Predicted Sedimentation Rates at Proposed Lake Ralph Hall
North Sulphur River, Texas

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ABSTRACT

The Upper Trinity Regional Water District (UTRWD) is proposing to build a 160,235 acre-feet water supply reservoir, Lake Ralph Hall (LRH), on the North Sulphur River (NSR), in southeast Fannin County, Texas. The NSR and its tributaries, within the boundaries of the proposed reservoir, as well as upstream and downstream, are deeply incised and eroding, the result of channelization and straightening in the late 1920s. The morphological adjustments of the river and the larger tributaries were described by a specifically-developed geomorphic model of incised channel evolution (NSRCEM), but the model varies significantly from those developed for alluvial streams (e.g. Schumm et al., 1984) because the river and principal tributaries have incised into erodible shales of the Ozan Fm. Vertical and lateral erosion rates in the shale are from 2 to 4 in./yr, respectively, and the rates are controlled primarily by slaking rather than hydraulic processes. The computed annual bed material yield to the proposed dam site that is primarily derived from bedrock erosion ranges from 82,000 to 281,000 tons under supply-limited and transport-limited assumptions, respectively. With the reservoir in place, the annual bed material yields reduce to between 30,000 and 44,500 tons because the reservoir inundates a very high proportion of the contributing channel area. Estimated annual watershed sediment yields derived from sheet, rill and ephemeral gulley erosion range from 81,000 to 147,000 tons, and these reduce to 50,000 and 90,000 tons, respectively with the reservoir in place. Estimates of total annual sediment yield to the reservoir range from 51 to 74 acre-feet which represent a loss of reservoir capacity over a 50-year period of 1.6 to 2.3 percent, respectively. Compared to estimates of sediment yield developed from other sources in the Blackland Prairie region including reservoir resurveys, measured stream sediment loads and watershed analyses, the LRH estimates are conservatively high. However, the impacts on reservoir capacity at LRH are minimized by the low drainage area to reservoir capacity ratio, the result of the historic channel erosion.

INTRODUCTION

The Upper Trinity Regional Water District (UTRWD) is proposing to build a 160,235-acre-foot (ac-ft) water supply reservoir, Lake Ralph Hall, on the NSR about 3.5 miles north of Ladonia in Fannin County, Texas (Figure 1). Fannin County is located within the Texas Blackland Prairie physiographic area (NRCS, 2001). The NSR originates near the axis of the Preston Anticline and flows east paralleling the general east-northeast strike of the south-southeast dipping Cretaceous-age bedrock (Barnes, 1967). The south-southeast dip of the underlying bedrock is the cause of the asymmetrical valley profile of the NSR. Down-dip preferential erosion has resulted in the north side tributaries being long and having relatively gentle slopes, while the south side tributaries are short and steeper (Figure 1).

The watershed is underlain by bedrock units of the Cretaceous-age Austin and Taylor Groups. Outcrops of the Roxton/Gober Chalk (Austin Group) provide grade-control that limits the extent of channel erosion in the north-side tributaries. The Ozan Formation (Taylor Group) crops out in the bed and banks of the mainstem NSR and the tributaries downstream of the chalk outcrop.

