Appendix N
Special Studies Concerning the Proposed Little River Reservoir

Freese and Nichols

Simon W. Freese, P.E. 1900-1990
Marvin C. Nichols, P.E. 1896-1969

MEMORANDUM

To: David Dunn, HDR Engineering, Inc.

From: Andres Salazar, Freese and Nichols, Inc.

Re: Impact of Sedimentation on the Yield of the Proposed Little River Reservoir

Date: October 8, 2004

Sedimentation Rates

The rate of sediment production for the proposed Little River Reservoir was estimated based on available data from the Soil Conservation Service and from volumetric surveys in surrounding reservoirs. Bulletin 5912 of the Soil Conservation Service[1] reports an annual sedimentation rate of 0.59 acre-feet per square mile in the Little River basin, which includes the Leon, Lampasas, and San Gabriel sub-basins. The calculated rates from volumetric surveys in surrounding reservoirs are listed in Table 1.

Table 1
Measured Sedimentation Rates in Surrounding Reservoirs [2]

Reservoir	Initial capacity (acre-feet)	Year	Last surveyed capacity (acre-feet)	Year	Time between surveys (years)	Capacity lost (acre-feet)	Uncontrolled drainage area (mi^2)	Sed. rate (acre-feet /mi^2/year)
Belton	456,884	1954	434,500	1994	40	22,384	2,503 [(a)]	0.22
Stillhouse Hollow	235,700	1968	226,063	1995	27	9,637	1,313	0.27
Granger	65,510	1980	52,525	2002	22	12,985	485	1.22
							Average	0.57

(a) This is average drainage area in time. [9 years with 3,531 sq. miles and 40 years with 2,272 sq. miles after Lake Proctor was built]

The sedimentation rate for Lake Granger is significantly larger than the rate at the other reservoirs because of high inflows during 1981 and from 1991 to 1993. The annual sedimentation rate estimated for the Little Reservoir is the average of the measured rates in near reservoirs, which is equal to 0.57 acre-feet per square mile. As confirmation, this value is similar to the value reported by the Soil Conservation Services.

[1] Soil Conservation Service. "Inventory and Use of Sedimentation Data in Texas". Bulletin 5912. January 1959.
[2] Texas Water Development Board. Volumetric Survey of Lake Belton (December 1994), Lake Stillhouse Hollow (August 1995), and Lake Granger (July 2003)

The total drainage area of the reservoir is 7,584 sq. miles, of which 2,010 squares miles are uncontrolled. The existing reservoirs of Granger, Stillhouse Hollow, and Belton located upstream of the proposed Little River Reservoir are operated for flood control and water supply. The trapping efficiency of sediment in these reservoirs is high because they do not spill frequently. Therefore, it was assumed that the rate of sediment production for the Little River Reservoir applies to the uncontrolled drainage area of 2,010 square miles.

Initial Area-Capacity-Elevation Relationships

Characteristics of the reservoir for the conservation pool at 330 and 310 feet were obtained from 10-foot contour lines of USGS 7.5 minute quadrangle maps. The initial area-capacity relationships are provided in Tables 2 and 3.

Projected Area-Capacity-Elevation Relationships

The estimated area-capacity-elevation relationship assuming 60 years of sedimentation at a rate of 0.57 acre-feet/sq. mile are also in Tables 2 and 3. The total loss of capacity is 68,742 acre-feet. The reduced capacity for the 330 elevation and for the 310 elevation are 809,029 acre-feet and 255,255 respectively. The projected area-capacity-elevation was found using the cone method in reverse for the different intervals of elevation.

