mean daily durations and flow volumes (Figure 3.10) for the dam site and the tributaries. One–dimensional HEC-RAS models were developed for the mainstem and for the major tributaries based on the 2-foot contour interval Digital Terrain Model (DTM) provided by CP&Y, and the models were calibrated to field-measured high-water marks for the 2002 (10-year event) and 2003 (25-year event) peak flows. Reach-averaged hydraulic output (effective width, hydraulic depth and average velocity) from the HEC-RAS models was used to compute sediment transport.

Field observations of the NSR and its tributaries indicated that in common with other incised streams, the morphological adjustments of the river and the larger tributaries can be described by a geomorphic model of incised channel evolution (Schumm et al., 1984; Simon and Hupp, 1986; Simon, 1989). A channel evolution model (NSRCEM) was developed for the NSR and its tributaries (Figure 2.19). The model varies substantially from those developed for alluvial streams (Figure 2.4) 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 (Figure 2.3). 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 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). It is likely that 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 applies equally to the larger tributaries that have eroded into the shale.

Between the FM 904 Bridge and the upstream end of the watershed, the NSR was subdivided into 10 subreaches (Table 2.2). Based on the NSRCEM, Subreaches 1 through 3 were classified as Type VI, Subreach 4 was classified as Type VII, Subreaches 5 through 8 were classified as Type VIII, and Subreaches 9 and 10 were classified as Type VII. Similar sequences are present in the larger tributaries. Incision in the headwaters of the NSR and the major north-side tributaries has been limited by outcrop of reasonably erosion resistant Roxton/Gober Chalk (Figure 2.2). Currently, the incised channel has the ability to convey in excess of the 100-year flood in-bank (Figures 2.5 through 2.18), the bed of the river is composed of shale, and therefore, the current supply of sediment to the channel is far less than the transport capacity.

The primary sources of bed-material-sized sediment are the exposed shale outcrops in the bed and banks of the river and the tributaries. Based on studies of the erosion of the shale (Allen et al., 2002; Crawford, in prep) and the results of analysis of stage-discharge rating curves for the Cooper gage (Figure 2.36) and comparative bridge profiles (Figure 2.34), erosion rates for shale exposed in the bed and banks of the channel are on the order of 2 to 4 in./year, respectively. Transport and slaking of the shale clasts results in a temporal and spatial transformation of initially gravel-sized material, which is transported as bed material, to silt-clay-sized wash load

(Figure 2.40) that has little or no morphological significance. At the upstream end of the NSR about 80 percent of the bed material that forms a thin veneer over in-situ shale slakes to silt-clay-sized material, whereas in the downstream reaches only about 10 percent of the bed-material slakes (Figure 2.42). Based on a supply-limited model of sediment-transport capacity, calibrated to the area of the bed covered by depositional bars, and incorporating the transformation of the bed material to wash load, the best estimate of sediment yield from channel sources to the dam site under pre-project conditions is 93,100 t/yr. Based on a somewhat unrealistic transport capacity-limited model, the worst-case estimate of sediment yield from channel sources to the dam site is 292,000 t/yr. With the dam in place, the best-case estimate of annual sediment yield from channel sources to the reservoir is 35,600 tons, and the worst–case estimate is 59,600 tons. The reduced amount of sediment is because the reservoir inundates a high proportion of the contributing channel area and eliminates it as a contributing source.

Estimates of the sheet-and-rill erosion on the watershed were developed with the Modified Universal Soil Equation (MUSLE) with appropriate parameters based on the subbasin topography and soil types (clays and loams) determined from the Soil Survey of Fannin County (NRCS, 2001). Application of the MUSLE with the appropriate parameters underestimated reported gross sheet-and-rill erosion rates on the Blackland Prairie soils (2 t/ac/yr), and therefore the alpha coefficient for the MUSLE was increased by a factor of 2.7. Ephemeral gully erosion for the cropland portions of the watershed 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). Sediment delivery ratios (SDR) for the sheet-and-rill erosion were estimated with Equation 5.4 (Renfro, 1975) that yields the highest SDR values. 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 with an assumption of 100-percent cropping in the watershed with a gross erosion rate of 3.74 t/ac/yr (Richardson, 1993). The best conservative 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. Under worst-case conditions 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. When placed in the context of reported sediment yields in the Blackland Prairie (Table 5.4), these estimates are very conservative especially because a 100 percent trap efficiency has been assumed for the reservoir.

Although estimated sediment yields to the Lake Ralph Hall reservoir are relatively low, the sediment yields could be further reduced by implementation of soil conservation measures on the watershed and by reducing the exposure of shale in the mainstem of the NSR and the tributaries between the upstream end of the conservation pool and the Roxton/Gober Chalk outcrop (Figure 2.2).

The potential downstream effects of the Lake Ralph Hall project on channel conditions and channel capacity are a concern. Potential problems could include sediment accumulation in the bed of the channel since operation of the reservoir will affect the magnitude and frequency of flows in the downstream channel, but will not affect sediment supply from the watershed, tributary and channel sources below the dam. Field and helicopter reconnaissance of the NSR from its confluence with the South Sulphur River to the headwaters indicates that the channel of the NSR is deeply incised for its entire length, and that the bed of the channel is composed of shale bedrock. Since the rates of bedrock erosion are controlled by the number of wetting and drying cycles (Allen et al., 2002), and not by hydraulic processes, the upstream dam is unlikely to have any effects on bedrock erosion rates. On an average annual basis, the shale will continue to erode vertically at a rate of about 2 inches per year and laterally at a rate of about 4 inches per year. Locally, near the mouths of some of the large tributaries downstream of the dam site (e.g., Hickory and Big Sandy Creeks) there are alternate bars in the bed of the channel, but these reflect local sediment supply and do not extend downstream for any distance. Under existing conditions, the best estimate of the annual total sediment yield to the dam site is about 174,000 tons (Figure 5.8), but only about 25 percent is composed of bed material, the remainder being wash load. Therefore, construction of the dam will reduce the morphologically-significant sediment yield to the channel downstream of the dam by about 25 percent, which will have an insignificant effect on the channel morphology in this sediment supply-limited system.