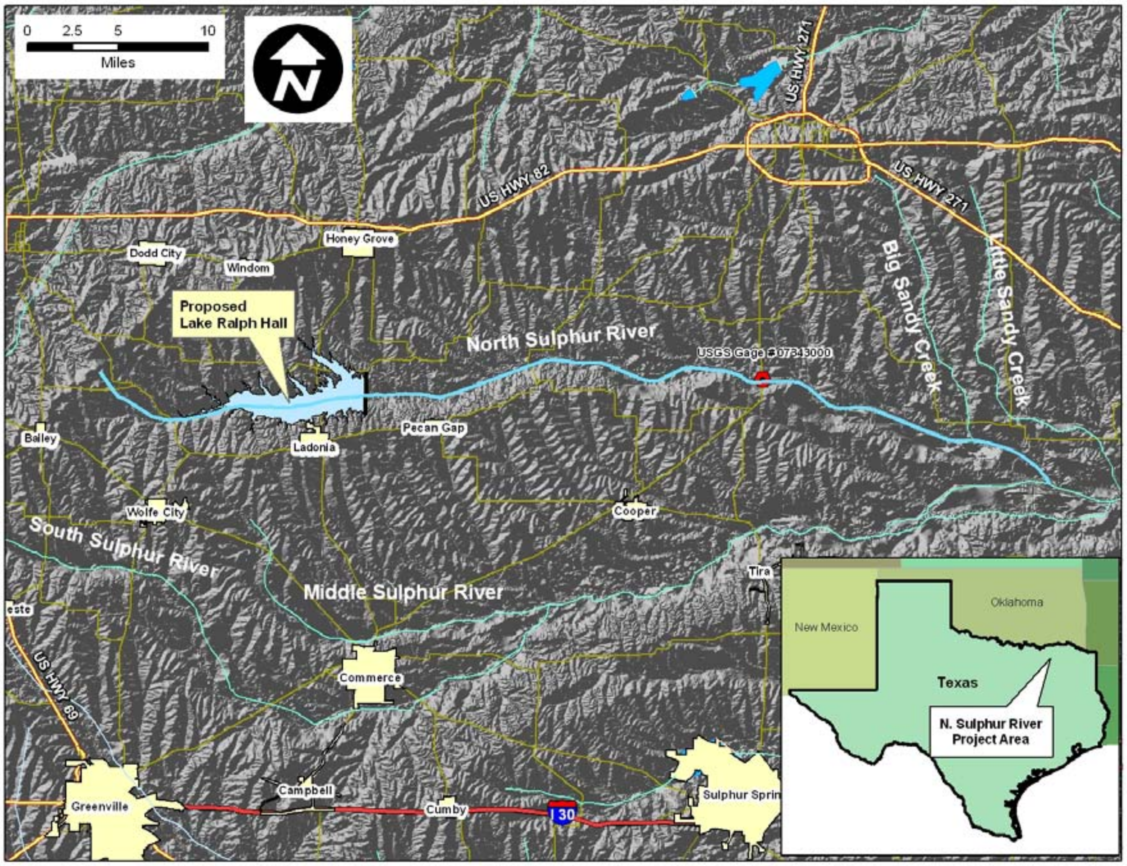

Figure 1. Map showing the location of the proposed Lake Ralph Hall on the NSR in Fannin County, Texas.

The Ozan Formation is a shale unit that is compact, highly jointed, and highly erodible and ravels when exposed to weathering. Four borings across the valley at the proposed dam location indicate that there is relief on the shale surface at the shale-valley fill contact (Kleinfelder, 2005).

The NSR and its tributaries, within the boundaries of the proposed reservoir, as well as upstream and downstream, are deeply incised and eroding. Current conditions are the result of channelization and straightening of the sinuous, meandering river and the lower reaches of its tributaries to prevent frequent overbank flooding on the NSR floodplain in the late 1920s (Williams, 1928; Avery, 1974). Prior to channelization, the NSR was a sinuous (1.7) meandering stream with a slope of about 4.3 ft/mi. In the vicinity of the proposed dam site, the natural channel was about 48 feet wide and 6 feet deep and had a hydraulic capacity of between 700 and 1,000 cfs. The channelized and straightened channel had a top width of 16 to 30 feet, and a depth of 9 to 12 feet with a slope of 6.5 ft/mi (Avery, 1974) and a hydraulic capacity of about 700 cfs. Currently, at the proposed dam site the NSR is 300 feet wide and about 40 feet deep, the bed and lower portions of the banks of the channel are composed of erodible shale (Ozan Formation), and the channel contains flows well in excess of the 100-year flood peak (38,000 cfs). Based on a comparison of the historical and present-day channel dimensions about 28M tons of sediment have been eroded from the mainstem NSR and its tributaries upstream of the proposed dam site since the 1920s.

Future loss of reservoir capacity due to sedimentation is major issue of concern for the Lake Ralph Hall project given recent sedimentation problems in Lake Cooper and other reservoirs in North Texas, and therefore, estimates of sediment yield from the 100-square-mile watershed upstream of the proposed dam are required. Potential sources of sediment include incised channel erosion (bed and banks) and watershed erosion (sheet, rill, ephemeral gully). Incised channels generally follow a temporally and spatially based evolutionary sequence from instability back to some form of equilibrium between the supplied water and sediment load and the channel morphology that has been described by a geomorphic model, the Incised Channel Evolution Model (ICEM) (Schumm et al., 1984; Harvey and Watson, 1986; Simon and Hupp, 1986). During the course of the evolutionary sequence, sediment loads derived from erosion of the incised and widening channel can be extremely high (10^3 to 10^6 t/yr), but tend to decease through time as a new state of equilibrium is approached (Harvey and Watson, 1986; Watson et al., 1986; Watson et al., 1988; Simon and Darby, 1999; Prosser et al., 2000). In the context of the NSR, the current sediment yield from the incised mainstem channel and the tributaries will depend on where these channels are in the evolutionary sequence. Sediment yield from the watershed is dependant on the land use within the watershed. Although approximately 75 percent of the watershed area was under cultivation for primarily row crops in the 1920s and 1930s, the current area in cropland is about 26 percent (Texas State Soil and Water Conservation Board, 1997).

