Hay Creek Setback Levees and Norland Impoundment Final Engineer's Report

HDR Engineering, Inc.

324 2nd Street East
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FINAL ENGINEER'S REPORT
HAY CREEK SETBACK LEVEES
AND
NORLAND IMPOUNDMENT

ROSEAU RIVER WATERSHED DISTRICT

May 2009

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

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ACRONYMS AND SHORT FORMS

AHPS	NWS Advanced Hydrologic Prediction Service
BMP	Best Management Practices
BWSR	Board of Water and Soil Resources
CD	County Ditch
CMP	Corrugated Metal Pipe
CN	Curve Number
CRP	Conservation Reserve Program
DEM	Digital Elevation Model
ERR/EA	Ecosystem Restoration Report and Environmental Assessment
EAW	Environmental Assessment Worksheet
EPA	Environmental Protection Agency
ESH	Emergency Spillway Hydrograph
FBH	Freeboard Hydrograph
FDR	Flood Damage Reduction
FEMA	Federal Emergency Management Agency
GAP	Gap Analysis Program
GIS	Geographic Information System
GPS	Geographic Positioning System
HEC	USACE Hydrologic Engineering Center

HMS	HEC Hydrologic Modeling System
JD	Judicial Ditch
LGU	Local Government Unit
LOS	Level of Service
MCEA	Minnesota Center for Environmental Advocacy
MnDOT	Minnesota Department of Transportation
MnDNR	Minnesota Department of Natural Resources
MnRAM	Minnesota Routine Assessment Method
MPCA	Minnesota Pollution Control Agency
NASS	USDA National Agricultural Statistics Service
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service, formally the SCS
NRE	Natural Resource Enhancement
NWS	National Weather Service
PRECIP	Precipitation (Type II Rainfall)
PMP	Probable Maximum Precipitation
PWT	Project Work Team
PRP	Preliminary Restoration Plan

R	Clark Storage Coefficient
RAS	HEC River Analysis System
RCP	Reinforced Concrete Pipe
RRFDRWG	Red River Flood Damage Reduction Work Group
RRWD	Roseau River Watershed District
SCS	Soil Conservation Service
SWCD	Soil and Water Conservation District
SWPPP	Storm Water Pollution Prevention Plan
SWMM	EPA Storm Water Management Model
$\mathbf{T_C}$	Time of Concentration
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WCA	Wetland Conservation Act
WSE	Water Surface Elevation

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1.0 INTRODUCTION

The Roseau River Watershed District (RRWD) has prepared a Final Engineer's Report for the Hay Creek Setback Levees and the Norland Impoundment (Project) located in Spruce, Enstrom, and unincorporated Norland Townships in Roseau County, Minnesota. The purpose of the Project will be to provide Flood Damage Reduction (FDR) with respect to flows from the Hay Creek and Norland drainage areas in order to help reduce flood flows on the Roseau River, affecting the City of Roseau and areas downstream. The drainage area which will be affected includes County Ditch 18 (CD 18), Judicial Ditch 61 (JD 61), and a portion of Hay Creek, also known as County Ditch 7 (CD 7). The Hay Creek Setback Levees will serve to reduce flooding on the land in the vicinity of CD 7. The Statutory authority under which this Project is being implemented is Minnesota Statute 103D.605, and this report satisfies Minnesota Statute 103D requirements for Final Engineer's Reports.

2.0 SUMMARY OF ACTIVITIES

The RRWD was formed on June 17, 1963 under provisions of Minnesota Statute 103D. The District covers portions of Beltrami, Lake of the Woods, Marshall, Kittson, and Roseau Counties. The District is flood prone; it is affected by repetitive flooding on a consistent basis. The primary reason for flooding in this area is due to topography. The west portion of the basin is the flat ancestral bed of Lake Agassiz, averaging 3 to 5 feet of vertical drop in elevation per mile. When heavy rains fall on this flat area, the land is unable to drain quickly and flooding can result. Compounding the flooding are the ridges and steeper topography in the southern and eastern portions of the watershed. These areas drain more quickly, and inundate the flatter land to the north and west.

The concept of a "Norland Project" has been in the planning stages for many years. Flood damage reduction has been discussed at the watershed and state level on numerous occasions, usually centering on development of some sort of flood control impoundment with embankments and a control gate. Most recently, the RRWD renewed planning efforts for a project in the Hay Creek Norland area after floods devastated the watershed and the City of Roseau in June 2002. The State Legislature appropriated specific funding for engineering and construction, which is administered through a grant from the Department of Natural Resources Flood Damage Reduction (DNR FDR) grant program.

Even a couple of years before the 2002 flood, the District had contacted the U.S. Army Corps of Engineers (USACE) regarding pursuing a federal sponsor for the Norland Project. An environmental assessment (EA) was published in 2003 detailing a proposed plan.

The following major elements were included in this plan:

- Introducing sinuosity into CD 7/Hay Creek to improve fish habitat;
- Construction of setback levees on Hay Creek to reduce localized flooding;
- A diversion structure and canal linking Hay Creek to the Norland impoundment for flood storage;
- A permanent pool within the Norland impoundment for wetland benefits.

Funding for USACE activities on the Norland proposal ended in 2005. This report draws heavily on the previous USACE-District work. However, the Project described in this report is different than the one presented in the USACE EA in that: 1) a restoration of the sinuosity of Hay Creek is not proposed, 2) the impoundment and connection channel are located along different alignments, in part to limit wetland impacts, and 3) the Hay Creek connection channel inlet is a controlled gate rather than a passive weir.

Flood Damage Reduction Approach

The RRWD's flooding problems will not be solved with the construction of one project at one specific location. Only a comprehensive approach, with many types of projects and various water management techniques, will be successful in solving the flooding problems in the District. The Red River Flood Damage Reduction Work Group (RRFDRWG) Agreement of December 1998 is the framework for flood damage reduction projects in the Red River Basin. The RRWD works within the guidelines of the mediation process established by the RRFDRWG in the development of potential flood control projects. The purpose of the mediation process was to reach an agreement on long-term solutions for reducing flood damage and ensuring the protection and enhancement of natural resources. The primary focus of this agreement is to balance economic, environmental, and social considerations when planning and implementing flood damage reduction and natural resource enhancement projects in the District. The District encourages participation by local, state and federal governments, natural resource agencies, conservation organizations, and local citizens in this planning process.