Based on the geologic map (Figure 2.2), and field observations, the characteristics of the shale exposed in the mainstem NSR and tributaries downstream of the dam site are similar to those upstream of the site, and therefore, it can be assumed that the sediment characteristics are also similar. This being the case, the bulk of the sediments being delivered to the NSR by the tributaries downstream of the dam will be composed of shale clasts that break down into wash-load size materials as they are exposed to transport and weathering processes (slaking). Furthermore, the NSR is a supply-limited system that has the capacity to transport considerably more bed material than is currently being supplied to the channel. Consequently, it is unlikely that significant amounts of sediment will accumulate in the bed of the river downstream of the dam. If sediment accumulation does occur it is highly unlikely that there will be significant loss of channel capacity. Even with the loss of channel capacity, flows far greater than the 100-year flood peak can be conveyed in-bank.

7.2. 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:

1. Channelization-induced degradation and widening of the NSR and its principal tributaries upstream of the dam site has resulted in the erosion of about 28M tons of sediment since the late 1920s. Current channel erosion rates are controlled by slaking rates of the exposed shale and not by hydraulic processes and are, therefore, less than historic rates.
2. 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.
3. 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.
4. In the absence of the Lake Ralph Hall project there will be continued erosion of the NSR and its tributaries. On average, where shale is exposed in the bed and banks of the channels, the channel depth will increase by about 8 feet and the channel bottom widths will increase by about 16 feet over a 50-year period. Increased channel depths are also

likely to cause further mass failure of the alluvial portions of the banks, thereby increasing channel top widths, as well.

5. No adverse downstream impacts on channel morphology or capacity are expected as a result of sediment trapping in the reservoir, or operation of the reservoir.

6. Watershed sediment yields could be reduced by implementation of best soil conservation management practices, reduction in the area under cultivation and re-establishment of riparian buffer areas along the channel margins where they have been cleared.

7. Channel sediment yields between the elevation of the top of the conservation pool and the downstream extent of the Roxton/Gober Chalk could be reduced by construction of in-channel structures that pond water and prevent weathering of the shale outcrop. Given the existing hydraulic capacity of the channels there is little likelihood that the in-channel structures would cause out-of-bank flooding.

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APPENDICES
(see enclosed CD)

APPENDIX A
Photographs of North Sulphur River and Tributaries

APPENDIX B
Sediment Sample Analysis Report (Kleinfelder, 2006)

APPENDIX C
HEC-1 Models for the Mainstem North Sulphur River and the Primary Tributaries

APPENDIX D
HEC-RAS Models for the Mainstem North Sulphur River and the Primary Tributaries

APPENDIX E
Fine Sediment Yield Calculations (Best Estimate and Worst Case; Existing Conditions)

APPENDIX F

Responses to Peer Review Prepared by Drs. Craig MacRae and Peter Allen

Mussetter
Engineering
Inc.

Consultants in
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Engineering Geomorphology

October 23, 2006

Mr. John Levitt, P.E.
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Re: Responses to Peer Review Prepared by Drs. Craig MacRae and Peter Allen

Dear Mr. Levitt:

We have reviewed the Peer Review comments on our Geomorphic and Sedimentation Evaluation of North Sulphur River and Tributaries for the Lake Ralph Hall Dam Project that were prepared by Dr. Craig MacRae of Aquafor Beech Limited, and Dr. Peter Allen of Baylor University. Our responses are keyed to the comments in their review, and are provided below.

2.0. FUNCTIONALITY OF REPORT

1. Explanation expanded in Section 3.1.3., p.3.1. In the absence of any other data, we assumed that the wetting–drying cycles recorded at the Cooper gage could be applied to the main stem North Sulphur River and tributaries. Figure 2.3 has been simplified to better reflect wet-dry cycles at the Cooper gage.

2. All calculations for watershed and channel sediment yields have been provided in Appendix E.

3. Gully erosion certainly exists in the watershed upstream of the dam, but was not quantified. Given the conservative nature of our sediment yield estimates, we believe that sediment yield as a result of gullying in the watershed upstream of the dam site is probably accounted for.

4. The locations of the Roxton/Gober Chalk outcrop were mapped in the field and are shown on Figure 2.2.

5. Review of the Harmel et al. (2006) and Baird and Richardson (1970) work does provide some insight into the under prediction of the USGS regression relations, but does not account for the magnitude of the difference. It is also likely that the incised nature of the mainstem and tributaries affects the time of concentration and thus increases the flood peaks.

6a. An Executive Summary has been added to the report.

6b. Table 5.1 contains the drainage area and slope data and has been cross referenced with Figure 3.8 on page 3.13.

6c. Figure 2.37 has been cross referenced in the report.

6d. Geologic units of interest to the study are shown on Figure 2.1.

6e. All cross sections have been plotted at same scale and have been replaced in the text.

7. Figures 2.5 through 2.18 have been left in the text.

8. The discussion in Section 2.2.2.1 has been expanded to differentiate between alluvial and bedrock controlled channels. The effects of the bedrock control are clearly shown in Figure 2.19 and are discussed in the accompanying text. The lower erodibility of the Taylor materials in comparison to the overlying alluvial materials is responsible for the "funnel" shape of the cross sections in the bedrock controlled reaches.