The primary objectives of this paper are to quantify sediment delivery to the proposed reservoir site for the 50-year project life under pre- and post-project conditions, and to evaluate the predicted sediment yields in terms of measured and estimated yields from other sources in the Blackland Prairie region.

HYDROLOGIC AND HYDRAULIC ANALYSES

Hydrologic analyses of the gage record at the USGS North Sulphur River near Cooper gage (USGS Gage No. 07343000) and HEC-1 models (USACE, 1990) were used to estimate peak flow frequencies (Table 1), mean daily flow durations and flow volumes for the dam site and the tributaries that were required for the watershed and channel sediment yield analyses.

One–dimensional HEC-RAS (v. 3.1.3) models (USACE, 2005) were developed for the mainstem (12 miles) and for the 11 major tributaries (26.6 miles) based on a 2-foot contour interval Digital Terrain Model (DTM). Vertical variation in n values was used to account for the reduced roughness at higher flow depths because flows up to and including the 100-year peak flow are contained within-bank. N values ranged from 0.048 at very low flows to about 0.022 at the 100-year peak flow in the main channel and ranged from 0.048 to 0.070 in the overbanks. A normal-depth downstream boundary condition with a slope of 0.2 percent was used at the downstream end of the mainstem model. The models were calibrated to field-measured high-water marks for the 2002 (10-year event) and 2003 (25-year event) peak flows (Table 1).

Table 1. Computed peak flows at the proposed dam site		
Flow (cfs)	Return Interval (yrs)	Exceedence Percent
12,700	2	50
21,100	5	20
27,000	10	10
31,900	25	4
34,600	50	2
37,900	100	1

Based on field observations of hydraulic controls and the locations of tributary confluences the mainstem of the NSR was subdivided into 10 subreaches (Table 2).

Table 2. Subreach delineations used for the reach-averaged hydraulic calculations.				
Subreach	Description	Upstream Station (ft)	Downstream Station (ft)	Subreach Length (ft)
1	Upstream	61,966	59,106	2,861
2	Allen Creek to Bear Creek	59,106	54,342	4,764
3	Bear Creek to Brushy Creek	54,342	44,264	10,078
4	Brushy Creek to Pickle Creek	44,264	37,423	6,840
5	Pickle Creek to Davis Creek	37,423	32,513	4,910
6	Davis Creek to Leggets Branch	32,513	28,138	4,375
7	Leggets Branch to Bralley Pool Creek	28,138	22,786	5,352
8	Bralley Pool Creek to Merrill Creek	22,786	10,214	12,572
9	Merrill Creek to proposed dam location	10,214	7966	9,588
10	Proposed dam location to FM 904	7966	6	620

Reach-averaged hydraulic output (effective width, hydraulic depth and average velocity) from the mainstem HEC-RAS model for the 2-, 10- and 100-year peak flows is provided in Table 3. Velocities range from 4.8 to 11.6 ft/s, hydraulic depths range from 3.7 to 17.2 feet, and effective widths range from 87 to 251 feet.

Table 3. Reach-averaged hydraulic output from the mainstem HEC-RAS model for the 2-, 10-, and 100-year events.									
Subreach	Main Channel Velocity (ft/s)			Main Channel Hydraulic Depth (ft)			Effective Width (ft)		
	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr
Upstream	4.8	5.6	5.6	3.7	5.6	6.5	87	107	126
Below Allen Crk	5.8	6.8	7.2	5.1	7.6	9.0	84	101	114
Below Bear Crk	6.0	6.5	6.8	5.2	7.8	9.3	100	128	145
Below Pot/Brushy Crk	6.7	7.7	8.1	6.9	9.7	11.0	120	158	188
Below Pickle Crk	7.3	9.3	10.1	6.4	9.8	12.0	150	163	172
Below Davis Crk	7.3	9.0	9.5	6.2	10.2	13.2	186	194	200
Below Leggets Branch	7.2	8.7	9.2	7.5	12.2	15.2	169	183	194
Below Bralley Pool Crk	7.2	7.9	8.3	8.4	13.4	16.0	169	202	228
Below Merrill Crk	7.6	8.8	9.6	10.1	14.6	17.2	166	210	229
Downstream	9.7	10.8	11.6	9.2	13.4	15.5	179	222	251