Table 2
Area-Capacity-Elevation Relationship with the Conservation Pool at 330 feet

	Initial Conditions		**60-year sedimentation**	
Elevation (Feet msl)	Area (Acres)	Capacity (Acre-Feet)	Area (Acres)	Capacity (Acre-Feet)
270	0	0	0	0
280	1,332	4,439	119	397
290	7,723	45,313	6,511	25,434
300	13,625	150,665	12,412	118,474
310	20,687	320,997	19,474	276,585
320	27,708	562,121	26,496	505,537
330	35,585	877,768	34,372	809,026

Table 3
Area-Capacity-Elevation Relationship with the Conservation Pool at 310 feet

	Initial Conditions		60 years of sedimentation	
Elevation (feet msl)	Area (acres)	Capacity (Acre-feet)	Area (acres)	Capacity (acre-feet)
280	1,332	4,439	0	0
290	7,723	45,313	5,638	18,795
300	13,625	150,665	11,540	102,944
310	20,687	320,997	18,602	252,255

Impact of Sedimentation on Yield.

The effect of sedimentation on the firm yield for the two options of conservation pool was determined for a period of 60 years. Firm yields were obtained with the Region G Water Availability Model of the Brazos Basin (Region G WAM) considering releases for environmental flows determined by the Consensus Criteria. The Region G WAM used in this evaluation is the same model used to determine surface water supplies during the development of the regional water plan. Results are listed in Table 4.

The firm yield of the 330 elevation is reduced by 3,800 acre-feet/year (3% of the initial value). The firm yield of the 310 elevation is reduced by 16,800 acre-feet or by 24%. The critical period for the 330 elevation option is April 1947 to March 57. This period is 5 years longer than the critical period for the 310 elevation option. Therefore, the 310 feet reservoir is impacted to a larger degree than the higher conservation pool.

Table 4
Firm Yields of the Little River Reservoir

Conservation pool	Initial firm yield (acre-feet/year)	Firm yield after 60 years (acre-feet/year)	Loss of yield (acre-feet/year)
330 feet	124,000	120,200	3,800
310 feet	69,400	52,600	16,800

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MEMORANDUM

To:	David Dunn, HDR Engineering, Inc.
From:	Andres Salazar, Freese and Nichols, Inc.
Re:	Assessment of Water Quality for the Proposed Little River Reservoir
Date:	October 8, 2004

An analysis of water quality for the proposed Little River Reservoir was prepared from historical stream monitoring data. The station at Little River at Cameron (USGS 08106500) was chosen as a representative site because it is located in the conservation pool of the on-channel alternative. Historical data collected by the U.S. Geological Survey and by the TCEQ was statistically summarized to evaluate the overall water quality in the stream. Data includes few samples at Big Elm Creek, a tributary of the proposed reservoir joining the main stem about 4 miles northeast of Cameron. The analysis also considered the impact of population growth expected in Williamson and Bell Counties.

A. Overall Assessment

Population density in the vicinity of the proposed location of the reservoir is low with most of the population concentrated in the cities of Cameron and Rockdale. Maps of land use show that the majority of the reservoir's surrounding area is rural, primarily small grain farming and livestock grazing. Some mixed rangeland and forest land is found south of the proposed location and west of I-35, between Lake Stillhouse Hollow and the City of Georgetown.

The reservoir will also receive the drainage and discharges from the cities of Temple, Belton, Killen, Round Rock and other cities in Bell and Williamson Counties located along the I-35 corridor. The discharge from the City of Georgetown is upstream of Lake Granger and does not flow directly into the Little River.

According to TWDB approved population projection[1], the population in Bell and Williamson counties are expected to increase 225% (more than triple) by 2060. Therefore, municipal return flows reaching the lower basin of the Little River are expected to increase significantly, but in less proportion than population growth because of water conservation and reuse plans.

The Texas Parks and Wildlife Department describes the portion of the Little River in Milam County (between FM 437 and FM 1600) as a slow moving stream with heavy vegetation on its

[1] TWBD Board-Approved Population Projections for the 2006 Texas Water Plan.

banks. The banks are steep and muddy. TPWD reports that the water quality is fair, although it usually has a murky appearance[2].

The TCEQ Clean Rivers Program currently classifies the entire Little River as fully supportive for general use and public water supply. The overall classification of the stream is Category 4b, which means that some water quality standards may not be supported or are threatened for one use, but pollution control requirements are reasonably expected to result in the attainment of the water quality standard in the near future[3].