3.0 TECHNICAL DISCUSSION

3.1. Sediment Yield

1. Table 5.4 was added to reflect the range of measured sediment yields in the Blackland Prairie region, and to put the computed estimated values in this report into perspective. We concur that the range of MEI estimated yields are higher than those reported in the literature, and support the conservative nature of the MEI analysis.

2. Watershed sediment yields for all of the tributaries upstream of the dam site were computed, but bed-material loads were only computed for the larger tributaries for which HEC-RAS models were developed. Regression relations between computed bed-material yield and drainage area were developed for the modeled tributaries that incorporated one south-side tributary, Long Creek. The regression equation (5.8) with an R^2 value of 0.9 was used to estimate bed material yields for the smaller un-modeled tributaries (Section 5.2.2.).

3.2. Rates of Degradation

We concur with the discussion of the mechanisms for, and rates of degradation of the exposed bedrock.

3.3. Erosion Hazard for the South and North Slope Tributaries

1. We agree that there are mass failures of the banks on the south side tributaries, but similar mass failures were also observed on the north side

tributaries. In general, the south side tributaries are smaller than the north side tributaries and therefore the sediment yields are likely to be lower. With the exception of Long Creek, the smaller south side tributaries were not hydraulically modeled, but bed material yields were computed with a regression equation developed from estimated yields from the north side tributaries (Section 5.2.2). The estimated bed material yield for Long Creek was very similar to those from the north side tributaries. In the absence of further data to the contrary, we have not differentiated between the north and south side tributary sediment yields.

2. Grading and revegetation of the banks of all the tributaries will reduce the potential for reservoir-related erosion and this is addressed in Section 6.1.

3.4. Downstream Impacts

Currently, only about 25 percent of the estimated total sediment load delivered to the dam site from upstream is composed of bed material. The remainder is wash load and this fraction has little or no morphological significance on the downstream channel morphology. While reductions in sediment delivery downstream of the dam can cause channel changes, the nature and magnitude of the channel changes depends on the relative magnitude of the change in effective sediment supply and the nature of the channel bed material downstream of the dam (Williams, G.P. and Wolman, M.G., 1984. Downstream Effects of Dams on Alluvial Rivers. USGS Professional Paper 1286). Given that the bed of the North Sulphur River downstream of the dam is composed of bedrock, it is apparent that the transport capacity of the river greatly exceeds the bed material supply under existing conditions. Therefore, a 25 percent reduction in the bed material supply is unlikely to have any significant effects on downstream channel erosion rates, especially since erosion rates in the bedrock are primarily controlled by weathering rates and not hydraulic processes. Reduction in the bed-load supply could reduce the covered area of the bed for some distance downstream of the dam and this could locally increase the rate of bedrock weathering. However, field observation did not indicate that the sediment veneer over the shale had an observable impact on the shale weathering rate.

We agree that the observations of the lack of effect of the dam on the alluvial channel of the South Sulphur River are probably inapplicable to the North Sulphur River given the great differences in the boundary materials.

3.5. MUSLE

Local experience in the Blackland Prairie region (R. Moore, NRCS, pers. Communication, 2006) indicates that the MUSLE model does not estimate ephemeral gully erosion very well in that region. Consequently, to preserve the conservative nature of the watershed sediment yield estimates, we conducted a separate calculation for ephemeral gully erosion rates.

4.0. SUPPLEMENTARY INFORMATION

The supplemental morphometric relations developed from field measurements of the tributaries and from plotted cross sections of the main stem in the report do confirm the general relations between channel width and depth and support the channel evolution models discussed in the report. However, without considerably more investigation and a larger data set, the height-width relations should be used with caution to predict future channel widths in the tributaries in the absence of the project and with the project in place. Where the channels have incised into the shale future channel widening is governed by the rate of lateral erosion of the shale, and field observations suggest that top bank erosion and channel widening in the overlying alluvium is limited by the relatively erosion resistant shale toe, which results in a funnel-shaped cross section. Over a long enough period of time the width-depth relations will apply, but until the temporal lag factor has been identified, the relations should be used for predictive purposes with caution.

Sincerely,

MUSSETTER ENGINEERING, INC.

Michael D. Harvey, Ph.D., P.G.
Principal Geomorphologist

MDH/bbv
Enclosure

APPENDIX G

Review of Mussetter Engineering, Inc.'s Geomorphic and Sedimentation Evaluation of North Sulphur River and Tributaries for the Lake Ralph Hall Project

By Aquafor Beech Limited in Association with Dr. Peter Allen

Aquafor Beech Limited

October 16, 2006

Chiang, Patel & Yerby, Inc.
1820 Regal Row
Suite 200
Dallas, Texas
75235

Attn: Mr. John Levitt, P.E.

Re: Review of Draft Report Entitled "Geomorphic and Sedimentation Evaluation of North Sulphur River and Tributaries for the Lake Ralph Hall Dam Project" prepared by Mussetter Engineering Incorporated.

Dear Mr. Levitt,

Please find attached a review of the above mentioned Report prepared by Drs. MacRae and Allen.

The North Sulphur River is one of the most interesting Rivers we have had the opportunity to study. Given the complex nature of the River's morphology we found the Report by Mussetter to be well written and a reasonable interpretation of the fluvial system.

It was a pleasure to have worked with you on this project.

