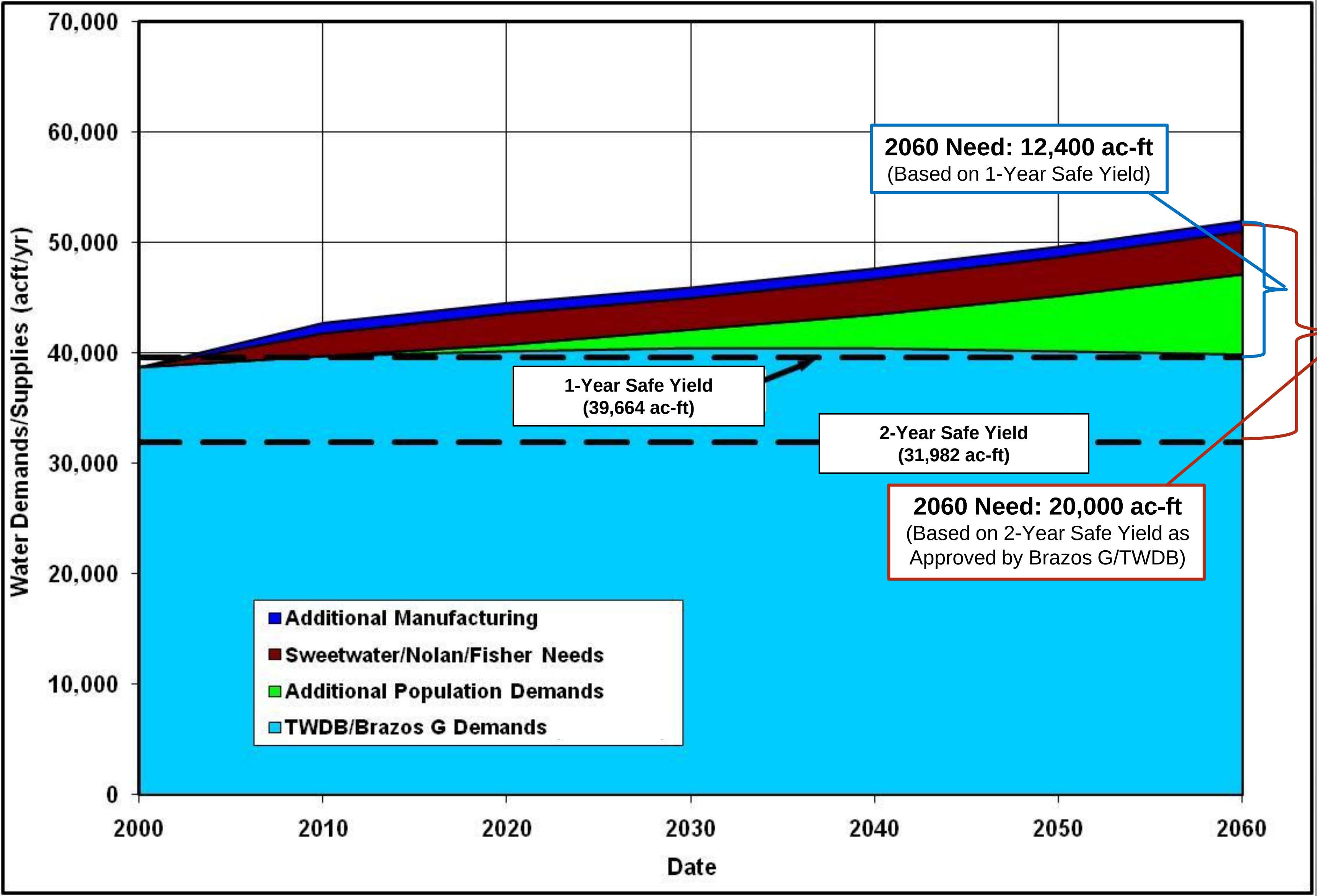
ITEM #6

UPDATED NEED FOR FUTURE WATER SUPPLY

WATER DEMANDS – 2060



UPDATED NEED FOR FUTURE WATER SUPPLY



2060 Need: 12,400 ac-ft
(Based on 1-Year Safe Yield)

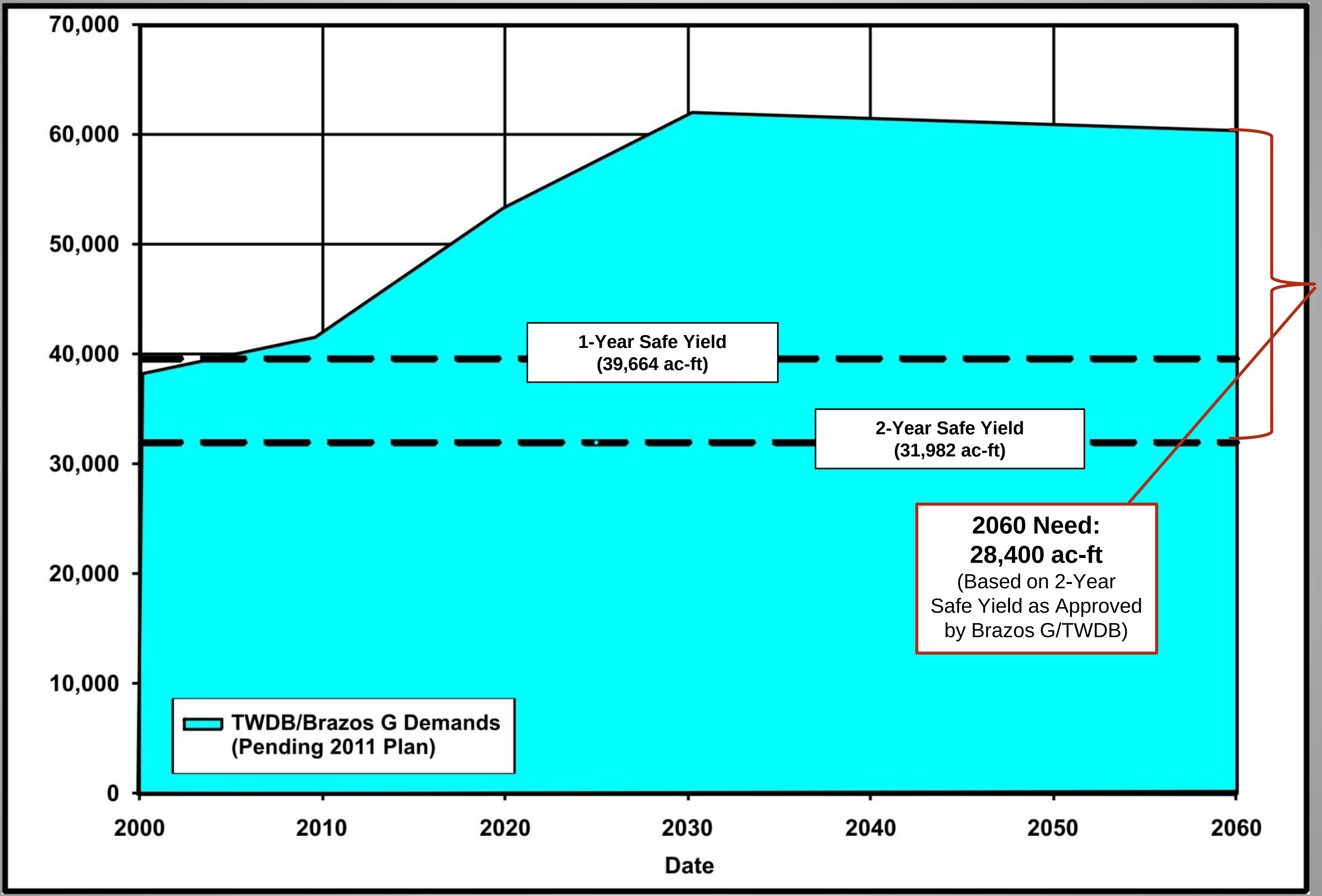
1-Year Safe Yield
(39,664 ac-ft)

2-Year Safe Yield
(31,982 ac-ft)

2060 Need: 20,000 ac-ft
(Based on 2-Year Safe Yield as Approved by Brazos G/TWDB)

Water Demands based on 2008 Alternative Water Demand Projections (2060 – 52,025 ac-ft)
Water Supplies: Fort Phantom Hill; Hubbard Creek Reservoir; Ivie/Hargesheimer WTP (2060 Conditions)