A Project Team was organized and has been meeting monthly to discuss Project planning and design elements, starting most recently in 2006. Project team members include:

- TODD MILLER – RRWD Board
- JIM COURNEYA - MPCA
- BRIAN KETRING – Roseau Co. HD
- KELMEN KVIEN- Landowner
- TORRIS BAKKEN – Spruce Township
- KELLY URBANEK - USCOE
- LEROY CARRIERE – RRWD Board
- DAN THUL - DNR Waters
- BRIAN DWIGHT -BWSR
- MIKE LARSON - DNR Fisheries
- STEVE LEE – RRWD Board
- LAVERNE VOLL – RRWD Board
- RRWD staff and others
- GRACIA NELSON – Roseau Co. EMO

The Project components discussed in this report have been discussed by the Project Team; to the extent that consensus has been achieved as an indication of willingness and agreement, to participate by the District, State, and Landowners, in attendance at the meetings.

3.0 PROJECT SETTING

The Hay Creek watershed has its headwaters in the Beltrami Island State Forest and includes a mix of forest, wetlands, and farmland. The Norland area originally was a habitat rich in forest and wetlands that drained overland to Hay Creek and the Lost River (immediately north of the Norland watershed). Drainage in the past for agricultural purposes dramatically modified Hay Creek and decreased wetlands in these areas. The uppermost 13 miles of Hay Creek were channeled into CD 9, which joins the downstream-most 6½ miles of Hay Creek, most of which is straight-line, doglegged CD 7, with no resemblance to the original creek or its flow path.

Construction of CD 18, JD 61, and associated laterals converted much of the Norland area to agricultural production. However, availability of CRP has helped marginal lands revert to nonagricultural status.

The Project itself is situated in the downstream-most portions of the Hay Creek and Norland drainage areas and is bordered to the north by the Lost River watershed, to the east by the "highlands" of the Norland drainage area, to the south by Minnesota Trunk Highway 11, and to the west by the Roseau River. The Project Area straddles the Glacial Washed Till Plain physiographic area, which comprises abandoned shorelines of former glacial Lake Agassiz. This zone is characterized by flat to gently rolling landscape, with local relief up to 15 feet and abundant peat deposits. Elevations range from approximately 1,260 feet above mean sea level in the headwaters of

Hay Creek, to less than 1,030 feet where Hay Creek joins the Roseau River. Natural ground surface elevations in the Project Area range from about 1,035 to 1,065 feet.

The proposed Project will be located within the Hay Creek and Norland drainage areas, outletting approximately 4½ river miles downstream of the City of Roseau, Minnesota. The creek, a tributary of the Roseau River, drains approximately 82 square miles. CD 18 and JD 61 drain approximately 42 square miles. The Norland Impoundment is to provide controlled storage for a portion of approximately 124 square miles of the Norland and Hay Creek watersheds in order to reduce the frequency and severity of flooding downstream on the Roseau River from CD 18, JD 61, and portions of CD 7. Figure 1 shows the location of the elements of the proposed Project within the Roseau watershed. The drainage area is provided in Figure 2. **Error! Reference source not found.** provides the existing conditions and Figure 4 includes corresponding photographs of the site area.

4.0 PROJECT NEED

The Hay Creek Norland area, City of Roseau, Stafford area, Roseau Lakebed area, Big Swamp area, the Roseau River, and the Red River of the North suffer from repetitive flood damages (See Planning Areas in Figure 6). Approximately 61,381 acres of agricultural land are contained within the 100 year floodplain in these areas. There are 85 miles of township, county, and state roads, 423 miles of legal ditches, and 123 township, county, and state bridges and culverts affected by flooding.

Primary Purpose

- The primary purpose of the Project is to provide a 50% reduction in the 10-year and a 30% reduction in the 100-year discharges from the Hay Creek/Norland drainage area, contributing to the Roseau River at its confluence approximately 4 miles downstream from the City of Roseau. The corresponding reduction in flows from the Hay Creek/Norland area will reduce peak flows on the Roseau River from 5% to 8% for a 100 year event, thereby reducing corresponding backwater affected river stages in the City of Roseau by as much as a tenth of a foot at its peak. It will also reduce flooding durations in the City of Roseau as well as reduce flood damages in flood prone areas downstream (See Figure 6).
- It is anticipated that the Project would reduce up to 30% of potential flood damages in the Hay Creek Norland basin. In the Hay Creek Norland area alone, the flood damage reduction would include increased protection, less flood depth, and reduced flooding duration, directly improving 13,300 acres of agricultural land, 24 miles of roads, 131 miles of ditches, and 27 culverts and bridges previously prone to flood damages.