Yours truly,

Craig MacRae
Senior Associate
Aquafor Beech Limited
920 Princess Street
Kingston, Ontario
K7L-1H1

Review of
Draft Report Entitled:

"Geomorphic and Sedimentation Evaluation of North Sulphur River and Tributaries for the Ralph Hall Lake Dam Project"

Authored By:

Mussetter Engineering Incorporated

Submitted To:

Chiang, Patel & Yerby Incorporated.

Prepared By

Aquafor Beech Limited

In Association With

Dr. Peter Allen

For

Chiang, Patel & Yerby Incorporated.

October 16, 2006

Project No.: 64670

4.0 SUPPLEMENTARY INFORMATION

Data characterizing hydraulic geometry attributes of the tributary channels were collected during the field reconnaissance to supplement data collected for the main stem of the North Sulphur River as presented in the Report. The supplementary information may be used to:

1. Document evidence of the magnitude of downcutting at selected locations;
2. Provide insight into models of channel evolution; and,
3. Provide a basis for estimation of sediment loadings from the tributary channels to the North Sulphur River.

Supplementary data includes the following measurements:

a) The top width of the floodplain channel (TW);
b) The height to Top of Bank of the floodplain channel (H);
c) The bottom width of the floodplain channel (B);
d) The width of the active channel at the depth of the dominant discharge (W_{BFL});
e) The depth of the dominant discharge (d_{BLF});
f) The bottom width of the active channel (W_{BED});
g) The slope of the bank (S_b) recorded for the left and right banks of the active and floodplain channels.

Distinct differences in channel form were observed based on the degree of incision into bedrock as noted in the Report. Consequently the channels can grouped into two main classes:

A) Those channels worn into alluvial materials; and,
B) Those channels that have downcut through the alluvium into the underlying bedrock, represented primarily by the Taylor Group of materials.

The later group was further differentiated into:

a. Those channels having contacted the Taylor materials but the depth of incision, for at least one bank, was $d<0.3d_{BFL}$ (where d_{BFL} represents the depth of flow for the dominant discharge). These channels are referred to herein as Rock Bed (RB-Type) channels; and,
b. Those channels where the depth of downcutting into the Taylor Group of materials is $d=0.3d_{BFL}$ for both banks. These channels are referred to herein as Bedrock Controlled (RC-Type).

Definition sketches for the above parameters are provided in Figures 4.1 and 4.2 for channels worn into alluvium and Taylor materials respectively.

In addition to the above observations documenting downcutting were noted along with bank material type and evidence of bank failure through slaking or slumping.

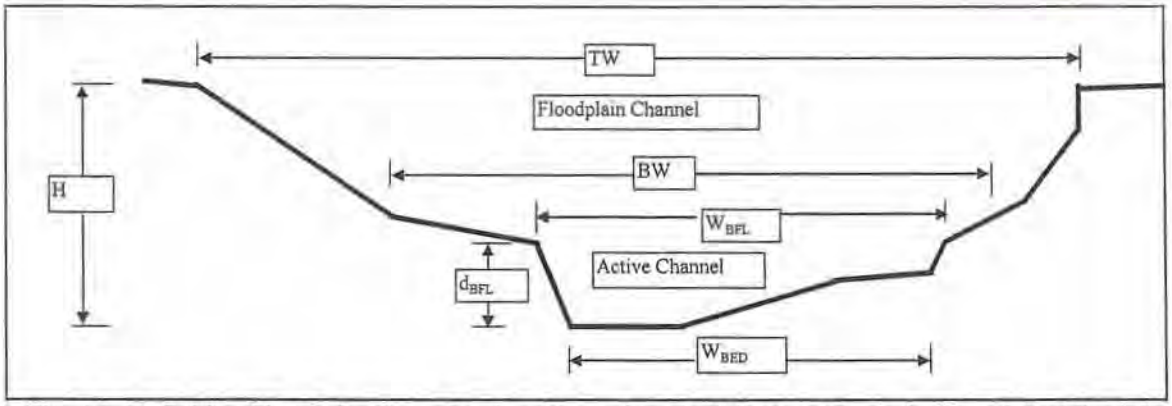

Fig. 4.1. Definition Sketch for Cross-Section Dimensions in Tributary Channels Worn into Alluvial Materials (AL-Type channels).

Supplementary observations were recorded at 23 selected locations as indicated in Table 4.1. One of the survey sites was recorded on the main stem of the North Sulphur River (Site2). One other survey site was located on a remnant of the pre-channelized main stem of the North Sulphur River (Site 1). The remaining survey sites were located on tributaries of the North Sulphur River. Sites 3 through 12 and Sites 17 and 18 are located on the north side of the River while Sites 13 through 16 are located on the south side.

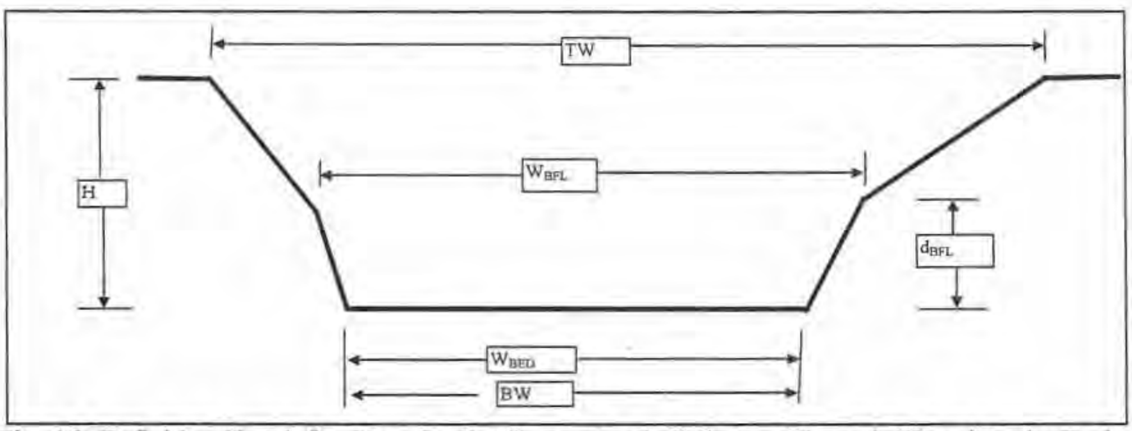

Fig. 4.2. Definition Sketch for Cross-Section Parameters in Tributary Channels Worn into the Taylor Group (RB-Type and RC-Type channels).

