WORKING PAPER #5

STREAM RESTORATION FOR FLOOD DAMAGE REDUCTION IN THE RED RIVER

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Historical Context

Prior to settlement,* streams of the Red River Basin (RRB) had sinuous meandering channels with corridors of riparian vegetation and diverse fish and wildlife communities. Riparian corridors of larger rivers in the Aggasiz lake bed were forested and generally corresponded to meander belt width while smaller streams were buffered by wetland and prairie vegetation (based on original surveys by the Trygg Land Office and Woolman, 1895). Sinuous deep streams with close connections to vegetated flood plains are the most geomorphically stable channel type for low relief landscapes (Rosgen 1996) and are typical in areas with geology similar to the Red River Basin. Historic fish assemblages in these streams were similar to present communities in the less altered reaches of the RRB but included some species such as the lake sturgeon which are now extirpated from the U.S. portion of the RRB (based on writings of Alexander Henry who explored the area around 1800 and Woolman, 1895). Water clarity in the late 1800s was apparently greater than present for many of the lakes and streams in the RRB while the Red itself was described as "turbid" or "muddy" similar to present day descriptions (Woolman, 1895).

While the historic RRB was well suited to fish and wildlife, it presented significant drainage and flooding problems for early farmers. Since settlement, numerous channels have been constructed or modified in the Red River Basin. As an economical means of providing drainage for agricultural lands, straight channels were constructed through areas where large marshes once existed. Some of these areas had meandering channels entering and leaving the marsh but no definable channel within the marsh. Channelization of existing stream channels was done primarily to provide flood damage reduction to agricultural lands by increasing the capacity and conveyance of the channel.

While early channel work generally met the goals of land drainage and flood damage reduction for adjacent land owners, it also had some unintended and often undesireable effects to natural resource values and downstream interests. Hydraulic effects include:

- increased hydraulic conveyance
- reduced flood storage

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* As used herein, settlement refers to european settlement

- reduced time of concentration
- increased peak flows directly downstream of the channelized reach

Natural resource effects include:

- substantial loss of aquatic habitat
- degraded water quality
- increased rate of erosion
- increased rate of sedimentation

While rationale for channelization was generally related to drainage or flood damage reduction, these local benefits may be counterbalanced by downstream flood damages associated with higher peak flows and increased sediment supply which can cause aggradation of the stream bed.

The Approach

The proposed approach for restoration of streams as a flood damage reduction approach would involve:

1) reconstruction of the channel using dimensions, patterns, and profiles derived from stable reference reaches in the watershed and regional reference data for stable stream reaches (Appendix), or by reconnecting isolated oxbows if present,

2) revegetating the riparian corridor and stabilizing the new stream banks by establishing bank vegetation and, where appropriate, using tree revettments or rock vanes as described by Rosgen (1996),

3) construction of setback levees outside of the meander belt with top elevations corresponding to a 10 year event,

4) optional construction of off-channel storage areas outside the levees.

For most sites in the basin reconstructed channels would be designed to have a low width:depth ratios, high sinuousity, and riffle/pool sequences. Channels of this type tend to have the greatest sediment carrying capacity and stability (Rosgen, personal communications), and diverse, high quality aquatic habitat. Specific dimensions would be based on site specific measurements. For stable stream reaches measured in the RRB, meander belt widths range from 5 to 21 times the bankfull width.

Off-channel storage areas could be designed to sequentially fill as the 10 year event (or other protection event) is exceeded. This would have the advantage of only flooding the area needed to store a given event. Design constraints for these storage areas would depend on specific hydrology, topography, and landowner interests.

Benefits of this approach would be multifaceted and include both flood damage and resource related aspects.

Flood related benefits include:

1) protection of adjacent farmland outside of setback levees for events up to a 10-year flood,

2) elimination of flood damages adjacent to stream by conversion to non-flood prone land uses,

3) increased channel storage,

4) more efficient use of flood plain storage during large events as areas outside of the setback levees would be reserved for flows greater than 10 year stage,

5) reduction or elimination of maintenance costs due to stable channel design and the ability of channel to move incoming sediment

Resource related benefits include:

1) restoration of diverse aquatic habitat for fish, mussels and other invertebrates, amphibians, reptiles, birds, mammals, etc. The restored channels would provide riffle/pool sequences and a variety of instream habitats which are key to the productivity and diversity of aquatic communities.

2) restoration of wetland and wooded riparian habitat associated with the river corridor. This would provide habitat connections for deer, small game, song birds and numerous species which depend on these migratory pathways. This corridor would eventually provide harvestable timber, old growth and snag habitat for both aquatic and terrestrial species.