FIGURE 1.
LOCATION OF IMPOUNDMENT

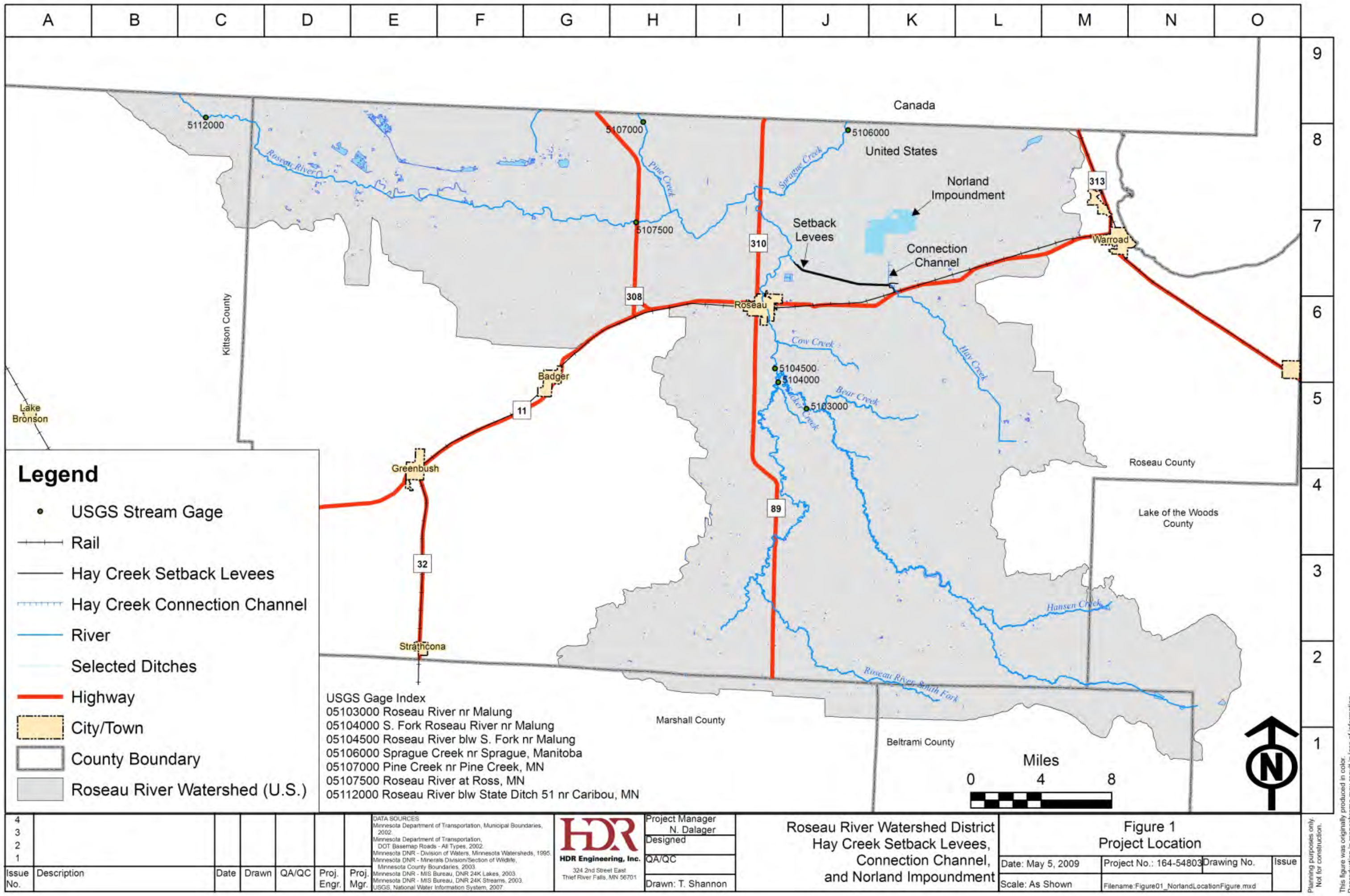

FIGURE 2.
DRAINAGE AREA

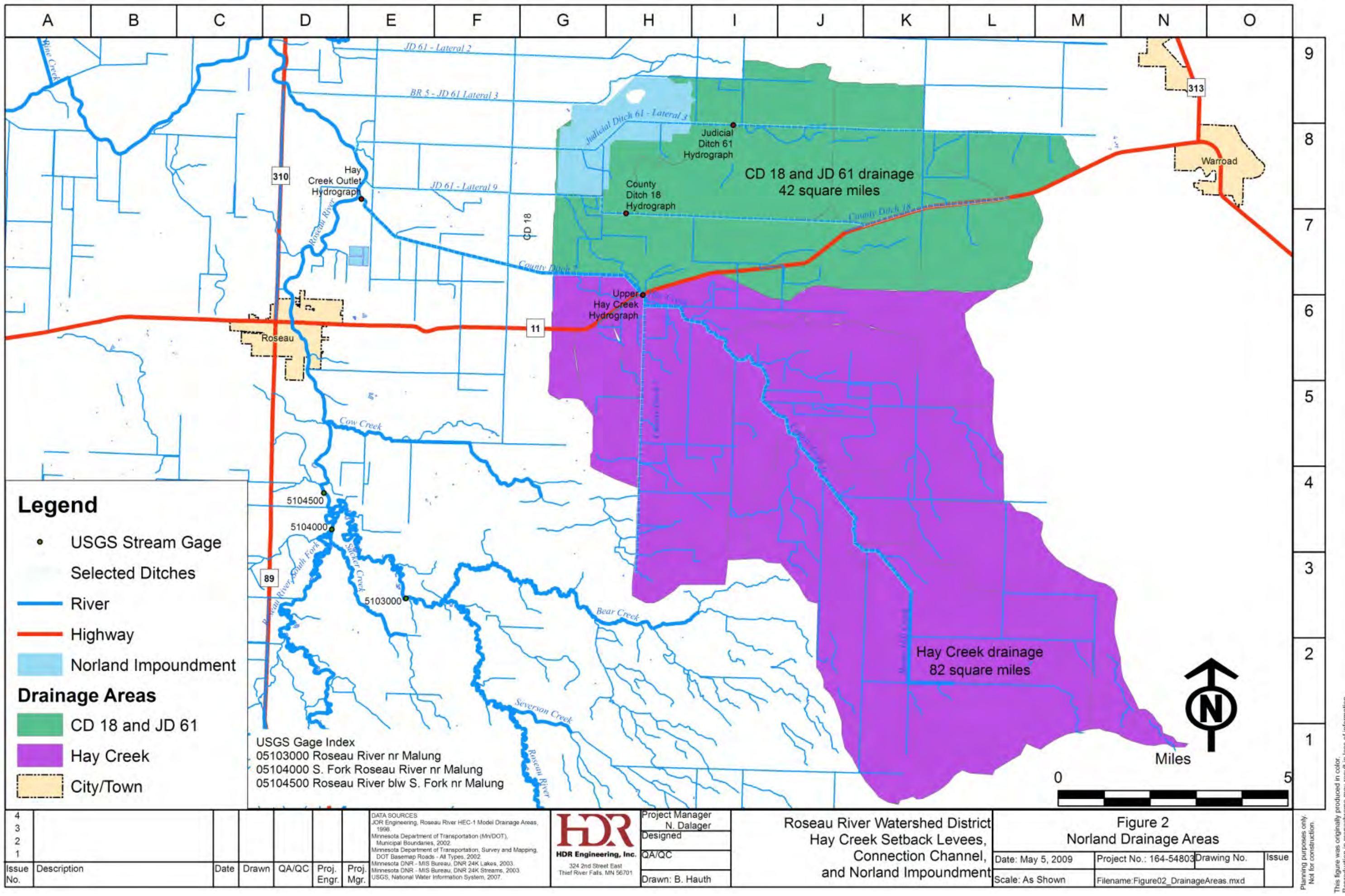

FIGURE 3.
EXISTING CONDITIONS

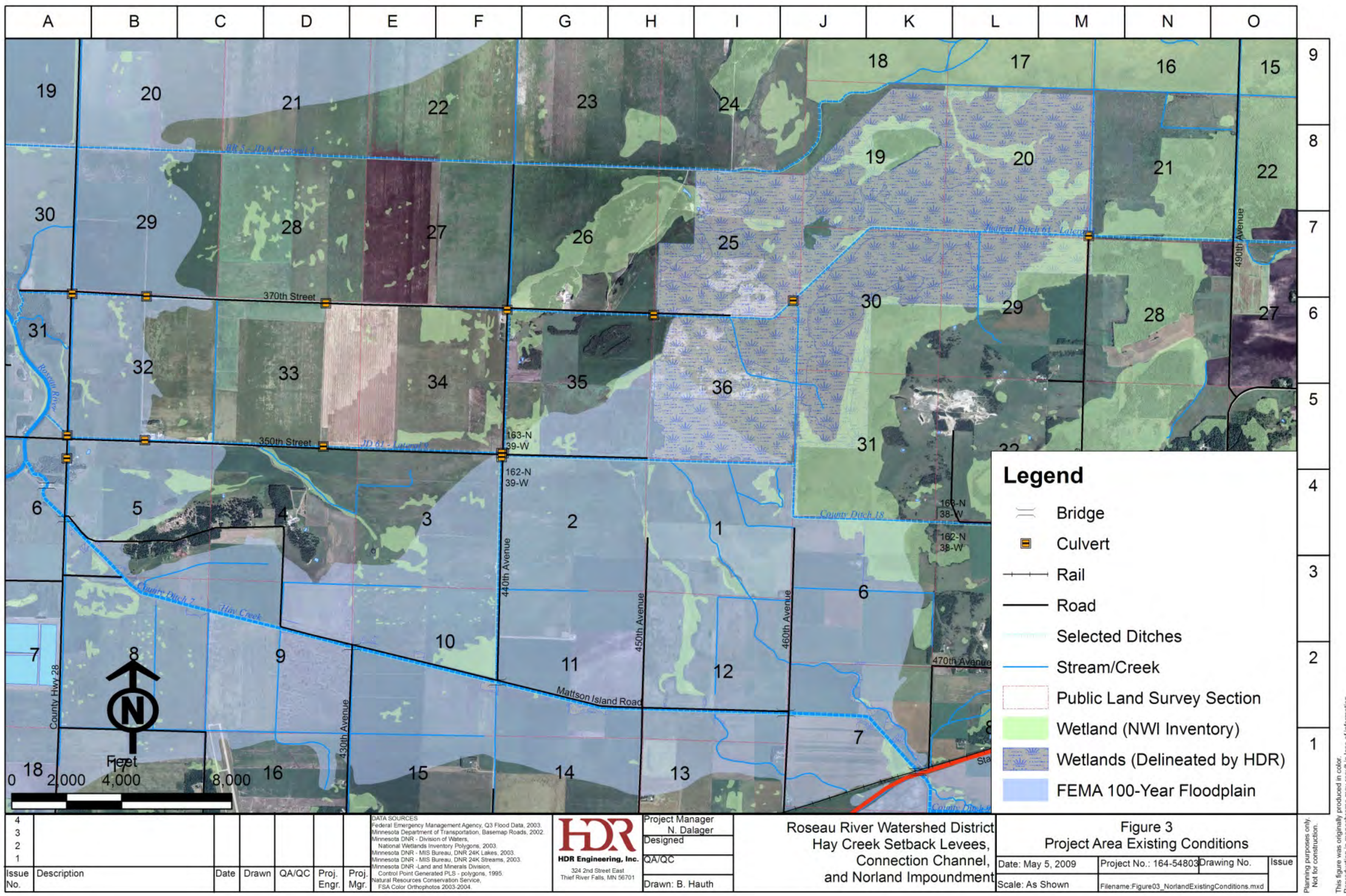

FIGURE 4.
AREA PHOTOGRAPHS

Photograph Number 1, File: HPIM1355.JPG
JD 61

Photograph Number 2, File: HPIM1366.JPG
Rail bridge on Hay Creek

Photograph Number 3, File: File_Picture 003.jpg
CD18 looking west at proposed inlet

Photograph Number 4, File: File_Picture 004.jpg
CD18 looking east, canal north to JD 61

Photograph Number 5, File: File_Picture 005.jpg
Ditch berm looking west; CD18 at left

Photograph Number 6, File: File_Picture 006.jpg
Connection ditch between CD18 and JD61

Photograph Number 7, File: File_Picture 007.jpg
JD61 at location of connection ditch from CD18

Photograph Number 8, File: File_Picture 008.jpg
JD61 at location of connection ditch from CD18

Photograph Number 9, File: File_Picture 010.jpg
Location of proposed JD61 inlet looking east

Photograph Number 10, File: File_Picture 018.jpg
Location of Lost Creek inlet looking north

Issue No.	Description	Date	Drawn	QA/QC	Proj. Engr.	Proj. Mgr.
4						
3						
2						
1						

HDR Engineering, Inc.
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Project Manager N. Dalager
Designed
QA/QC
Drawn: T. Shannon

Roseau River Watershed District
Hay Creek Setback Levees, Connection Channel, and Norland Impoundment

Figure 4
Area Photographs

Date: March 17, 2008 | Project No.: 164-51365 | Drawing No. | Issue
Scale: n/a | Filename Figure04_NorlandExistingConditionsPhotographs.mxd

Secondary Purpose

The secondary goals of the Project include:

- Reducing peak discharges, flood stages, and flood durations/damages on downstream areas, and on the Red River of the North. It is anticipated that the Project could reduce 5% of future potential flood damages in Stafford, 2% in Roseau Lake Bed, and 1% or less in the Big Swamp, and the Red River of the North. This potential for flood damage reduction would include increased protection, less flood depth, and reduced flooding duration, improving 57,098 acres of agricultural land, 49 miles of roads, and 97 culverts and bridges previously prone to flood damages.