Current levels of return flows do not have a significant impact on the water quality at the Cameron gage. Samples of biochemical oxygen demand and dissolved oxygen collected since 1968 have shown that the river has maintained a good quality to support aquatic life and recreation. Levels of phosphorous and ammonia have been low. Pathogens are within a normal range typical of a surface water stream. If municipal return flows increase significantly, compliance with environmental standards and frequent monitoring are fundamental to preserve the good water quality of the stream.

The primarily source of pollution would be non-point runoff from agricultural and livestock activities and municipal discharges. However, the impact of municipal return flows can be controlled because these discharges must follow environmental standards for wastewater treatment effluents and they will be mixed with a larger amount of natural runoff, attenuating the concentration of any pollutant from municipal effluents. A more detailed discussion about the impact due population growth on water quality is presented on Section C.

B. Water Quality Parameters

The water quality parameters evaluated are listed in Table 1. These were obtained from historical samples collected by the USGS and the TCEQ in the vicinity of the reservoir. Table 1 shows that most of the parameters have a good quality and that water quality appears to be acceptable for the development of the reservoir. A detailed discussion for aquatic life and human health is provided next.

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[2] Texas Parks and Wildlife Department. An Analysis of Texas Waterways. A Report on the Physical Characteristics of Rivers, Streams, and Bayous in Texas.
[3] Texas Commission of Environmental Quality. Draft 2004 Texas Water Quality Inventory - Status of All Waters.

Table 1
Statistics of the Most Representative Water Quality Parameters for the Little River near Cameron

Parameter	No. of samples	Min.	Max.	75%	Median	25%	Average	Acceptable Range for use in water supply	Standard for drinking water after treatment	Units
Alkalinity	435	80	278	153	178	202.5	178.7	DOT	DOT	mg/L
Arsenic	65	0.5	7	2	3.8	5	3.6	< 190	50	μg/L
Ammonia Nitrogen	94	0	0.53	0.03	0.06	0.1375	0.1		0.5	mg/L
BOD	171	0	7.4	1	1.4	2.3	1.77	< 4.0	n/a	mg/L
Calcium	556	35	92	54	61	69	61.7	DOT	DOT [(a)]	mg/L
Chlorides	664	2.6	203	30.6	41	52	42.6	< 75	300	mg/L
Dissolved Oxygen	305	5.1	13.5	7.8	8.7	9.9	8.9	> 4.0	n/a	mg/L
Dissolved Phosphorous	112	0.005	1.8	0.08	0.22	0.3825	0.3		DOT	mg/L
E. Coli	35	5	2500	41	139.1	308	412.5	Less than 20% over 5,000 mpn	0	mpn/100 mL
Fecal Coliform	92	4	3100	39	102	300	289.2	Less than 20% over 5,000 mpn	0	mpn/100 mL
Fluorides	454	0	0.8	0.3	0.3	0.4	0.4	< 4.0	4.0	mg/L
Iron	65	0	200	5	7	14	15.5		300	μg/L
Lead	46	0	53	0	<1.0	<4.0	.<2.8	< 5.0	5.0	μg/L
Magnesium	557	2.5	26	9.4	13	15	12.4	DOT	DOT [(a)]	mg/L
Manganese	50	0	120	0.25	2	5	6.6		50	μg/L
Mercury	58	<0.1	<0.5	<0.1	<0.1	<0.1	<0.102	<1.3	0.0122	μg/L
Nickel	48	nd	<17	nd	<1	<4	<3.61	<210	-	μg/L
Nitrate + Nitrite	133	0.04	3.8	0.75	1.2	2	1.4		10	mg/L
pH	700	6.6	8.7	7.5	7.8	8	7.7	5.0 – 9.0	Near 7.0	
Sodium	482	3.7	118	22	30	42	33.4		-	mg/L
Sulfates	656	5	178	29	36	46	38.0	< 75	300	mg/L
Total Dissolved Solids	323	106	574	271	318	386	324.3	< 400	1000	mg/L
Total Phosphorous	184	0.03	2	0.16	0.28	0.5125	0.4	DOT	DOT	mg/L
Turbidity	98	0.5	950	25	55.5	93	104.5	< 250	1.0	NTU

DOT = Concentration level of constituent depends on treatment process. There is not a unique standard.
(a) = Determine total hardness of water. Total hardness or drinking water depends on quality of the source and treatment process. There is not a unique standard.