3) substantially reduced bank erosion, sediment supply, and soil loss

4) improved water quality due to reduced erosion and buffered field runoff,

In some cases, straight channels were constructed in areas which were once large marshes and no channel was present historically. Even though these types of ditches did not replace natural channels, the principals of fluvial geomorphology still apply and conversion to a meandering channel would have similar benefits.

Potential problems with setback levees

The primary disadvantage of this approach is that currently farmed areas within close proximity to the stream would have to be taken out of production. The significance of this to the land owner would depend on productivity of those areas, the extent of flood damages, the intrinsic value of a restored stream and stream corridor to the landowner, and the availability of programs such as CRP or other non-floodprone means of obtaining income from those areas between the setback levees.

As with any flood control project, low levels of flood protection can induce future damages by inducing developement in the protected area. Appropriate floodplain zoning of protected areas should continue to be enforced to eliminate those damages. Farmsteads and urban areas should be provided with higher levels of protection to prevent future catrostrophic damages.

The setback levees may also create local drainage problems landward of the levees. This problem can be adressed by designing overflow areas on the levees to allow water to renter the channel at the downstream end of each section, with specific provisions for off-channel storage areas, or with flap-gated culverts which allow local drainage prior the stream's flood peak.

Feasibility and appropriate locations

Feasibility of channel restoration as a flood damage reduction strategy is probably greatest in low gradient reaches of straight streams (channelized or created waterways) where large areas of adjacent lands are flood prone. Locations which fit this description are widespread in the lake bed below the beach ridge and interlake regions of the valley. In terms of resource gains, the benefits would apply anywhere stream reaches are degraded but would generally be greatest in streams with larger drainage areas and perenial flows.

Another consideration is the presence of clay soils which would allow use of material excavated for channel construction in construction of setback levees. These soils are present over much of the Aggasiz Lake Bed Region. Excavation and fill quantities could be balanced by small adjustments in channel sinuosity and size of excavated riparian wetlands.

Case Example

A proposed restoration for Hay Creek is attached as a case example of this approach in the Red River Basin.