BED MATERIAL CHARACTERISTICS

The reach-averaged hydraulics for the mainstem and the tributaries were used in conjunction with sediment gradations derived from samples of bed material from the mainstem (9) and tributaries (5) to compute sediment transport. Because a significant portion of each sample contained shale clasts, the samples were slaked and subjected to both wet and dry sieving to develop realistic gradations for modeling purposes. Median (D_{50}) grain sizes for dry and slaked samples are provided in Table 4, as are the silt/clay (<0.075 mm) percentages for the samples following slaking.

Table 4. Dry and slaked median grain sizes for the North Sulphur River and tributary bed material samples.

Sample	Dry D_{50} (mm)	Slaked D_{50} (mm)	Silt/Clay percent after slaking
NSR 0		<0.075	32
NSR 1	2.4	2.02	11
NSR 2	1.72	<0.075	88
NSR 3	3.65	1.2	43
NSR 4	2.72	0.69	44
NSR 5	2.17	1.26	43
NSR 6	2.48	1.51	26
NSR 7	2.33	1.21	28
NSR 8	2.18	1.64	12
Baker Creek 1	2.4	1.5	82
Bralley Pool Crk. 1	3.8	<0.075	64
Bralley Pool Crk. 2	2.7	<0.075	72
Bralley Pool Crk. 3	2.8	<0.075	89
Merrill Crk. 1	1.5	<0.075	78

The transformation of the slaked bed material from silt-clay dominated in the upstream reaches to non-shale sand-sized material in the downstream reaches is summarized in Figure 2. In the upstream reach (NSR2) the silt-clay content is greater than 80 percent. At the Bralley Pool confluence (NSR0), the silt-clay content reduces to about 30 percent, at the FM 904 Bridge (NSR8) it is about 12 percent, and at the USGS gage near Cooper (NSR1), it is reduced to about 10 percent. Conversely, the non-shale component varies from less than 20 percent upstream to about 90 percent downstream. Transformation of the bed material has no impact on the total volume of material delivered to the reservoir because 100-percent trap efficiency is assumed, but it has significant implications for modeling of the bed material transport.

INCISED CHANNEL EVOLUTION

In the context of the current status of the NSR, and sediment yield to the dam site, it is important to know the evolutionary stage of the incised mainstem and tributaries. In the channelized streams of the humid southeastern U.S., the channel evolution sequence can take about 40 to 50 years to complete (Schumm et al., 1984; Schumm, 1999; Simon, 1989). For the incised arroyos of the semi-arid southwest the sequence takes about 100 years (Gellis et al., 1995). Therefore, it could be expected that the NSR, that was channelized about 75 years ago, has completed the evolutionary sequence and might be approaching a new state of equilibrium with the imposed flows and sediment loads. Depending on location, there are indications that this has in fact occurred. However, it is equally apparent that there are sections of the NSR and its tributaries that are interspersed with apparent equilibrium sections that are still actively widening, and have very little or no sediment accumulation on the bed, which is composed of erodible shale, both conditions which are indicative of ongoing disequilibrium. Therefore, it is apparent that the NSR does not fully fit the previously developed models of incised channel evolution.