B.1 Water Quality Assessment for Aquatic Life

The ability of a stream to support aquatic life is usually determined by the concentration of dissolved oxygen. Dissolved oxygen ranged from 5.1 to 13.5 mg/L in more than 300 samples collected since 1968. The sampled average was 8.9 mg/L. Following the Criteria of the TCEQ Surface Water Quality Standards on dissolved oxygen, the stream is classified as exceptional for supporting aquatic life. A stream is classified as exceptional if the minimum dissolved oxygen is above 4.0 mg/L and the mean is above 6.0 mg/L. The data from the Cameron gage met both criteria.

The aquatic life standards that apply to the Little River are shown in Table 2. A comparison of the stream data (Table 1) with these standards indicates that sulfates, chlorides, and lead have registered values not in compliance with the desirable level.

Table 2
Applicable Standards for Aquatic Life at the Little River

Parameter	Units	Maximum	Average	Standard for Aquatic Life
Arsenic	µg/L	7	3.6	360/190 [a]
Chlorides	mg/L	203	42.6	75
Fecal Coliform	mpn/100 mL	3100	289.2	200
Lead	µg/L	53	2.8	126/5 [a]
Mercury	µg/L	<0.5	<0.102	2.4/1.3
Nickel	µg/L	<17	<3.61	1896/210 [a]
pH		8.7	7.7	6.5-9.0
Sulfates	mg/L	178	38.0	75
Total Dissolved Solids	mg/L	574	324.3	400

[a] Expressed as acute/chronic. Acute is the toxicity level that rapidly (less than 96 hours) induces an effect. Chronic is the toxicity level that produces sub-lethal effects in a long-term period of exposure.

Chlorides and Sulfates

The standard concentration for sulfates was exceeded only 6 times in 656 samples. The maximum concentration was 178 mg/L, much higher than the standard for aquatic life of 75 mg/L. However, data showed that high concentrations do not occur frequently, with sporadic peaks that disappeared in 2 or 3 days. The samples of chlorides exceeded the standard 4% of the time. However, sampling on subsequent days after the peak showed lower levels near the average of 42 mg/L.

A water quality model developed to analyze the variation of chlorides and sulfates in the reservoir showed that the reservoir attenuates the peaks of high concentration. This model estimated the maximum concentration of chlorides to be 62 mg/L and the maximum concentration of sulfates to be 55 mg/L for the reservoir with the conservation pool at 330 feet. With the conservation pool at 310 feet, the maximum concentrations were 80 mg/L and 66 mg/L for chlorides and sulfates respectively.

Coliforms

Values for fecal coliform exceeded the standard of 200 mpn/100 mL on 30% of the samples. However, the standard refers to the geometric mean of five samples in less than 30 days. Samples collected within less than 30 days did not show a geometric mean above the standard.

Lead

There are 66 samples of lead available. All of the samples met the acute criteria of 126 μg/L, meaning that there would be no effect on aquatic species due to short-term exposure (96 hours or less) to the level of lead in the stream. 60 of the samples were below the chronic toxicity standard of 5 μg/L. Only one was above this standard with a concentration of 53 μg/L. The remaining five samples reported the concentration to be less than 10 μg/L. It is impossible to determine if these samples met the chronic standard because the reported value is the physical maximum limit rather than the actual concentration. Since there is the possibility that these five samples violated the standard, lead appears to be a potential risk in the stream, but it is not possible to determine its magnitude because of the lack of exact measurements for concentrations below 10 μg/L.

All other parameters analyzed are in compliance with aquatic life standards. With the possible exception of lead, all water quality parameters are able to support a healthy stream. Further testing will provide a better indication over time.

B.2 Assessment for Human Health Protection

Values for human health protection from the Texas Surface Water Quality Standards determine the concentration of freshwater to prevent contamination of drinking water, fish, and other aquatic life to ensure that they are safe for human consumption. The applicable standard values for the Little River for human health are listed in Table 3. These standards apply for a stream designated or used for public drinking water supply.