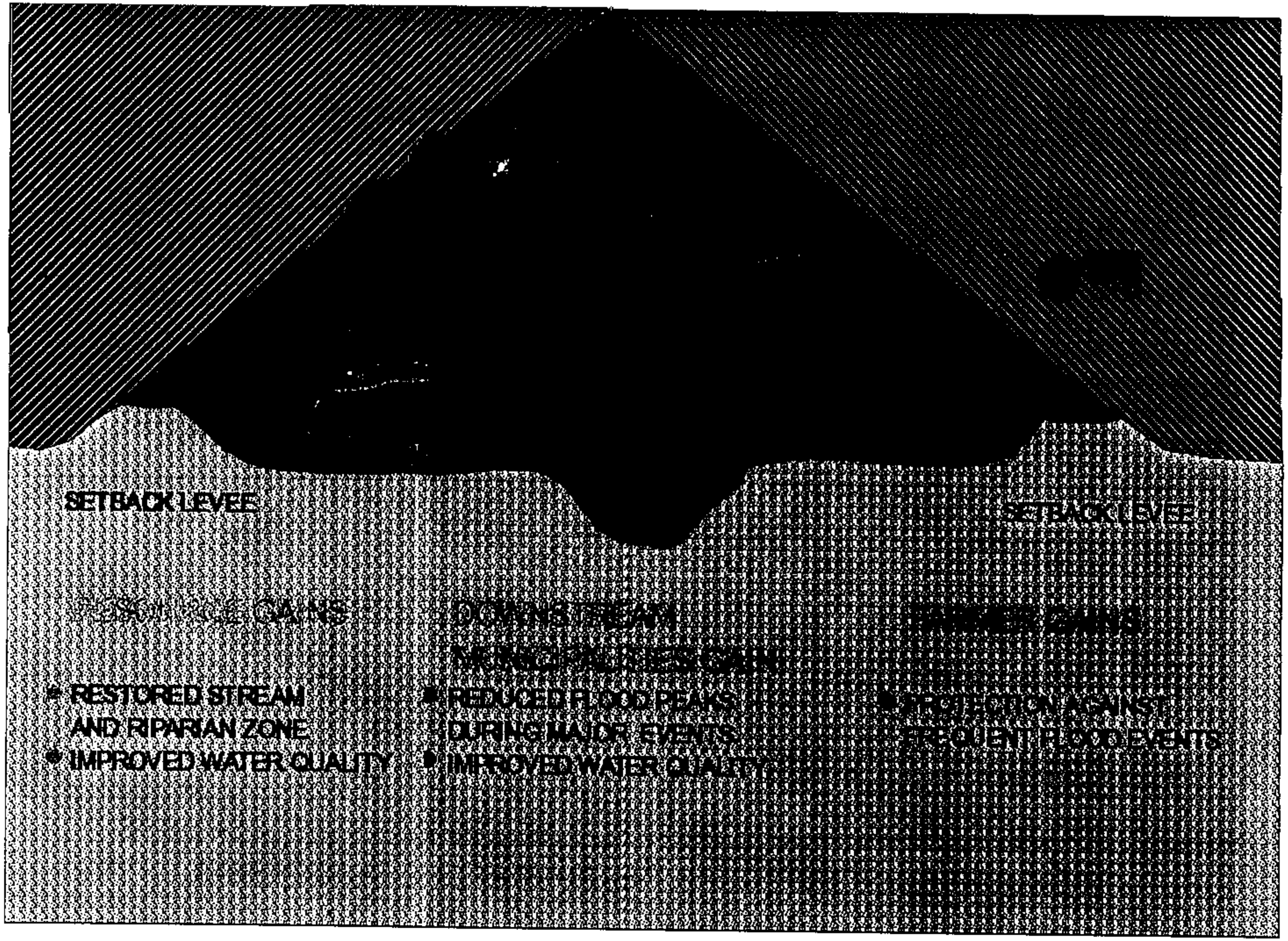
Literature Cited

Rosgen, D. 1996. Applied River Morphology. Printed Media Companies. Minneapolis.

Trygg, J.W. Composite maps of U.S. Land Surveyors' original plats & field notes. Trygg Land Office. Copyright 1964.

Woolman, A.J. 1895. A report upon ichthyological investigations in Western Minnesota and Eastern North Dakota. United States Commission of Fish and Fisheries.

RESTORATION OF A CHANNELIZED STREAM



Hay Creek Project
Roseau River Watershed
Roseau County
Minnesota

JOR Engineering, Inc.

Introduction

Hay Creek is a channelized stream in the Roseau River watershed in northwestern Minnesota. The upper reach of the creek is maintained as County Ditch Number 9. The lower reach of the creek is maintained as County Ditch Number 7. County Ditch 7 is a straight channel with confining road grades or spoil banks on both sides. Bank erosion and instability cause major road and ditch maintenance problems as the creek attempts to establish a natural meander pattern. Frequent widespread flooding and erosion occur on adjacent agricultural lands when channel capacity is exceeded. Water from Hay Creek is also a major contributor to flooding downstream on the Roseau River.

The Hay Creek Project provides a solution to the problems associated with erosion and flooding. It will also provide fish, wildlife, and esthetic values by creating a riparian corridor that will include a meandering stream pattern of pools and riffles and flood plain and floodway vegetative and hydrologic characteristics.

Description

The watershed area of Hay Creek is about 112 square miles and includes a mix of forest, wetlands, and cropland. It originates at Bemis Hill in the Beltrami Island State forest. Bemis Hill is about 90 feet high with a peak elevation of 1260. From the base of the hill water flows about 13 miles in County Ditch 9 to TH 11 where the ground elevation is about 1060 and the drainage area is increased to 80 square miles. County Ditch 7 conveys the water from TH 11 a distance of about 6.5 miles to the Roseau River. The ground elevation near the outlet is about 1037 and the channel bottom is at about 1029.

There are no long term gaging stations on Hay Creek. The Roseau River Watershed initiated a stream gaging program in 1996. The highest measured flow on Hay Creek was 1222 cfs at CSAH 12 on July 18, 1996 following a 7 inch rainfall. The peak flow was estimated at about 1300 cfs. The drainage area at this point is 40 square miles. It is also considered possible to have crossover flows from the Warroad River which would enter downstream from CSAH 12.

County Ditch 7, from the Roseau River upstream to TH 11, has a straightened length of about 6.5 miles and an elevation drop of about 22 feet. This is an average gradient of 3.4 feet per mile or 0.064%. The original plans on the ditch show a depth of about 5 ½ feet, a bottom width of 16 feet and 1 to 1 side slopes. Assuming an n value of .04, the bank full channel capacity would be about 270 cfs. We have estimated the 5 year peak flow at this point to be 670 cfs.

Proposed Project

The proposed project is in the lower 6 ½ mile reach of Hay Creek (County Ditch 7) from TH 11 downstream to the Roseau River. It includes reconstruction of the creek, setback levees, and agricultural diked storage.