The hydraulic geometry relationships for the tributary channels and Site 1 are provided in Figures 4.3, 4.4 and 4.5. The relationship between Height to Top of Bank (H) and Bottom Width (BW) is illustrated in Figure 4.3. The square of the coefficient of calibration (R^2=0.37) for the fitted line is relatively poor. However relationships between H and channel Top Width (TW, Fig. 4.4) and Top Width with Bottom Width (Fig. 4.5) were found to be R^2=0.67 (fair) and R^2=0.73 (good) respectively.

Table 4.1. Summary of Supplementary Field Survey Site Location and Channel Type

Site ID	Location			Channel Type				
	Latitude	Longitude	Description	Main	Tributary	Classification		
						AL	RB	RC
1	33°27.257'	095°56.463'	Pre-channelization remnant of N. Sulphur R. south of current main channel d/s of culvert under Highway 34	?		?		
2	33°27.390'	095°56.531'	N. Sulphur R. u/s of Highway 34 Bridge	?				?
3	33°27.517'	095°56.544'	Small unnamed tributary north of N. Sulphur R. d/s of culvert under Highway 34		?	?		
4	33°27.524'	095°56.555'	Small unnamed tributary north of N. Sulphur R. u/s of culvert under Highway 34		?	?		
5			Merrill Creek 609 ft d/s of County Rd 1550 Bridge		?			?
6	33°28.888'	095°56.463'	Bralley Ck. 90 ft d/s of County Rd. 1550		?			?
7a	33°29.259'	095°58.014'	Davis Ck. 203 ft d/s of County Rd. 1550		?			?
7b			Davis Ck. 150 ft d/s of County Rd. 1550		?			?
7c			Davis Ck. 50 ft d/s of County Rd. 1550		?			?
8a	33°29.240'	095°58.692'	Leggets Br. 220 ft d/s of County Rd. 1550		?	?		
8b			Leggets Br. 250 ft d/s of County Rd. 1550		?	?		
9	33°29.265'	095°59.735'	Davis Ck. 200 ft d/s of County Rd. 1550		?		?	
10a	33°29.314'	095°59.738'	Davis Ck. tributary 30 ft u/s of culvert under County Rd. 1550		?	?		
10b			Davis Ck. tributary 20 ft d/s of culvert under County Rd. 1550		?		?	
11a	33°29.288'	096°00.777'	Pickle Ck. 400 ft d/s of County Rd. 1550		?	?		
11b			Pickle Ck. u/s of culvert		?	?		
12			Bushy Ck. d/s of County Rd. 1550		?		?	
13	33°26.421'	095°56.161'	Unnamed tributary 60 ft. u/s of County Rd. 3540 east of Highway 34		?	?		
14			Unnamed tributary 40 ft d/s of culvert under County Rd. 3640 east of Highway 34		?	?		
15	33°26.867'	095°55.296'	Unnamed tributary d/s of County Rd. 3640 near Pleasant Grove Cemetery		?		?	
16	33°26.867'	095°55.296'	Hedrick Br. 300 ft u/s of County Rd. 3640		?	?		
17			Pot Ck 60 ft d/s of County Rd 3330		?			?
18	33°28.614'	095°03.518'	Pot Ck 180 ft u/s of Gober Outcrop		?			?

Figures 4.6 and 4.7 illustrate relationships for cross-section parameters for the active channel for all channel Types. The relationships as represented using the square of the coefficient of calibration ranged from fair for Bankfull Width (W_{BFL}) as a function of the depth of the dominant discharge (d_{BFL}, Fig. 4.6) to very good for W_{BFL} as a function of Bed Width (W_{BED}, Fig. 4.7). The inclusion of all channel Types explains some of the scatter observed in the plots because of differences in the width:depth (W_{BFL}/d_{BFL}) ratios. The average values for the width:depth ratios were W_{BFL}/d_{BFL} =5.7, 7.9 and 11.1 ft for AL-Type, RB-Type and RC-Type respectively. Consequently it is possible that stronger relationships could be developed based on channel Type given a larger data base.

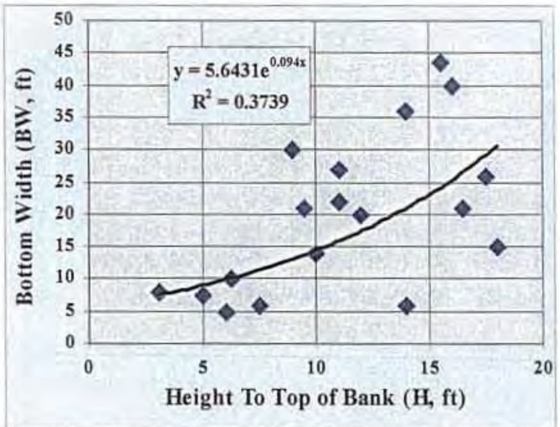

Fig. 4.3. Relationship Between Bottom Width and Height to Top of Bank For AL-Type Channels Tributary to the North Sulphur