- Providing a reduction in riverbank erosion and bank sloughing along the Roseau River (State Ditch 51). .
- Water quality enhancement from improved dissolved oxygen levels via augmentation discharges.
- Wetland restorations resulting from mitigation of Project impacts in the impoundment footprint.

Other Factors

The City of Roseau ("City") and the RRWD are subject to frequent and damaging floods. The annual probability of minor flooding is 49% and major flooding is 21%. The National Weather Service (NWS) Advanced Hydrologic Prediction Service (AHPS) lists minor flooding in the City of Roseau at 16 feet of stage. Moderate flooding occurs at 18 feet of stage, and major flooding occurs at 19 feet of stage. The top of levees in Roseau is at 22 feet of stage.

Table 1 lists several significant flood events on the Roseau River. The most significant and recent event occurred on June 12, 2002. A total of nearly 7 inches of rainfall was recorded in the City from June 8 to 10, 2002. The temporary levee system was overtopped resulting in flooding throughout most of the City. Damages exceeded $120 million with over 50 buildings unsalvageable.

Flood stage observations within the City of Roseau as well as the U.S. Geological Survey (USGS) stream gage "Roseau River below South Fork near Malung" (gage number 05104500) are provided, as available. Comparing the flood stage information recorded at Roseau and at the USGS gage shows a strong correlation. The rating curve at the gage can be used to provide a river flow and probability of exceeding for various flood stages in Roseau. Table 2 provides the flood frequency for the gage itself and Table 3 links the flood frequency information to the City of Roseau flood events.