Reconstruction of the creek (Design parameters developed corroboratively by JOR Engineering and MNDNR)

The existing straight channel will be replaced with a meandering channel. Streams have a natural tendency to meander as scour occurs on one side of the channel and deposition occurs on the other. Control of meandering on straightened channels such as Hay Creek requires intensive maintenance. Because of their ability to better manage sediment and channel vegetation, stable meandering channels are actually as efficient as typical straightened channels. Meandering channels also develop a series of pools (in the bends) and riffles (in the straights) which greatly improve the fisheries habitat. Other fish and wildlife benefits are provided by flood plain though which the channel meanders and periodically floods.

The above are compelling reasons to restore a meandering channel pattern. Unfortunately, the design of a meandering channel is far more complicated than the design of a straight channel, and depends on watershed conditions that are almost impossible to define. Fortunately however, the channel can be expected to adjust over time to account for minor design deficiencies. Data collected and analyzed by others (Rosgen, 1996) from stable natural channels provides broad design guidelines. These have been refined regionally through data collection by MNDNR.

The channel should have the capacity to carry the 1.5 yr flow at a bank full stage. A preliminary estimate of the 1.5 yr flow is 250 cfs, based on an n value of 0.03. Channel dimensions and pattern are related to the bankfull channel capacity.

The preliminary channel design has a 31 foot top width. The riffle channel would have a 5 foot depth, an 11 foot bottom width, and 2 to 1 side slopes. The pool channel would have a 7.5 foot depth, a 1 foot bottom width, 1 to 1 side slopes on the outside and 3 to 1 side slopes on the inside of the bends. The meander ratio would be about 1.5 resulting in a channel slope of .00043. The meander belt width would be about 500 feet with a bend radius of 60 to 90 feet. The typical cross sections and meander pattern are shown on the attached figures.

Set Back Levees and Floodway

A confined floodway will be created by set back levees. It will provide a total capacity of 700 cfs without overtopping. Considering a channel capacity of 250 cfs, the required floodway capacity will be about 450 cfs. At a minimum, the floodway width must equal the meander belt width of 500 feet. Assuming a floodway width of 500 feet, the required depth of flow would be about 2.1 feet based on an estimated overbank n value of 0.12.

The set back levees will be a combination of roads and spoil banks on both sides of the floodway. They will be about 2.5 feet high with 20 to 24 foot top widths and 4 to 1 side slopes.

The riparian zone between the levees will be permanently vegetated with trees, shrubs, native forbs, and grasses. It will be seasonally flooded and can be depressionally excavated to create deeper wetland pockets. The area between the levees will provide about 1000 acre-feet of flood storage at a stage of 2.5 feet. Flood storage capacity could be increased by setting the levees farther back or by raising the levee elevation.

There are 4 existing road crossings over County Ditch 7. These will be retained and replacements will be box culverts preliminarily sized at 14'W X 8'H. The floor of the culverts will be set at 6 feet below bank elevation which will be about 1 foot below the riffle elevations. This will allow easy fish passage at low flows. The average velocity through the culverts would be about 2.9 fps at bank full stage. This should also be adequate for fish passage. However, if fish migration problems do occur, baffles may be installed on the culvert bottom to locally slow velocities and provide rest areas. At the design flow of 700 cfs, the average velocity in the culverts will be 6.4 fps resulting in head loss through the culvert of about 1 foot. The head loss through the culverts will help to control the flow rate on Hay Creek during major floods and increase the utilization of storage. The road grades traversing the floodway will be high enough to prevent overtopping.

Because the water level within the floodway may be above the adjacent field elevations for extended periods of time, drainage ditches will be included outside of the levee to provide an outlet for local drainage.

Agricultural Diked flood Storage

When the capacity of the floodway is exceeded at about 700 cfs, water will be allowed to begin flooding adjacent agricultural fields. Without additional upstream flood control, this can be expected to occur about once every 5 years in the spring and about once every 10 years in the summer. Agricultural land north of County Ditch 7 will be diked to form individual flood pools in order to confine flood damaged areas to the minimum necessary to provide the required storage. The ag pools will be filled sequentially, beginning with the least damage prone areas. Flooding of the pools may be accomplished by a combination of overflow spillways and gates. Flood waters stored within the pools will be retained until after the Roseau and Red Rivers have crested and then will be released at times and rates most likely to minimize overall damages.

The quantity of water stored will depend on the magnitude of the flood event. The intent is to store all water in excess of 700 cfs. For a 100 year spring flood this volume would be about 12,000 acre-feet. Pool designs are currently preliminary. However, the required capacity appears to be easily attainable. It would be desirable to further reduce Hay Creek flows during critical flood periods on the Roseau River. This would require additional storage and control facilities.