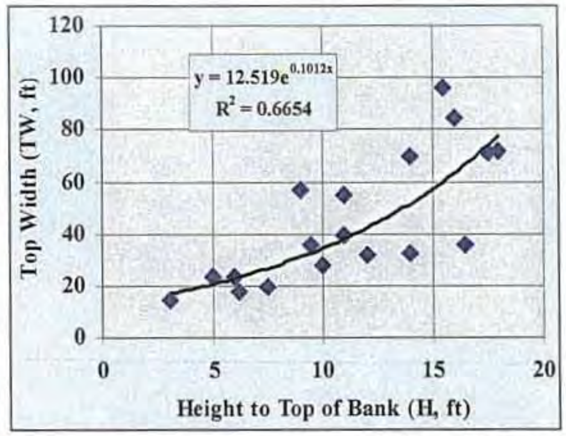

Fig. 4.4. Relationship Between Top Width and Height to Top of Bank for AL-Type Channels Tributary to River. the North Sulphur River.

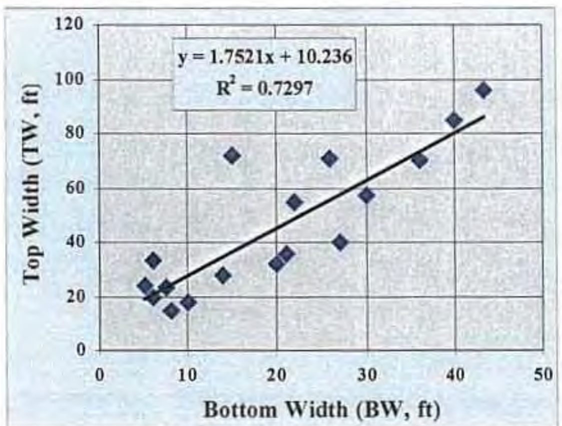

Fig. 4.5. Relationship Between Top Width and Bottom Width for AL-Type Channels Tributary to the North Sulphur River.

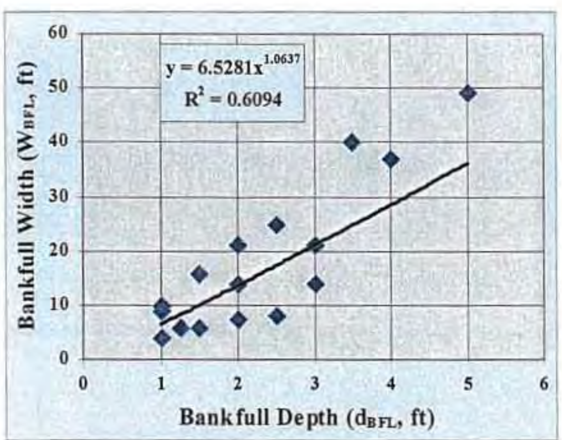

Fig. 4.6. Relationship Between Bankfull Depth And Bankfull Width For the Active Channels Tributary to the North Sulphur River

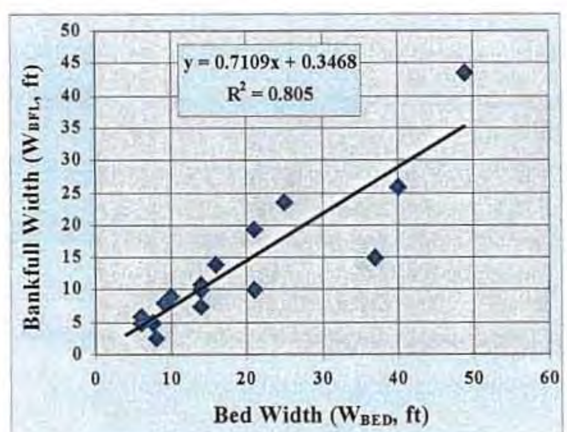

Fig. 4.7. Relationship Between Bed Width And Bankfull Width For the Active Channels Tributary to the North Sulphur River.

The relationship between the floodplain channel and active channel as represented by Top Width (TW) as a function of bankfull width (W_{BFL}) was found to be fair (Fig. 4.8).

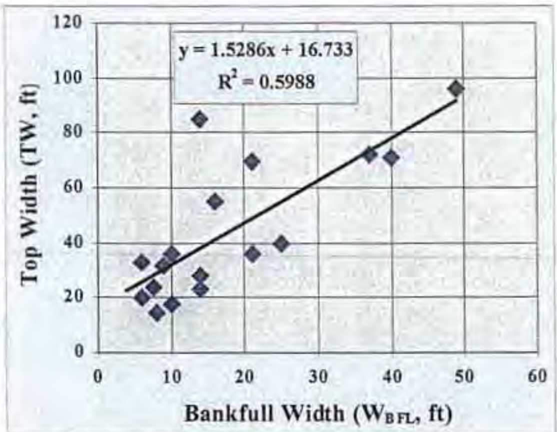

Fig. 4.8. Top Width of the Floodplain Channel as a Function of Bankfull Width of the Active Channel For Tributaries of the North Sulphur River.

The tributary observations represent small scale channel systems relative to the main stem of the North Sulphur River. Combining the data sets broadens the spatial scale for examination of possible relationships. Potential relationships as presented in Figures 4.9 through 4.11 were very good to excellent. The data for the main stem of the North Sulphur River were obtained from Site 2 reported above and Figures 2.5 through 2.18 of the Mussetter Report.