Figure 5 provides the Federal Emergency Management Agency (FEMA) flood plain of Hay Creek and the downstream area, while Figure 6 provides a basin-wide map of flood prone areas.

TABLE 1. HISTORIC FLOOD EVENTS AT ROSEAU, MN AND SOUTH FORK NEAR MALUNG

Date	River Stage [ft]		South Fork near Malung Gage Flow [cfs]
	At City of Roseau	At South Fork near Malung (USGS Gage Number 05104500)	
06/12/2002	23.40	26.96	16,000
04/19/1996	21.10	Not recorded	Not recorded
05/19/1996	20.90	Not recorded	7,310
05/13/2004	20.50	22.43	7,280
04/03/2006	19.69	21.16	4,350
04/19/1997	19.10	Not recorded	4,300
03/29/2004	18.41	Not recorded	Not recorded
04/08/1999	17.60	18.22	3,300
03/31/1986	16.50	17.38	3,450
04/08/2001	15.79	Not recorded	Not recorded
7/18/1968	Not recorded	22.32	5,750
4/25/1979	Not recorded	21.78	5,480
6/29/1985	Not recorded	21.14	5,170
4/11/1969	Not recorded	21.59	5,110
4/3/1966	Not recorded	23.37	5,050
4/24/1950	Not recorded	22.51	4,750
4/13/1965	Not recorded	21.9	4,660
7/3/1975	Not recorded	18.93	4,180
8/2/2001	Not recorded	19.59	4,090
4/21/1948	Not recorded	18.39	3,940
3/31/1967	Not recorded	18.67	3,410
6/12/1962	Not recorded	16.98	3,330

TABLE 2. FLOOD FREQUENCY AT ROSEAU RIVER BELOW SOUTH FORK NEAR MALUNG

Reoccurrence Interval [year]	Annual Probability of Occurrence [%]	Expected Flow [cfs]	South Fork near Malung Gage Stage [ft]
500	0.2	13,200	26.5
100	1	10,100	25.3
50	2	8,720	24.6
10	10	5,290	21.7
5	20	3,780	19.3
2	50	1,770	13.8

TABLE 3. CITY OF ROSEAU FLOOD EVENT LEVELS

City of Roseau Flood Event	River Stage at City of Roseau [ft]	South Fork near Malung Gage		Annual Probability of Occurrence [%]
		Stage [ft]	Flow [cfs]	
Minor Flooding	16.0	16.6	2,600	49%
Moderate Flooding	18.0	19.0	3,600	29%
Major Flooding	19.0	20.2	4,300	21%
Top of Levees	22.0	24.6	8,700	2%