All parameters analyzed met the standard with the possible exceptions of lead and mercury.

Table 3
Applicable Standards for Human Health at the Little River

Parameter	Units	Maximum	Average	Standard for Human Health
Arsenic	µg/L	7	3.6	50.0
Barium	µg/L	103.3	66.4	2,000
Cadmium	µg/L	<8	2.06	5
Fluorides	mg/L	0.8	0.4	4.0
Lead	µg/L	<53	<2.8	5.0
Mercury	µg/L	<0.5	<0.102	0.0122
Nitrate + Nitrite	mg/L	3.8	1.4	10.0

Data from 58 samples of mercury were available. One had a concentration of 5 µg/L, and another reported 2 µg/L. The remainder 56 samples reported concentrations of mercury of less than 0.1 µg/L. For this majority of the samples, it is not possible to determine if the human health standard was violated.

The magnitude of the risk for human health regarding lead and mercury cannot be concluded with the available data because of the uncertainty about actual concentrations. There is the possibility that few samples were above the human health standard, but this possibility could not be verified. A more detailed monitoring of lead and mercury is recommended.

B.3 Assessment for Use in Water Supply

Water quality for treatment and water supply is good. None of the parameters reflects a significant problem for water treatment. Alkalinity, turbidity, pH, iron, biochemical oxygen demand, and coliforms are within a range that indicates the water can be treated for water supply with usual processes such as filtration and disinfection.

C. Expected Impact due to Population Growth

Table 4 lists the current permitted municipal wastewater treatment plants above the proposed reservoir site that are not captured by existing reservoir in the area (Belton, Stillhouse Hollow, Georgetown and Granger). The majority of the cities in Bell and Williamson Counties have municipal return flows located directly upstream of the proposed reservoir. One exception is the City of Georgetown, which is located next to the San Gabriel River, upstream of Lake Granger.

Current levels of return flows have not significantly impacted the water quality measured at Cameron. The average flow for year 2000 at the Cameron gage was 664 cfs or 430 mgd. The total discharge from the wastewater treatment plants for the year 2000 was 33.7 mgd. This means that the municipal return flows composed about 8% of the total flow at the Cameron gage for the year 2000. The year 2000 is representative of low flow conditions since this year is within the low 25-percentile of annual flows.

Table 4
Wastewater Treatment Plants with Effluent Directly Upstream of the Reservoir Site

City or Name	County	Permit number	Permitted discharge (mgd)	Effluent 2000 (ac-feet)	Effluent 2000 (mgd)
Anderson Mill MUD	Williamson	11459.001	1.3	0	0.00
Authority TBRSS [a]	Bell	11318.001	10	6719	5.98
Authority/LCRA BCRWS East [b]	Williamson	10264.002	11.8	0	0.00
Authority/LCRA BCRWS West [b]	Williamson	10264.001	3	9634	8.60
Bell County WCID#1	Bell	10351.003	6	4495	4.01
Bell County WCID#1	Bell	10351.002	15	8820	7.87
Bell County WCID#2	Bell	11090.001		59	0.05
Bell County WCID#2	Bell	11091.001		0	0.00
Block House MUD	Williamson	13031.001	0.5	303	0.27
Brushy Creek MUD	Williamson	11865.001	0.45	389	0.35
City of Bartlett	Bell	10880.001	0.325	0	0.00
City of Cameron	Milam	10004.001	0.96	0	0.00
City of Cedar Park	Williamson	12308.001	2.5	0	0.00
City of Copperas Cove	Coryell	10045.004	0.8	0	0.00
City of Copperas Cove	Coryell	10045.003	2	547	0.49
City of Copperas Cove	Coryell	10045.005	3.05	0	0.00
City of Harker Heights	Bell	10155.001	3	1547	1.38
City of Holland	Bell	10897.001	0.2	77	0.07
City of Leander	Williamson	12644.001	2.25	731	0.65
City of Taylor	Williamson	10299.001	4	1880	1.68
City of Temple	Bell	10470.002	7.5	2617	2.33
TOTAL				37,820	33.73

[a] Temple-Belton Regional Sewerage System
[b] Brush Creek Regional Wastewater System

The average annual flow at the Cameron gage is 1,740 cfs (1,126 mgd). Comparing the average gaged flow to the amount of return flows, the 2000 return flows are about 3% of the average flow at the Cameron gage.