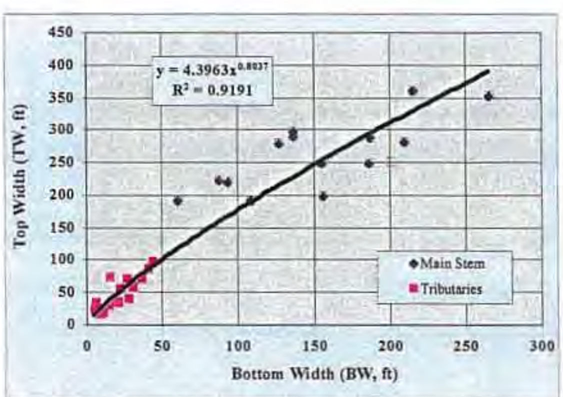

Fig. 4.9. Top Width of the Floodplain Channel as a Function of Bottom Width for the North Sulphur River Upstream of the Proposed Dam.

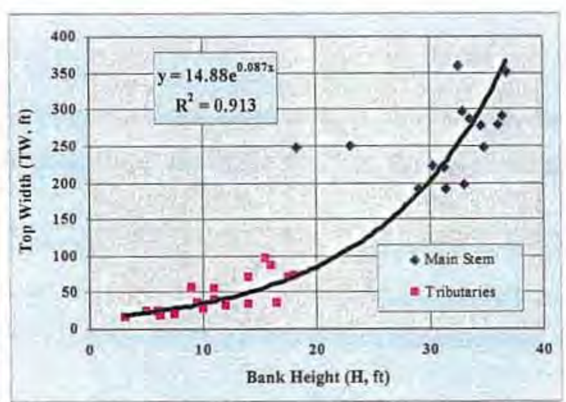

Fig. 4.10. Top Width of the Floodplain Channel as a Function of Bank Height for the North Sulphur River Upstream of the Proposed Lake Ralph Hall Dam

The relationships illustrated in Figs. 4.9 through 4.11 suggest that the North Sulphur River is behaving in a predictable and consistent manner. Further, it is possible to predict the evolution of channel morphology in the tributary channels based on behavior of the main stem of the North Sulphur River. Consequently the channel evolution models applied to the main stem of the River are applicable to the tributary channels.

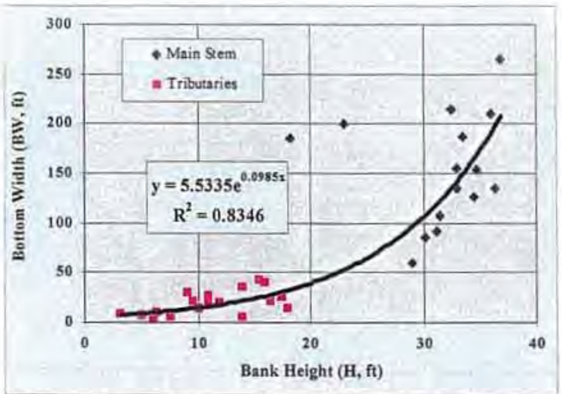

Fig. 4.11. Bottom Width as a Function of Bank Height for the North Sulphur River and Tributary Channels Upstream of the Proposed Lake Ralph Hall Dam.

Some of the scatter observed in the relationships presented above is related to differences in the resistance of the boundary materials, stratification, groundwater characteristics, aspect, livestock access and the type, density and distribution of riparian vegetation among other factors. Differences in boundary material resistance may be approximated by the slope of the banks of the channel as presented in Figures 4.12, 4.13 and 4.14.

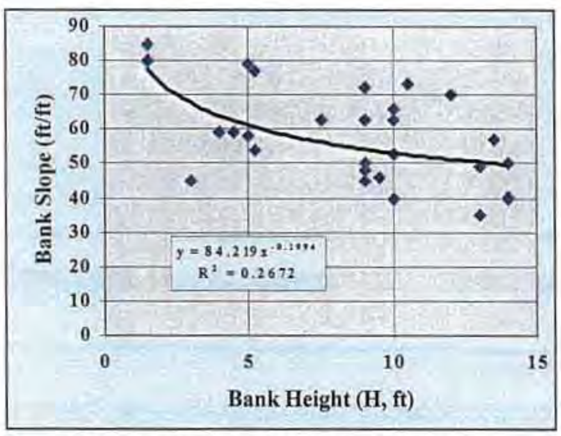

Fig. 4.12. Bank Slope As A Function Of Bank Height For AL-Type Tributary Channels To The North Sulphur River Upstream Of The Proposed Lake Ralph Hall Dam.

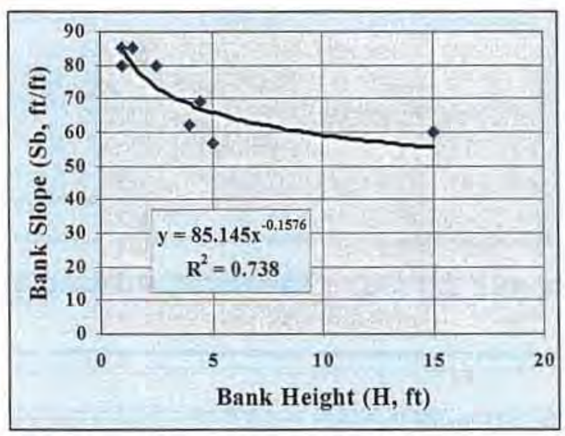

Fig. 4.13. Bank Slope As A Function Of Bank Height For RB- And RC-Type Tributary Channels To The North Sulphur River Upstream Of The Proposed Lake Ralph Hall Dam.

The relationships in Figs. 4.12 through 4.14 suggest that bank slope decreases with bank height, which is also a surrogate variable for decreasing effectiveness of root binding associated with riparian vegetation. Although the number of observations is limited the data provides a means to approximate the change in bank slope with degradation.