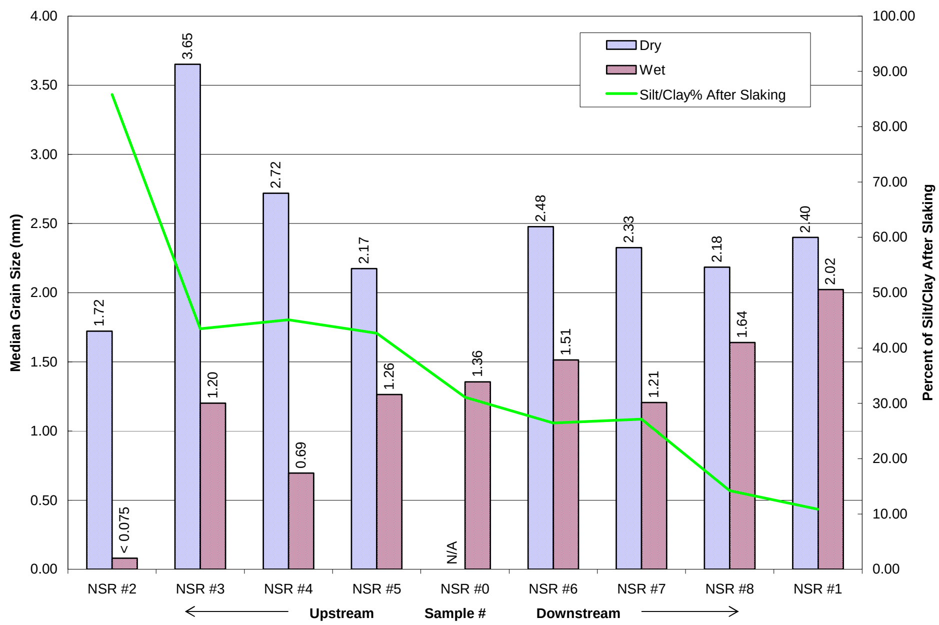

Figure 2. Changes in the median sizes of the dry- and wet-sieved bed-material samples of the North Sulphur River as well as the silt-clay content of the samples following slaking arranged from upstream to downstream.

Based on field observations, a modified version of the incised channel evolution model was developed for the NSR and its tributaries (NSRCEM) (Figure 3). The model varies substantially from those developed for alluvial streams (Schumm et al., 1984; Simon and Hupp, 1986; Simon, 1989) in that it does not predict an equilibrium end point because both vertical and lateral erosion of the exposed shale outcrop is controlled by wetting and drying cycles (Tinkler and Parish, 1989; Allen et al., 2002) and not hydraulic processes. There is little doubt that following channelization in the late 1920s the NSR incised and widened (Avery, 1974) and followed the typical channel evolution sequence while the channel boundary materials were composed of alluvium (Types I through V). However, exposure of the shale added a significant complicating factor to the evolution of the channel. Based on the flow record at the USGS gage on the NSR near Cooper, there are an average of six wetting and drying cycles per year. Flow events in the channel remove the weathering products and re-initiate vertical and lateral erosion into the shale. As a rule, lateral erosion rates exceed vertical erosion rates in bedrock and result in the formation of gravel-covered strath surfaces that become terraces when vertical erosion of the bed occurs

(Leopold et al., 1964; Schumm, 1977) (Type VI). Deep-seated slump failures of the overlying alluvium (CH and CL materials) bury the strath surfaces (Type VII) and prevent lateral erosion of the shale. Resulting channel narrowing may actually accelerate erosion of the shale exposed in the bed, which in turn leads to undercutting of the erosion-resistant, root-reinforced alluvium thereby leading to re-exposure of the shale in the toe of the banks and ongoing lateral retreat of the shale (Type VIII). Over time the incision into the shale will induce further mass failure of the alluvial valley fill and a Type VII condition will be reestablished at a lower bed elevation and there will be additional channel widening. The NSRCEM indicates that the primary sources of channel- derived sediment delivered to the reservoir will be shale outcrops in the bed and lower banks of the channels. Furthermore, the model suggests that inundation of the exposed shales within the reservoir will greatly reduce the supply of sediment to the reservoir.