FIGURE 5.
FEMA FLOOD INSURANCE RATE MAP OF PROJECT AREA

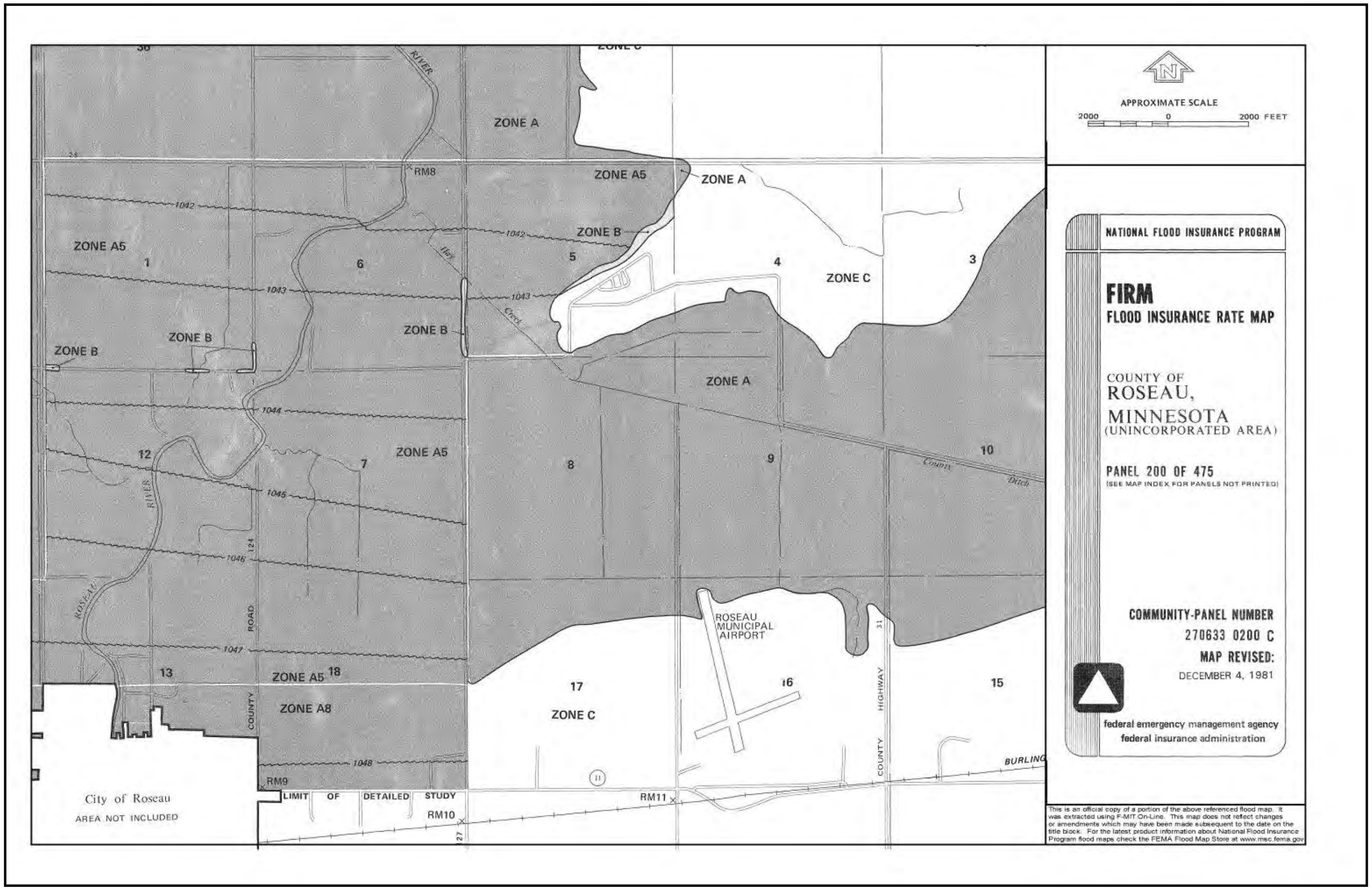
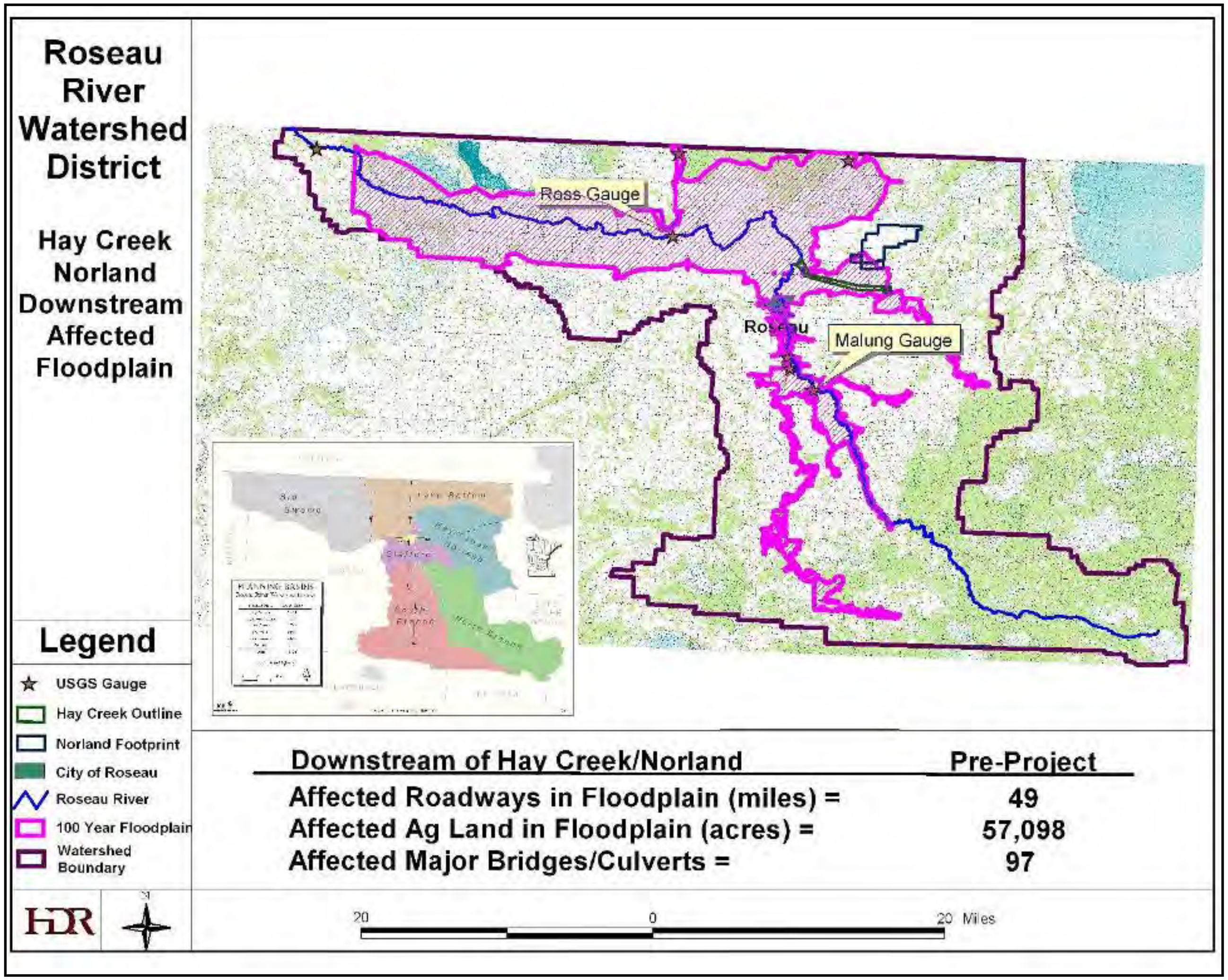


FIGURE 6.
BASIN-WIDE FLOOD PRONE AREAS



5.0 PROJECT FEATURES

The Project site includes the following Project features:

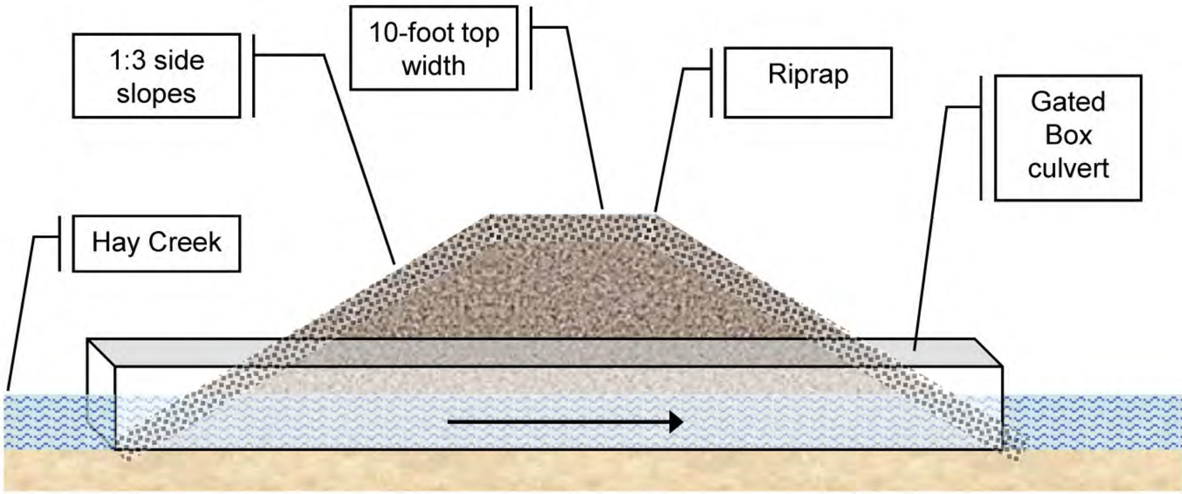
- Inlet Channels and Hay Creek Connection Channel
- Typical embankment sections
- Principal outlet and inlet structures
- Principal outlet channel
- Emergency spillway and associated channel
- Exterior ditches

Each project feature is described in additional detail below. Throughout this Report, two vertical datums are used. Survey work and previous modeling studies performed by the Army Corps of Engineers were made in the National Geodetic Vertical Datum of 1929 (NGVD29). The subsequent plan set developed for this Project was set in the North American Vertical Datum of 1988 (NAVD 88). Generally for this area, a NAVD88 elevation is 1.4 feet greater than the corresponding NGVD29 elevation. Elevation information in this report is specified as either NGVD29 or NAVD 88. Generally, elevations in this report are related in NGVD29, while elevations in the corresponding engineering plan set are specified in NAVD88.