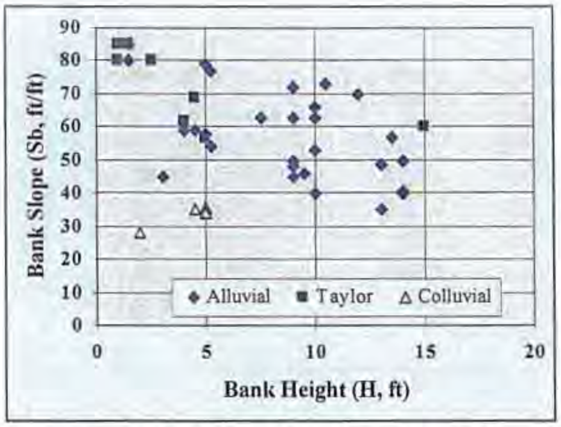

Fig. 4.14. Comparison of Bank Slope For AL-Type and RB- and RC-Type Channels Worn Into the Taylor Group of Materials and Colluvial Deposits.

The relationships presented above may be used to predict changes in channel form through time knowing the rate of downcutting. Downcutting may be approximated as noted in the Report using historic cross-section and sediment yields as well as literature values noted in this review. Supplementary data from which rates of downcutting in the tributary channels may be derived was also collected during the field reconnaissance as reported below.

Site 3: The depth of downcutting at Site 3, a small unnamed tributary crossing under Highway 34 north of the main stem of the North Sulphur River was estimated to be 7 feet below the culvert invert Fig. 4.15. Gabions and a concrete splash pad have been installed beneath the original culvert invert with the top of the new splash pad 5 feet below the original invert elevation. The channel has subsequently downcut and estimated 2 feet below the invert of the new splash pad. Knowing the dates of construction of the original culvert and new splash pad would allow for estimation of downcutting over this interval. A second rate may be obtained over the interval between construction of the new splash pad and the current date.

The incision of the channel downstream of the culvert is contrasted by a scour pool of approximately 0.5 feet in depth upstream of the culvert (Site 4).

Site 7b: Post-settlement alluvial deposits were observed in the upper bank region of Davis Creek at Site 7b. These deposits represent the probable elevation of the thalweg at the time of channelization of the main stem of the North Sulphur River. The deposits were observed 6 feet below the top of bank, 18 feet above the current channel thalweg representing a probable depth of incision of 12 feet.

Site 7c: Concrete from the old bridge buried in granular material was exposed in the bank of the active channel. The stratum containing the concrete was approximately 1.5 feet thick. The channel has downcut through this unit and 3 feet into the underlying Taylor material. If the date of replacement of the bridge on County Road 1550 is known then the rate of downcutting can be approximated.

Site 10b: The thalweg of Davis Creek immediately downstream of the culvert at County Road 1550 is approximately 10 feet below the culvert invert. The channel has cut through 8 feet of alluvium and 2 feet into the underlying Taylor shale.

Site 11b: The thalweg of Pickle Creek 48 feet downstream of culvert under County Road 1550 is 5 feet below the invert of the culvert.

5.0 CONCLUSIONS

In summary the Mussetter report was found to be an insightful, comprehensive, and well documented overview of past and current erosion processes as well as future erosion potential and morphologic evolution of the upper North Sulphur River (NSR). This represented a unique challenge because the River does not conform to the majority of Blackland Prairie channel systems. Indeed the North Sulphur River is infamous in North Texas for the dramatic stream erosion/degradation that has occurred over the past 75 years due to past channelization projects. Deciphering its history is difficult owing to disaggregated data and often poor historical records. However this Report provides a fair, descriptive story of the erosion history and quantitative assessment of erosion potential for the upper North Sulphur River watershed.

A summary of major points discussed in Section 3.0 Technical Review is provided below.

Section 3.1: Given the rates of erosion in the Blackland in reservoir studies, gage data, and assumptions provided in the text, and our limited field observations in the North Sulphur River Basin, the cited 1630 tons per square mile per year appears to be a reasonable estimate of future erosion rates in the basin. The worse case scenario cited by the Mussetter report of 4280 tons per square mile appears to be a reasonable upper limit for erosion in this watershed given the cited information and past studies by the authors.

More extensive quantification of the tributary contribution to the estimate of sediment yield would help substantiate the values in the Report. Our preliminary field assessment indicates that there is a predictable continuum from the tributaries to the main channel which could be useful in this explanation of the future impacts of tributary erosion in the watershed.

Section 3.2: Slaking is the limiting factor in controlling the rate of future degradation in this climatic regime of seasonal wetting and drying and shale bed material. It follows that mitigation measures for the control of erosion must prevent exposure of the shales to the elements. This may be achieved either through burial or submergence of the Taylor materials.

Much of the work done by Dr. Allen and others on sedimentary rock incision supports the rates of degradation cited by the Mussetter Report; in the range of 1-3 inches per year.

Section 3.3: Mitigation measures such as grading and planting the banks along the shoreline of the proposed lake and other forms of toe control could significantly reduce the sediment yield associated with mass failure of the banks and reduce the sediment loads entering the proposed reservoir. There are numerous reservoirs already built which are in such shale terrain that could be studied and used to assess the magnitude of this potential problem prior to design.

When estimating sediment yields to the North Sulphur River it may be advisable to differentiate between the north and south side tributaries.

Section 3.4: More explanation of the potential effects on the receiving channel downstream of the project is warranted.

Section 3.5: If the MULSE model is typically thought to include ephemeral gully erosion 5.1.3 then the procedure used in the report would tend to be conservative or overestimate sediment yield.

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