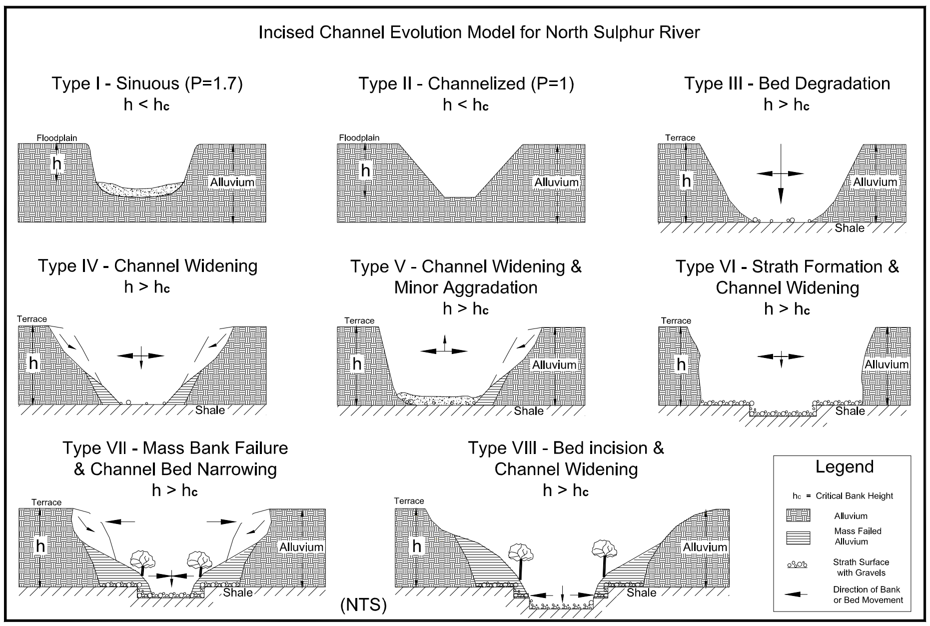

Figure 3. Channel evolution model (NSRCEM) for the North Sulphur River.

WATERSHED SEDIMENT YIELD

Estimates of the sheet-and-rill erosion in the watershed were developed with the Modified Universal Soil Equation (MUSLE) (Williams and Berndt, 1972) using values for the equation variables based on the subbasin topography and soil types (clays and loams) determined from the Soil Survey of Fannin County (NRCS, 2001). Watershed sheet-and-rill sediment yields were computed for each subbasin for the 2- through 100-year storm events and the annual sediment yield was developed from probability weighting of the individual storm events (Mussetter et al., 1984). Although previous studies (Smith et al., 1984) have shown that the sediment yields predicted by the MUSLE are reasonable for Blackland Prairie soils, the computed annual sediment yields for the North Sulphur River were about 37 percent of observed sediment yields in the Blackland Prairie region (2.0 t/ac/yr; Alan Plummer and Associates, 2005). Therefore, the value of the alpha coefficient (95) in the MUSLE was increased by a factor of 2.7. Sediment delivery ratios (SDR) were estimated from a relationship developed for the Blackland Prairie region (Renfro, 1975). Ephemeral gully erosion for the cropland portions of the watershed (26 percent) was estimated to be equivalent to the sheet-and-rill gross erosion rates on the basis of the soil erosion literature (Laflen et al., 1986). For the ephemeral gully erosion, the SDR was estimated to be 0.67 (Alan Plummer and Associates, 2005). Worst-case watershed sediment yields were estimated using an assumption of 100-percent cropping in the watershed with a gross erosion rate of 3.74 t/ac/yr (Richardson, 1993), which was the highest erosion rate reported in the Blackland Prairie literature.

Based on the MUSLE and ephemeral gully analyses, the most realistic and defensible estimate of the current annual watershed sediment yield at the dam site is about 81,000 t/yr which reduces to about 69,000 t/yr with the reservoir in place, since the reservoir reduces the contributing watershed area. Under the worst-case conditions, with the assumption of 100 percent cropping in the watershed, the existing annual watershed sediment yield to the dam site is about 147,000 t/yr, and this reduces to about 90,000 t/yr with the reservoir in place.

TOTAL SEDIMENT YIELD

The total sediment yield to the proposed dam location includes the watershed sediment yield (transported as wash load) and the sediment yield that results from erosion of the bed and banks of the mainstem NSR and its tributaries (channel sediment yield). The geomorphic characteristics of the NSR (Figure 3) indicate that the sediment supply is less than the hydraulic capacity of the channel to convey the supplied sediment load, and thus the NSR is a supply-limited channel, where the sediment deficit is obtained from bed and bank erosion. A sediment routing analysis was conducted to compute the sediment yield to the dam site. Bed material transport capacities for the mainstem and the tributaries were computed using the Meyer-Peter and Müller bed-load transport equation (MPM, 1948) and Einstein's depth integration of the suspended sediment discharge (Einstein, 1950). Bed material rating curves were developed from the reach-averaged hydraulic output from the HEC-RAS models of the mainstem and tributaries and the appropriate sediment gradations. Rating curves were then integrated over the subreach hydrographs for the 2- through 100-year events and the average annual bed material capacities were computed on a probability weighted basis (Mussetter et al., 1984).