Floodwater from the drainage area south of County Ditch 7 cannot be stored in the Ag pools north of the ditch. Moderation of flows from this area can be accomplished by culvert sizing along the exterior drainage channel.

Compatibility with other flood control measures.

This project will work in conjunction with the Norland Impoundment Project to protect the frequently flooded areas north and east of Roseau. They will also reduce the backwater effect at Roseau thereby increasing the capacity of the river through the city. The Norland project is a significant factor in making the Hay Creek project feasible. That is because it will eliminate flood flows from County Ditch 18 which currently enters Hay Creek midway between TH 11 and the Roseau River. It is also conceivable that the Norland and Agricultural Diked storage pools could be used in conjunction to optimize flood control benefits and reduce the frequency of use of the agricultural diked storage.

Installation of upstream impoundments, wetland storage, watershed BMP's, or culvert sizing in the Hay Creek watershed would reduce future flows and therefor reduce the frequency of use of the agricultural diked storage areas, raise the overall level of protection, and extend flood control benefits upstream along County Ditch 9.

Estimate of Costs (preliminary)

Stream Restoration including meander channel, setback levees, and exterior drainage channels.

Land Rights	550	acres	@	$500	$275,000
Excavation	460,000	cuyd	@	$1.25	$575,000
Side crossings	10		@	$3,000	$30,000
Channel crossings	none				
Site shaping & Grading					$50,000
Seeding & Planting	550	acres	@	$300	$165,000
Gravel	5,000	cuyd	@	$8.00	$40,000
Contingencies					$230,000
Engineering & Administration					$350,000
				Total	$1,685,000

Agricultural Diked Storage (typical examples)

Pool 1 (700 acre-feet at 1055)					
Land Rights	700	acres	@	$250	$175,000
Embankment	100,000	cuyd	@	$1.50	$150,000
Spillway and control					$100,000
Seeding	25	acres	@	$400	$10,000
Gravel	1,250	cuyd	@	$8.00	$10,000
Contingencies					$80,000
Engineering & Administration					$115,000
				Total	$640,000

Pool 2 (4480 acre-feet at 1054)					
Land Rights	1120	acres	@	$250	$280,000
Embankment	200,000	cuyd	@	$1.50	$300,000
Spillway and control					$100,000
Seeding	50	acres	@	$400	$20,000
Gravel	1,500	cuyd	@	$8.00	$20,000
Contingencies					$160,000
Engineering & Administration					$230,000
				Total	$1,110,000

Pool 3 (5500 acre-feet at 1053)					
Land Rights	1100	acres	@	$250	$275,000
Embankment	220,000	cuyd	@	$1.50	$330,000
Spillway and control					$100,000
Seeding	50	acres	@	$400	$20,000
Gravel	1,500	cuyd	@	$8.00	$20,000
Contingencies					$165,000
Engineering & Administration					$210,000
				Total	$1,130,000

Note: The cost of dikes that may be shared with Norland impoundment are included in the above estimates.

Fish and Wildlife Benefits

In addition to flood control, this project is expected to provide outstanding fish and wildlife benefits. The following evaluations were provided by MNDNR based on preliminary design concepts.

Fisheries (by DNR, Baudette Area Fisheries, September 30, 1998)

The proposed Hay Creek Stream Restoration Project is expected to benefit the local fishery. Hay Creek is a tributary of the Roseau River. The Roseau River has populations of game fish, such as northern pike and walleye, as well as non-game fish. Currently, the lower portion of Hay Creek has poor fisheries habitat. Channelization has resulted in a straight, shallow channel of mostly sand and silt substrate with little submerged vegetation. Great extremes in water level and flow also reduce the productivity of Hay Creek as a fishery. With its link to the Roseau River, Hay Creek has the potential to support a more diverse population of game and non-game fish if habitat is diversified and flow is moderated. The Hay Creek stream restoration project will create better fish habitat and create more stable stream flows.

The proposed setback levees and the reconstruction of a more natural, meandering channel will diversify habitat in Hay Creek. The setback levees will provide a wider flood plain area with depressions that will retain water for a longer period of time while moderating the extremes of water level variation. Combined with the increased duration of water retention, vegetation on this flood plain will provide northern pike spawning and rearing habitat. This will also improve aquatic resources for other fish species. Restoration will create pool and riffle areas within the stream. Pool areas can provide habitat for larger fish such as walleye. Deep pools also provide a refuge for all species during low flow periods and winterkill conditions. Gravel riffle habitat is appropriate substrate for walleye spawning. Water retained in the flood plain should help maintain flow to the main channel during dryer periods, so more habitat will be available than at present, during these times. Habitat will also be increased for northern pike and other species if submerged vegetation is established in the project area.