According to TWDB approved population projections, population in Bell and Williamson Counties in 2060 is expected to be more than triple of the 2000 population. Growth would increase significantly the level of return flows. However, wastewater treatment plants must follow TCEQ regulations for treated effluents. Although the levels of return flows are expected to increase significantly, natural runoff would still be the primary component of the flow at the reservoir site.

Pollutants from return flow are expected to be controlled causing a minimum damage to the quality of the natural runoff. Therefore, no significant impact is expected assuming that the higher level of return flows will meet the state standards for municipal wastewater effluent.

D. Conclusions and Recommendations

1. Water quality is not a major concern for the development of the reservoir. Chlorides and sulfates have sporadic peaks of concentrations. However, these peaks are diluted quickly and do not impose a risk for the aquatic habitat or human consumption.

2. Effects of lead and mercury are inconclusive at this time. It is recommended to collect and measure more detailed samples of lead and mercury to determine the risk on human health from the consumption of water and fish.

3. If this reservoir is built, it is recommended to adopt a program of monitoring and enforcement for wastewater effluents to ensure that these effluents will not deteriorate the quality of the runoff flowing into the reservoir.

4. Overall, water quality is good and appropriate for a conventional treatment process for water supply.

Freese and Nichols

MEMORANDUM

TO: Region G Water Planning Group

FROM: Chuck Easton, John Rutledge

SUBJECT: Little River Reservoir, Desktop Geotechnical Study

DATE: May 20, 2005

INTRODUCTION

The proposed Little River Reservoir was identified as a recommended strategy in the 2001 plans for Region G and Region H. One of the concerns raised as a result of the inclusion of the project was the potential viability of the site for a large reservoir. In response to this, a "desktop" geotechnical study was performed, reviewing available soils and geologic mapping and other related information to determine is the location was likely to be a viable dam site.

GEOLOGY

As shown in Figure 1, which is an excerpt from the Geologic Atlas of Texas, Austin Sheet, the geologic deposits within the depth of interest for the dam and reservoir are Recent alluvium, Pleistocene fluviatile terrace deposits, and Eocene coastal plain sediments. The alluvium includes thick floodplain deposits of fat clay and underlying channel deposits of sand and gravel. The alluvium may be up to 60 feet thick. The terrace deposits are in raised plains along the streams and include gravel, sand, silt and clay. The Eocene formations generally dip southeastwards at 1 to 2 degrees from horizontal. They include:

- The Carrizo Sand – An important aquifer east of the dam site. It is absent within the reservoir area, but a remnant is exposed in Sugar Loaf Mountain immediately downstream of the right abutment of the dam site. It is a potential source of sand for embankment drains and/or embankment shells.
- The Wilcox Group – Consisting mainly of sand and clay deltaic deposits, it includes ground-water aquifers and lignite resources. It is exposed in the valley sides and uplands flanking the reservoir and underlies terraces and alluvium in the valleys. The formations of the Wilcox group are as follows:
    - The Calvert Bluff Formation underlies the dam site and the east 2-1/2 miles of the reservoir. It consists primarily of mudstone containing sand-filled channel deposits and is 500 to 700 feet thick at the dam site.

  - The Simsboro Formation underlies the central part of the reservoir area about 4.3 miles long. It is an important aquifer consisting primarily of sand with clay layers, and is 300 to 500 feet thick.
  - The Hooper Formation underlies most of the western part of the reservoir area. It is mostly mudstone with sandstone, and is 300 to 500 feet thick.
- The Wills Point Formation of the Midway Group underlies the Big Elm Creek branch of the reservoir and possibly part of the Little River branch south of Cameron. It consists of clay with silt and sand and is about 500 feet thick.