The sediment routing analysis by subreach was conducted on an annual basis. The upstream sediment supply was estimated from the percent of the channel bed covered by depositional bars that overlie the bedrock as measured on the orthophotography of the watershed (Struiksma, 1999). The annual volume of material eroded from the shale bed and banks was computed using annual degradation and widening values of 2 in. and 4 in., respectively (Allen et al., 2002), and the slaking rate of the shale was estimated using the celerity of the bed material wave (Li et al., 1988), the length of the subreach and the time period over which material is transported. Bed material and wash loads from the tributaries were computed in a similar manner and were added to the appropriate subreaches. Finally, the watershed sediment yield was added for each subreach. Under existing pre-project conditions, the routing analysis indicated that about 147,000 t/yr (86 ac-ft) would be transported to the dam site. With the dam in place, the annual sediment delivery is reduced to about 104,000 t/yr (51 ac-ft) because the bulk of the bed material load is derived from shale outcrop that will be inundated by the reservoir.

In order to identify the upper physical limit for the sediment yield to the reservoir, a hydraulic capacity-limited analysis was conducted which assumed that the sediment supply equaled the transport capacity, a condition that clearly does not apply to the NSR and its tributaries. The sediment-continuity analysis involved comparing the upstream and tributary supply to a given subreach with the computed hydraulic capacity. If the supply exceeded the capacity, deposition occurs and the supply to the next downstream subreach is limited by the capacity of the current subreach. If the capacity exceeds the supply, degradation is indicated and the deficit is balanced through erosion of the channel bed and banks. The analysis was carried out using the bed-material capacity rating curves for the mainstem NSR and for the primary tributaries, and the wash-load component was accounted for by adding the watershed fine sediment yields and the amount of wash load that would result from breakdown of the shale material. To be conservative, it was assumed that the upstream bed-material supply for each subreach completely breaks down to wash load (or sand), and that erosion of the channel bed and banks balances the reduction in sediment load, thereby maintaining a sediment load that equals the hydraulic capacity at the downstream limit of the subreach The continuity analysis indicated that the total volume delivered annually to the proposed dam site would be about 373,000 t/yr (184 ac-ft/yr) if there was an unlimited supply of bed material to the system. The sediment-continuity analysis was also carried out for with-dam conditions and indicated that the total sediment load deposited in the reservoir will be about 128,000 t/yr (63.3 ac-ft/yr).

In summary, under conservative assumptions regarding existing conditions in the watershed, and assuming that the channel is supply limited, which is the most appropriate assumption, based on the observed geomorphic conditions, the best estimate of annual sediment yield to the dam site under pre-project (without-dam) conditions is 85.9 ac-ft (174,000 tons). With the reservoir in place, the contributing watershed area is reduced as is the length of channel that is supplying sediment, and therefore, the annual sediment yield to the reservoir reduces to 51.4 ac-ft (104,000 tons). Therefore, the best conservative estimate of sediment delivery to the 160,235 ac-ft reservoir over the project life of 50 years is about 2,570 ac-ft which represents a loss of reservoir storage of approximately 1.6 percent over the project life. Under the assumptions of the worst case, and highly improbable, watershed (100 percent of the watershed under cultivation with no soil conservation measures) and channel sediment yields (transport capacity limited assumption) the estimated annual yield to the dam site is 217 ac-ft (439,000 tons). With the reservoir in place, this reduces to an annual yield of 74 ac-ft (150,000 tons). Therefore, the worst-case estimate of sediment delivery to the 160,235 ac-ft reservoir over the 50-year project life is about 3,700 ac-ft, which represents a loss of reservoir storage capacity of approximately 2.3 percent.

To put the estimated annual sediment yields at the dam site into perspective, a review was conducted of other sediment yield studies in the Blackland Prairie region of Texas (Table 5).

With the exception of the Simon et al. (2004) Ecoregion analysis 50th and 75th percentile values that were based on only six data points, and the highest suspended sediment value measured at the Talco gage (TDWB, 1974), when there was likely a much higher channel erosion component, the conservatively based best estimate of annual sediment yield is significantly higher than other reported data for the Texas Blackland region. The worst-case estimate significantly exceeds any measured or estimated values, and can be, therefore, considered to represent an upper limit that would encompass all likely sediment sources in the watershed.

Although the estimated sediment yields are conservatively high, the impacts of the sediment on the reservoir capacity are minimized by the low drainage area to reservoir capacity ratio for Lake Ralph Hall (Figure 4), the result of the historical channel degradation and widening.