An additional benefit of this project will be the stabilization of the channel within Hay Creek. Sediment transport in channelized streams tends to homogenize habitat as it has done in Hay Creek. Reduction of silt transportation in Hay Creek, which flows into the Roseau River, will extend the fisheries benefit to the watershed below.

Wildlife (by DNR, Baudette Area Wildlife, September 30, 1998)

The proposed Hay Creek Flood Project would convert 6.5 miles of channelized (ditched) waterway to a meandered channel confined by setback levees. The area within the levees would be 400-600 acres. This design provides a wider flood plain and consequently more water storage capacity than the existing waterway. Additional benefits would be a more stable channel which translates into less sediment transport, and improved fish and wildlife habitat. The flood plain would moderate high and low flows. Excavating depressions in the floodplain could provide additional flow moderation, material for levee construction, and ponded water, a desirable wildlife habitat feature.

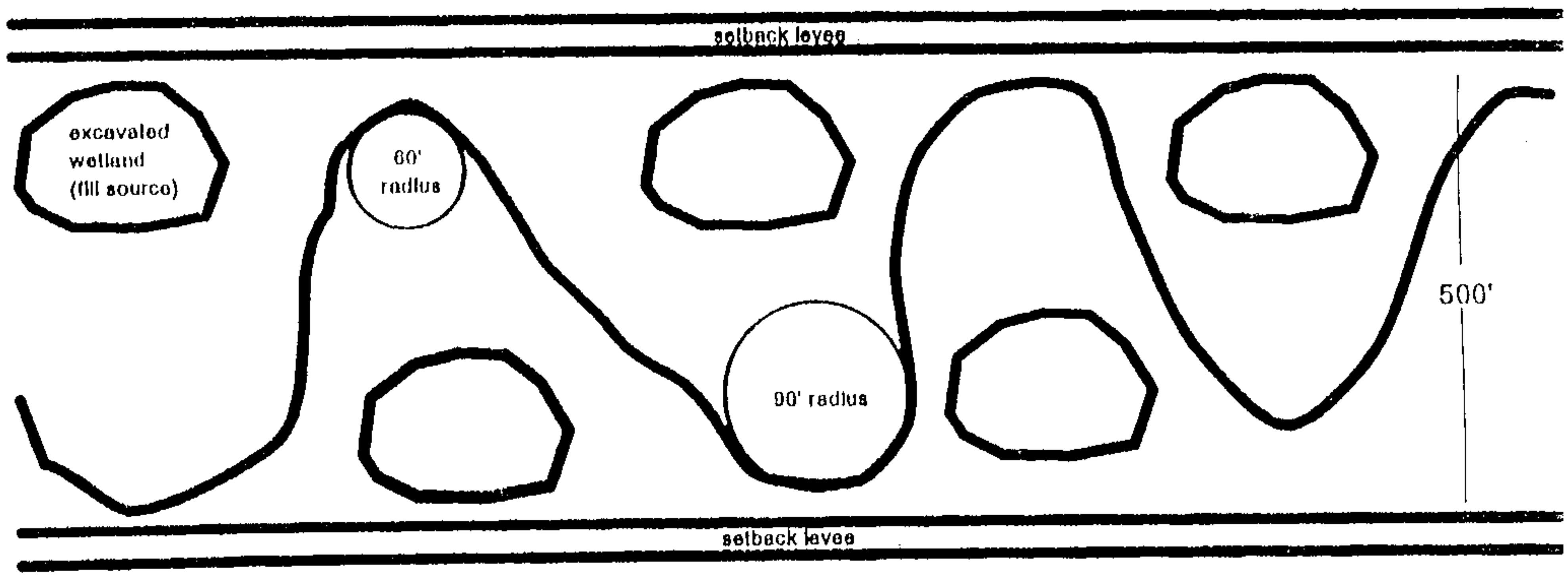
The project would benefit the wildlife resource by providing more and better quality habitat than the existing waterway. Floodplain acreage would be a mix of permanent vegetation, channel water and possibly ponded water. Land use in the project's vicinity is largely agricultural, and the project would be developed primarily at the expense of agricultural land. From a wildlife habitat perspective, it would be best if the project's plant community, is to the extent possible, site adapted native vegetation. There has been some discussion about using prescribed fire as the principle vegetation management technique.