UPDATED NEED FOR FUTURE WATER SUPPLY



Water Demands based on Pending Region G 2011 Plan (2060 – 60,339 ac-ft)
Water Supplies: Fort Phantom Hill; Hubbard Creek Reservoir; Ivie/Hargesheimer WTP (2060 Conditions)

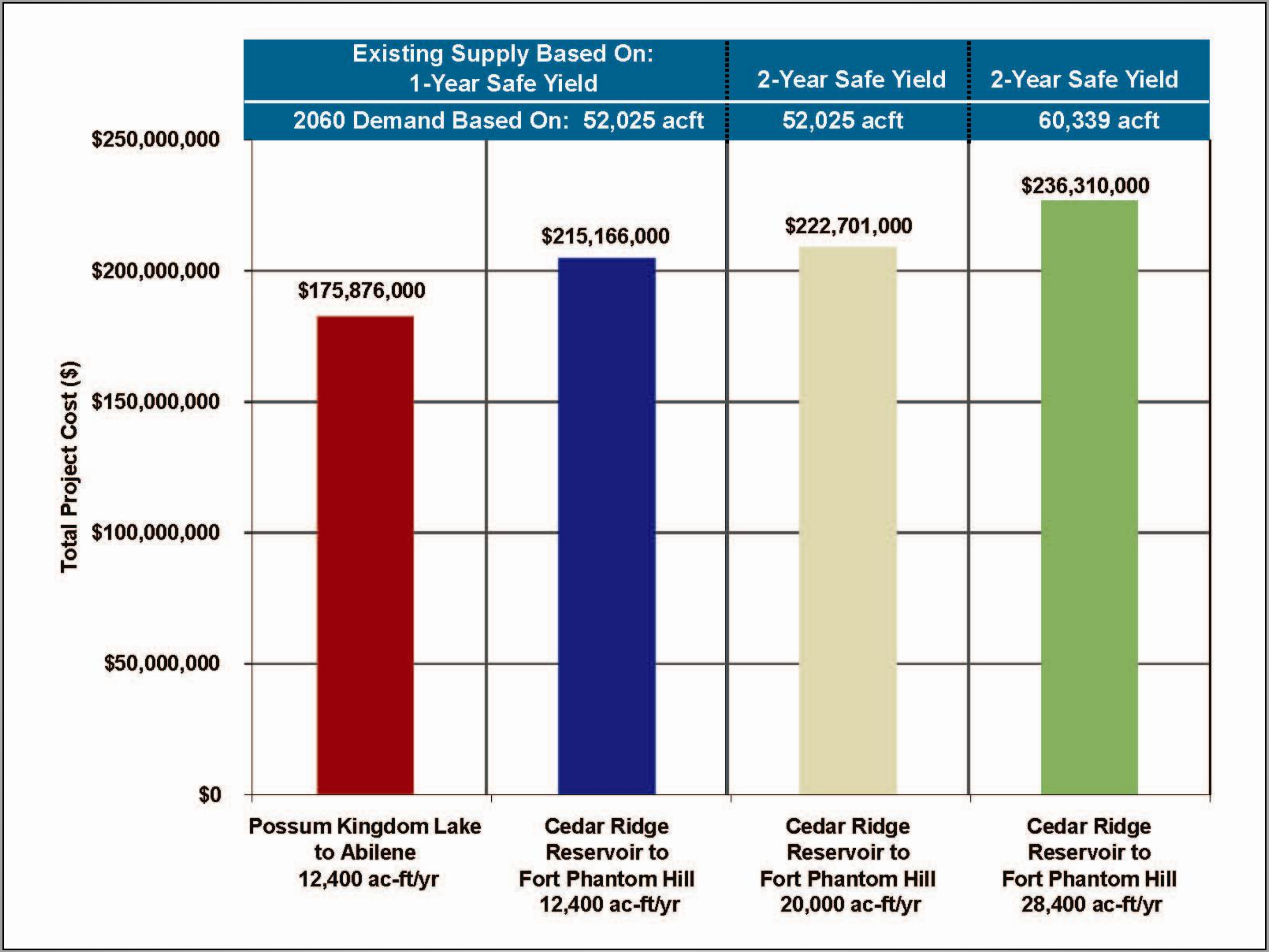
CITY OF ABILENE

ITEM #7

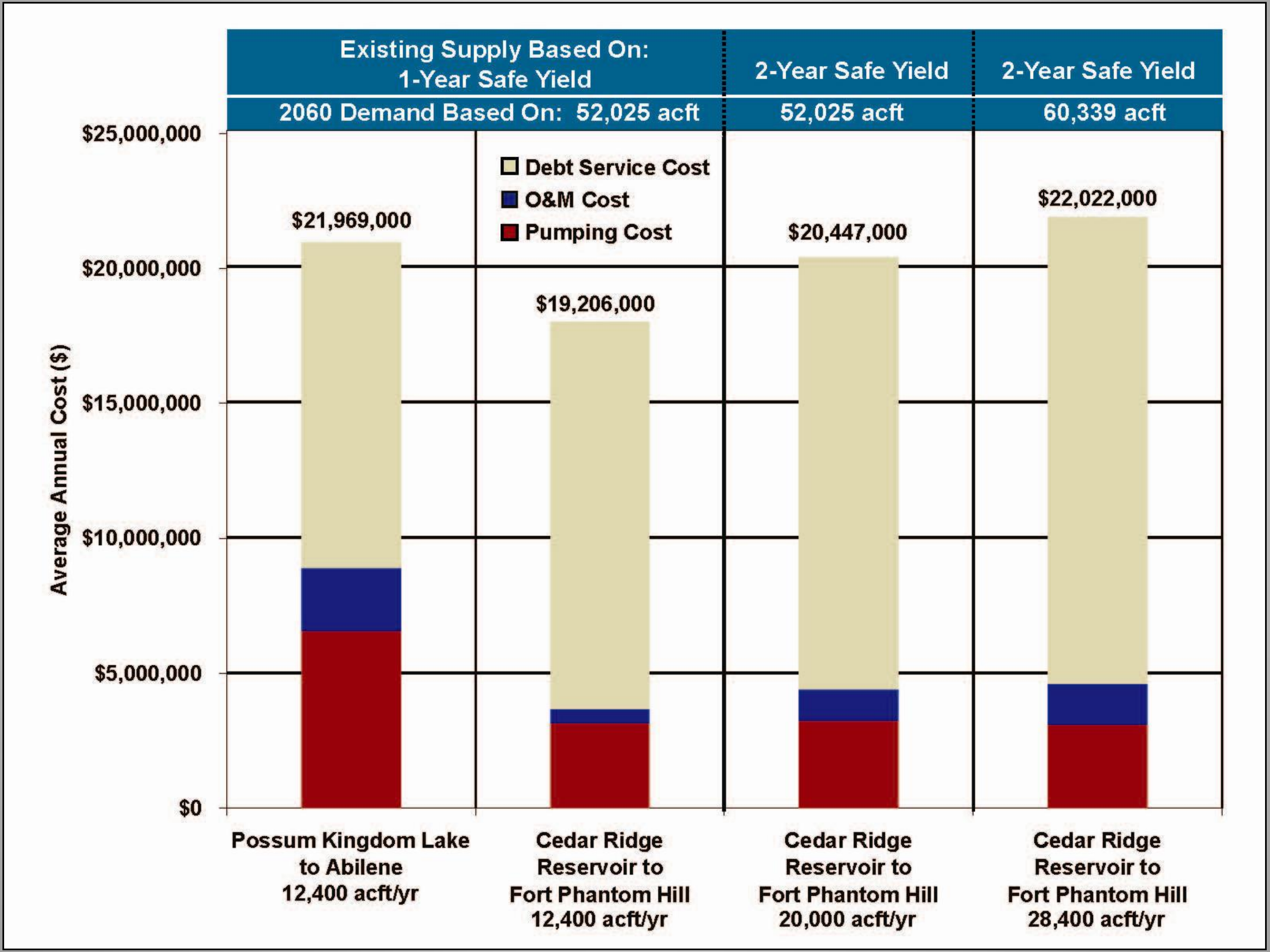
UPDATED PROJECT DEVELOPMENT COSTS

CEDAR RIDGE RESERVOIR /
RAW WATER FROM POSSUM KINGDOM LAKE

COMPARISON OF TOTAL PROJECT COSTS



COMPARISON OF AVERAGE ANNUAL COSTS



ITEM #8