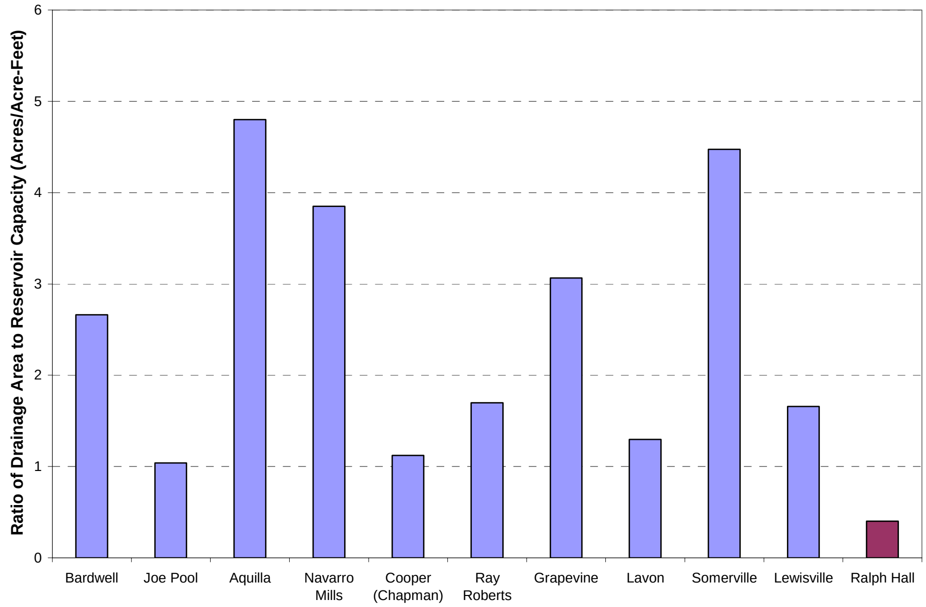

Figure 4. Drainage area to reservoir capacity ratios for reservoir in North Texas.

Table 5. Comparison of estimated sediment yields from Texas Blackland Prairie watersheds.

Source and Type of Data	Annual Sediment Yield at Dam Site (t/yr)	Unit Annual Sediment Yield (t/sq mi)	Unit Annual Sediment Yield (t/ac)	Annual Sediment Yield (ac-ft)
Best estimate	174,000	1,740	2.7	86
Worst-case estimate	439,000	4,390	6.9	217
Alan Plummer and Associates (2005) reservoir surveys	100,000	1,000	1.6	49
Greiner (1982) sheet, rill, gully and channel erosion	105,600	1,056	1.7	51
Simon et al. (2004) Blackland Ecoregion analysis	25th Perc. 25,500 50th Perc. 179,000 75th Perc. 375,300	255 1,790 3,753	0.4 2.8 5.9	13 88 188
Coonrod et al. (1998) suspended sediment yields in Texas watersheds	104,900	1,049	1.6	52
Texas Dept. Water Resources (1979) maximum suspended sediment load, Sulphur River at Talco, Texas (1968)	264,200	2,642	4.2	130
NRCS, Birket (1994) Mill Creek sediment analysis	108,220	1,082	1.7	53

CONCLUSIONS

The geomorphic, hydrologic, hydraulic and sediment-transport studies conducted for this investigation of the Lake Ralph Hall project allow the following to be concluded regarding sediment yield to the proposed reservoir:

1. The conservative estimate of total annual sediment yield to the dam site under pre-project conditions is 86 ac-ft (174,000 tons). With the reservoir in place, the contributing watershed area is reduced, as is the length of channel that is supplying sediment, and therefore, the total annual sediment yield to the reservoir reduces to 51 ac-ft (104,000 tons). Therefore, estimated sediment delivery to the 160,235-ac-ft reservoir over a 50-year period, assuming 100-percent trap efficiency, is about 2,570 ac-ft, which represents a loss of reservoir storage capacity of approximately 1.6 percent.
2. Under the assumptions of the worst-case watershed (100 percent of the watershed under cultivation with no soil conservation measures) and channel sediment yields (transport capacity limited assumption) the estimated total annual sediment yield to the dam site is 217 ac-ft (439,000 tons). With the reservoir in place, the worst-case reduces to an annual sediment yield to the reservoir of 74 ac-ft (150,000 tons). Under these circumstances, estimated sediment delivery to the 160,235 ac-ft reservoir over a 50-year period, assuming 100-percent trap efficiency, is about 3,700 ac-ft, which represents a loss of reservoir storage capacity of approximately 2.3 percent.

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