5.1 INLET CHANNELS AND HAY CREEK CONNECTION CHANNEL

Flows may be delivered to the Norland Impoundment from several sources. Two are existing ditch systems: County Ditch 18 (CD 18) and Judicial Ditch 61 (JD 61). A proposed connection channel, between Hay Creek and CD 18, is also a source of water. Figure 7 illustrates the diversion structure and channel inlet structure at Hay Creek if this connection channel is constructed.

FIGURE 7.
HAY CREEK DIVERSION STRUCTURE



Note: For planning purposes only. Not for construction.

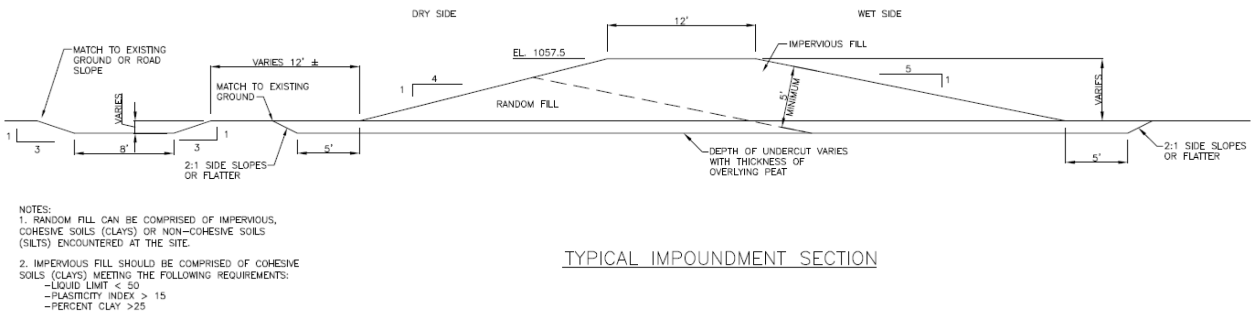
5.2 TYPICAL EMBANKMENT SECTIONS

Figure 8 illustrates a typical embankment cross section. Existing or proposed exterior or interior ditches will have an 8-foot wide bottom with 3:1 side slopes. An offset is reserved next to the ditch for construction of a maintenance road that will allow access to the exterior ditch or exterior embankment slope. A second maintenance road will be constructed on the crest of the embankment. The top of embankment is at 1057.5 feet (NGVD29) or 1,059 feet (NAVD88). This elevation includes a 6-inch overbuild to allow for settling, as recommended by the Geotechnical Engineer.

The embankment slopes are 4:1 on the exterior and 5:1 on the interior. Both slopes exceed the minimum 3:1 slope provided in the NRCS's TR-60 Earth Dams and Reservoirs and the U.S. Bureau of Reclamation's Design of Small Dams. The shallower slope in the interior provides for improved wave dissipation, erosion resistance, under seepage resistance, and improved overall stability of the embankment.

The setback levees will consist of lower embankments with 3:1 side slopes and varying top widths, ranging from 8-feet to 24-feet, where the embankment will be used as a township road.

FIGURE 8.
TYPICAL EMBANKMENT DETAIL



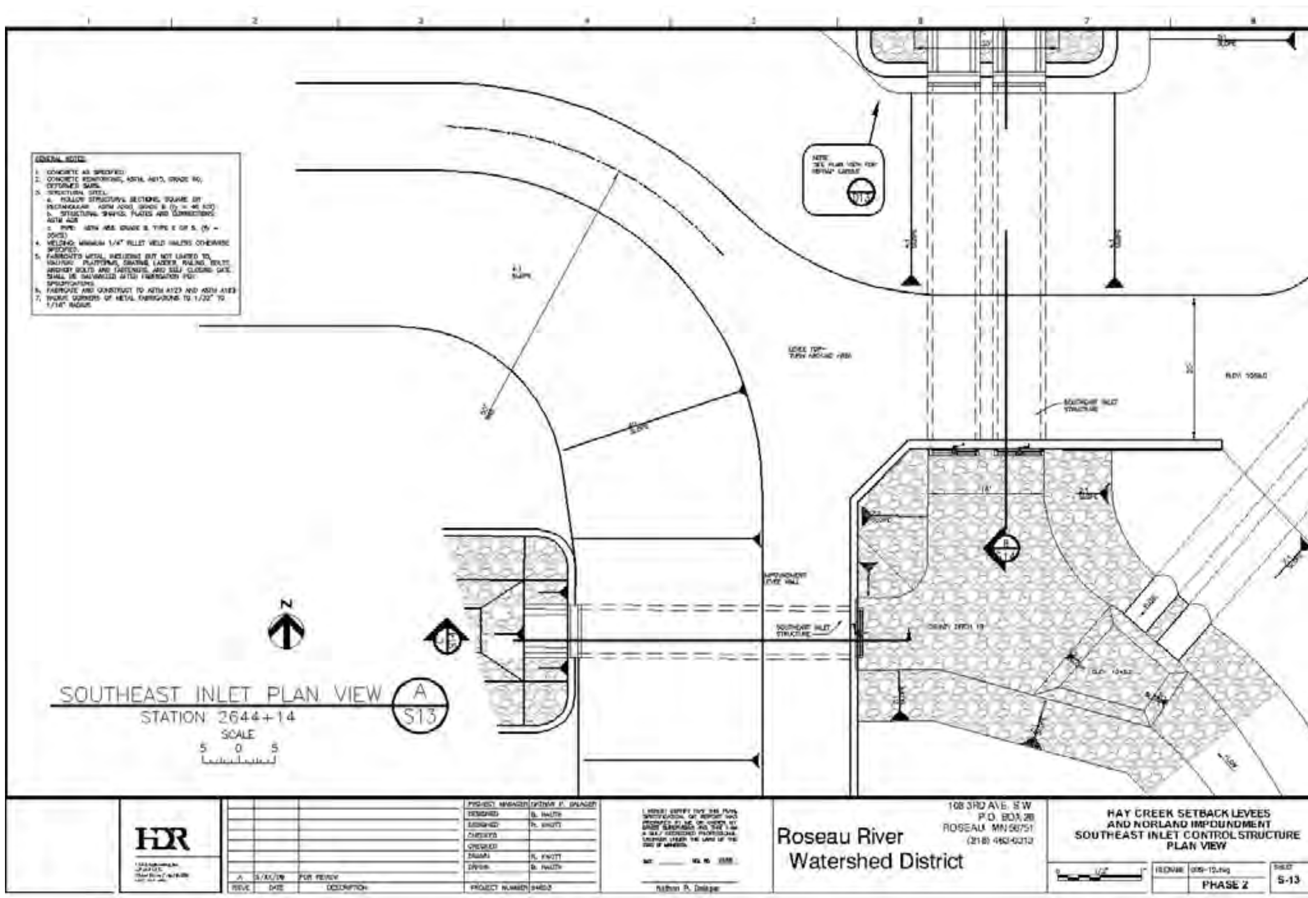
Note: For planning purposes only. Not for construction. Refer to engineering plan sets.