Deer would use this site during the spring, summer and fall. Black bear and wolves may travel through the floodplain. One wildlife benefit of this project is the travel variety of small mammals, furbearers such as coyote, red fox, racoon, mink, and river otter would use the project. A large variety of both breeding and migrant bird species would use the project vicinity. Some examples are Canadian geese, mallard, blue-winged teal, northern harrier, sharp-tailed grouse, great blue heron sandhill crane, common snipe, belted kingfisher, eastern kingbird, marsh wren, common yellowthroat, red-winged blackbird, and Le Conte's sparrow.

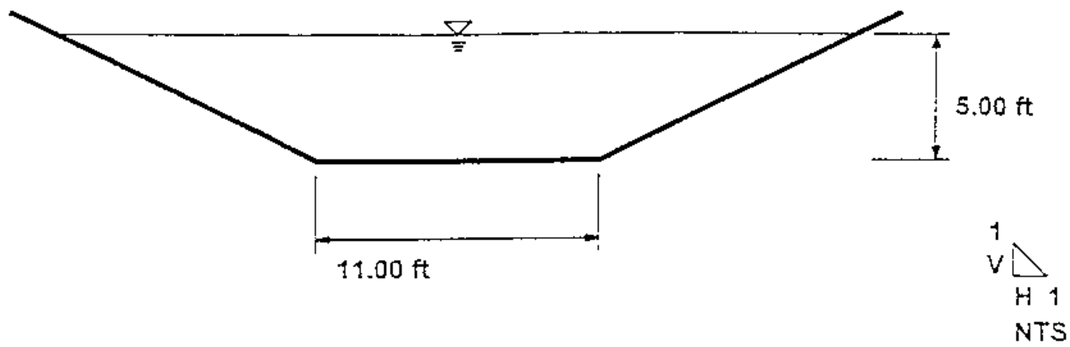
If excavation in the floodplain makes ponded water available, and the ponds are large enough, waterfowl brood rearing could occur. Amphibians such as the American toad, western chorus frog, green frog, northern leopard frog would also benefit from the presence of ponded water. The possibility also exists for painted turtle and common garter snake to inhabit the site.

The project is also expected to benefit aquatic organisms including fish. Wildlife species such as otter, kingfisher and painted turtle that depend on these organisms for food will benefit too. The reduced silt load and moderated flow benefits should provide some wildlife habitat benefits downstream of the project site in the Roseau River.

Typical Meander Pattern



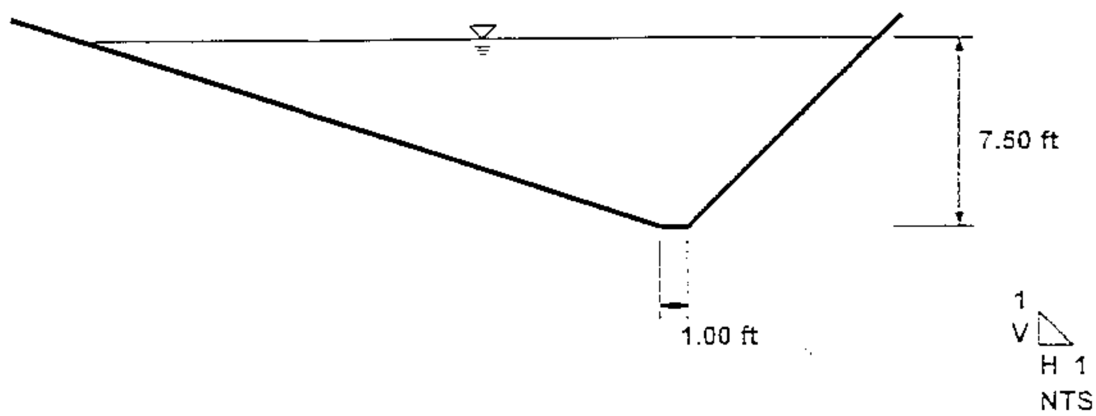
Riffle Cross Section



Section Data		
Mannings Coefficient	0.030	
Channel Slope	0.000501	ft/ft
Depth	5.00	ft
Left Side Slope	2.000000	H : V
Right Side Slope	2.000000	H : V
Bottom Width	11.00	ft
Discharge	250.00	cfs