UPCOMING ACTIVITIES

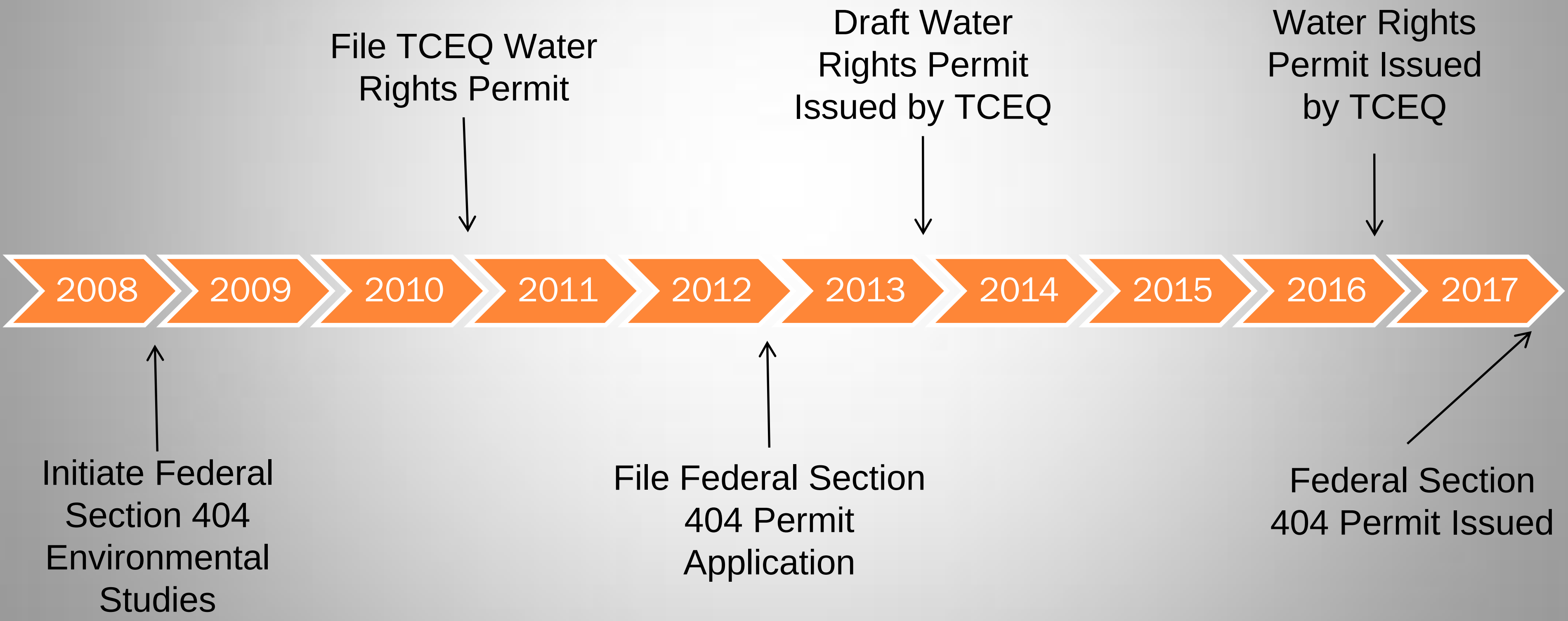
CEDAR RIDGE RESERVOIR

UPCOMING ACTIVITIES

- Continued Coordination with Ranches / Property Owners
- Develop Project Management Plan with Corps of Engineers (COE)
- Continued Inter-agency Coordination
- Continued Coordination with Brazos G Planning Group
- Continued Environmental Analyses
    - Brazos Water Snake Surveys
    - Aquatic Life Monitoring Surveys
    - Vegetation Mapping
    - Wetlands Survey
- Water Rights Permit Application Submission to TCEQ
- Initial Cultural Resources Evaluation
- Federal Section 404 Permitting and Mitigation Plan Preparation
- Installation of New USGS Streamgage at Lueders

CEDAR RIDGE RESERVOIR

PERMITTING SCHEDULE



File TCEQ Water Rights Permit

Draft Water Rights Permit Issued by TCEQ

Water Rights Permit Issued by TCEQ

Initiate Federal Section 404 Environmental Studies

File Federal Section 404 Permit Application

Federal Section 404 Permit Issued

ITEM #9

QUESTIONS AND DISCUSSION