The Mexia Fault System runs east-northeastward through or immediately east of the dam site. One mapped fault trace 6 miles long terminates about one-half mile west of the left abutment, and a longer fault trace terminates about 2-1/2 miles southeast of the right abutment. The faults cut through the Eocene materials and impede water flow in the aquifers. The faults are considered to be inactive.

SOILS

Important surficial soils mapped in and near the reservoir area include:

- Catalpa Clay and Trinity Clay in the floodplain. These are thick, fat, calcareous clays underlain by sand and gravel.
- Milam Fine Sandy Loam and Irving Fine Sandy Loam in terraces. These are generally underlain by gravel.
- Bell Clay, Norfolk Fine Sand, Ochlockonee Fine Sandy Loam, and Kirvin Fine Sandy Loam in the uplands. Underlying materials include gravel, fine sand, clay and shale.

DESIGN ISSUES

Lignite Resources

Near-surface (0 to 500 feet deep) lignite resources have been identified and inferred in the Wilcox Group formations underlying parts of the reservoir area. They are found primarily in the lower part of the Calvert Bluff Formation and upper part of the Hooper Formation. The lignite presumably will impact property acquisition costs.

Seepage Losses

As shown on the attached map, the aggregate thickness of sand in the Wilcox Group formations below the reservoir site is several hundred feet. Net seepage losses into the Wilcox Group regional aquifers will depend on the existing water levels, the permeability of the natural clay blanket in the reservoir floor, and the availability of exit paths to the surface downstream from the reservoir. As shown on the attached map, the present altitude of the groundwater in the Wilcox aquifer is higher than the proposed reservoir surface throughout most of the reservoir area, so groundwater gain may exceed loss. The floodplain clays will limit seepage rates through the reservoir floor. A clay blanket may be needed in part of the sandy river bed. Water level contours suggest that groundwater may surface through springs into the Brazos River 4-1/2 miles east of the dam site. The reservoir may increase this flow. A rough estimate of this leakage is 15,000 acre-feet per year.

Much of the water lost to seepage will appear at the relief wells, where it could easily be recovered. Additional groundwater might be recovered at a channel dam in the Little River just above the Brazos River. Water lost to seepage and not recovered directly will either contribute to the groundwater resource or appear in the Brazos River, improving quality and base flow.

Dam Foundation

The foundation soils are thick fat clay over sand and gravel over dense sand, sandstone, mudstone and shale. The moderate strength of the clay will require stabilizing berms. Soft clays may exist in abandoned channels. Differential settlement and stability are possible concerns at abandoned channels and may require overexcavation, additional berms, or staged construction.

Underseepage

Water seepage beneath the embankment may be an important issue, depending on the existence of sand layers at shallow depth. A relatively deep slurry trench cutoff and a series of relief wells will probably be required. Relatively high flows from relief wells are likely. The abutments include terrace gravel deposits overlain by a few feet of clay. Underseepage control in the abutments may require a core trench or slurry trench cutoff and relief wells or blanket drains.

Spillway Foundation

The spillway foundation is expected to be gravel deposits of relatively low compressibility. Underseepage and modest settlements will be design issues.

Construction Materials

The local geologic materials are favorable for dam construction. Fat clay is abundant in the floodplain for impervious core and clay blanket construction. A homogeneous section of clay can be considered to minimize haulage, but will require flat slopes. Gravelly soils from terrace deposits on both sides of the valley are potentially excellent materials for embankment shells. Sandy and gravelly clays from terrace and upland deposits can also be considered, but will be more variable. Sand from the Wilcox Formation in hills near the right abutment may be suitable for drainage blanket construction and/or for soil-cement slope protection. Existing sand and gravel quarries are mapped between Cameron and the dam site. Limestone for riprap is probably available about 70 miles west of the site, though soil cement is likely to more cost effective wave protection.

ADDITIONAL STUDIES

In addition to development of more detail on the issues discussed above, benefit could be gained by including the following in preliminary and final design geotechnical studies:

- Availability of commercially produced aggregates for concrete, soil cement, and drains.
- Suitability of fly ash from the lignite power plant at Alcoa for use in soil-cement and concrete.