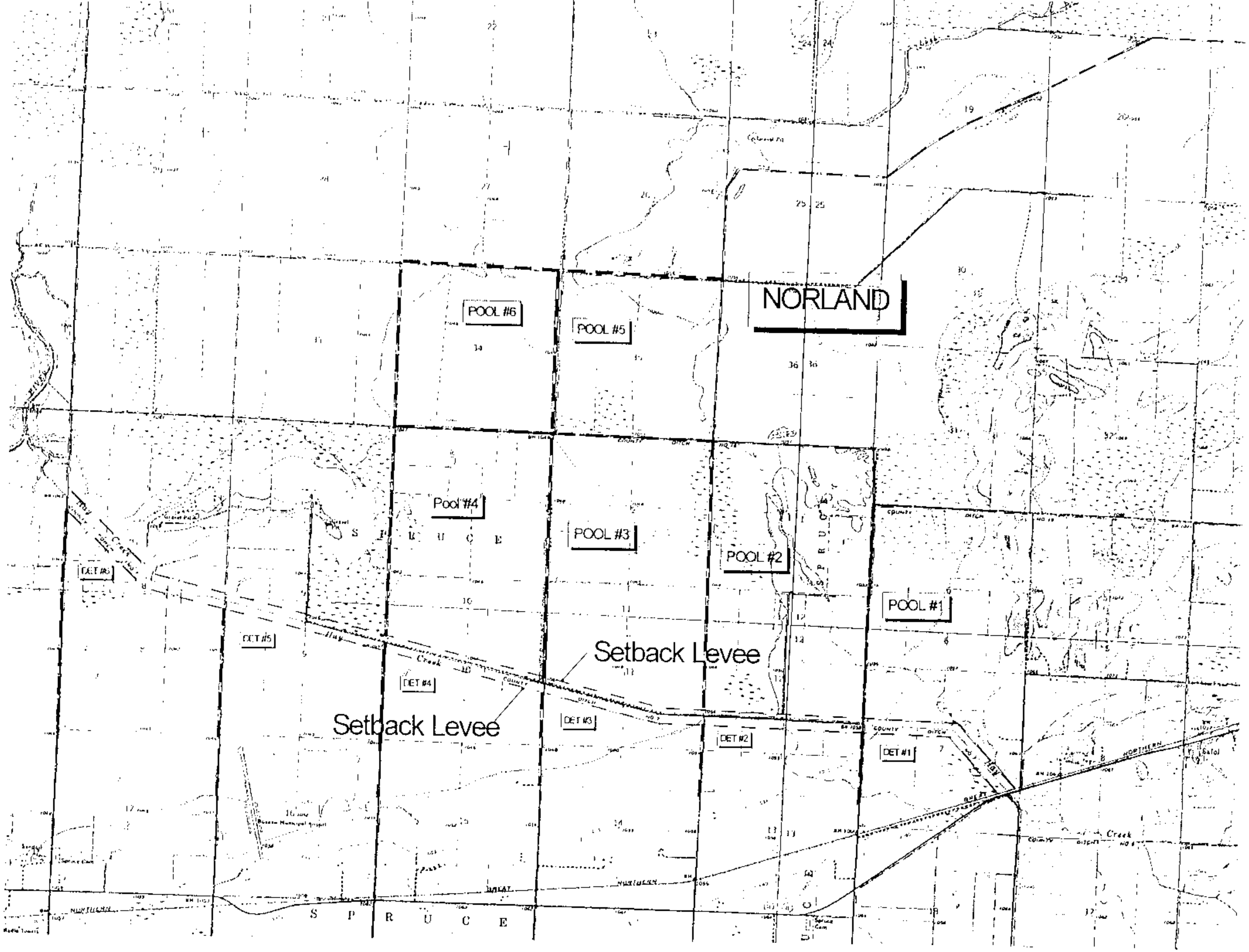
Flow Area	105.00	ft²
Wetted Perimeter	33.36	ft
Top Width	31.00	ft
Critical Depth	2.19	ft
Critical Slope	0.011748	ft/ft
Velocity	2.38	ft/s
Velocity Head	0.09	ft
Specific Energy	5.09	ft
Froude Number	0.23	
Flow is subcritical.		

Pool Cross Section



Section Data		
Mannings Coefficient	0.030	
Channel Slope	0.000346	ft/ft
Depth	7.50	ft
Left Side Slope	3.000000	H : V
Right Side Slope	1.000000	H : V
Bottom Width	1.00	ft
Discharge	250.00	cfs

Flow Area	120.00	ft²
Wetted Perimeter	35.32	ft
Top Width	31.00	ft
Critical Depth	3.72	ft
Critical Slope	0.012374	ft/ft
Velocity	2.08	ft/s
Velocity Head	0.07	ft
Specific Energy	7.57	ft
Froude Number	0.19	
Flow is subcritical.		


NORLAND
POOL #1
POOL #2
POOL #3
Pool #4
POOL #5
POOL #6
DET #1
DET #2
DET #3
DET #4
DET #5
DET #6
Setback Levee
Setback Levee
S P R U C E
S P R U C E
Hay Creek
Creek
Salol
NORTHERN