5.3 INLET AND OUTLET STRUCTURES

Figure 9 illustrates the type of inlet work suggested for this impoundment. Gated inlets will be operated to allow flows to enter the impoundment. Figure 10 illustrates the type of primary outlet work suggested for this impoundment. The operation of the outlet gate is described in Section 8.3. When the impoundment water surface reaches the secondary inlet structures, the outlets discharge at a rate to prevent the use of the emergency spillway for the 100-year storm events and the Emergency Spillway Hydrograph (ESH). Linking the impoundment with Hay Creek allows for additional inflows, which lowers the secondary inlet structure elevation.

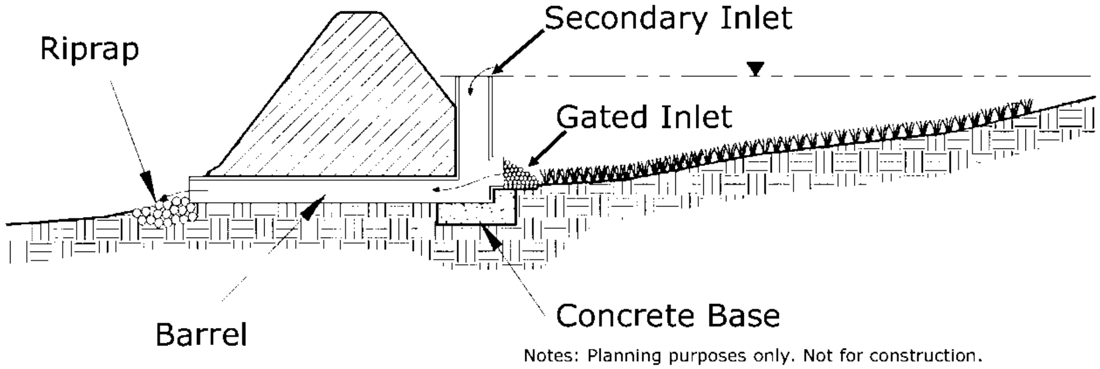
The maximum velocities from the outlets will occur when the impoundment is full and both the gated and secondary inlet structures are discharging flow. An energy dissipating stilling basin is planned, along with the appropriate rip-rap sections downstream. The design will require control of seepage around the pipe through use of anti-seep technologies including careful compaction of select clay borrow and use of filter drains.

FIGURE 9.
INLET STRUCTURE DETAIL



Note: For planning purposes only. Not for construction. Refer to engineering plan sets.

FIGURE 10.
PRIMARY OUTLET AND SECONDARY INLET STRUCTURE DETAIL.



5.4 PRINCIPAL OUTLET CHANNELS

The three impoundment outlets discharging to JD 61 and its laterals, and CD 18, respectively, will discharge directly to the ditches, when downstream conditions allow. CD 18 currently flows into CD 7, which is currently planned as the continued outlet for CD 18. Section 8.3 addresses the operating plan and the proposed interaction with the County drainage systems. Backflow will be allowed down the connection channel as long as no flooding is occurring in adjacent areas.

5.5 EMERGENCY SPILLWAY

The emergency spillway will be located at an elevation of 1,055 feet (NGVD29). The spillway will be located in the northern half of Section 20 and will be 1,000 feet in length.

5.6 EXTERIOR DITCHES

Exterior ditches will be constructed on the west and south sides of the impoundment. Lost Creek will provide drainage on the north side of the impoundment. The southwest portion of the impoundment will be drained by CD 18 or a constructed exterior ditch, dependent on the alternatives discussed in Section 6.0.

When the impoundment is full to elevation 1,055 feet (NGVD29), Lateral 3/JD 61 will be allowed to drain via the south exterior ditch. The inlet control structure invert going south into the exterior ditch will be set at elevation 1,053.1 feet (NGVD29), allowing exterior drainage into CD 18 from Lateral 3/JD 61, only when the impoundment is full. Any ponded water below 1,053.1 feet

(NGVD29) will be contained in the Lateral 3/JD 61 channel. Side inlet pipes with flapgates will be provided where appropriate for exterior drainage along the setback levees. As referenced in the Operating Plan in Section 8.3, passage of flows between JD 61 and CD 18 systems, even for a short time, must be approved by the County Board (Ditch Authority). It is also proposed that some improvements be made to the CD 18 or JD 61 systems to accommodate short-term increased flows from JD 61. It is only when the impoundment is full and is dewatering that this transfer of flows between systems would occur.

6.0 PROJECT ALTERNATIVES AND DESIGN CRITERIA

This section describes the impoundment alternatives considered along with the design criteria used to evaluate each alternative.

6.1 PROJECT ALTERNATIVES

Six impoundment alternatives were considered in this report. These alternatives are listed in Table 4 and illustrated in Figure 11. The differences between the alternatives are based on the storage capacity and presence of a connection channel. Three of these alternatives will utilize a connection channel between Hay Creek and the Impoundment to store flood flows from the Hay Creek drainage area, in addition to the CD 18 and JD 61 drainage areas. The remaining three alternatives do not use a Hay Creek-Norland connection channel. Within the connection or non-connection alternatives, there are three storage sizes. The inundated area consists of a main cell of 3,013 acres; the combination of the main and west cells of 3,255 acres; and a combination of the main and south cells of 3,292 acres.

Additional specifications for the alternatives are provided in Section 7.0.

TABLE 4. LIST OF DESIGN ALTERNATIVES

Alternative Number	Description
1-1	Main cell impoundment without Hay Creek connection channel
1-2	West and Main cells impoundment without Hay Creek connection channel
1-3	South and Main cells impoundment without Hay Creek connection channel
2-1	Main cell impoundment with Hay Creek connection channel
2-2	West and Main cells impoundment with Hay Creek connection channel
2-3	South and Main cells impoundment with Hay Creek connection channel

FIGURE 11.
IMPOUNDMENT STORAGE CELLS

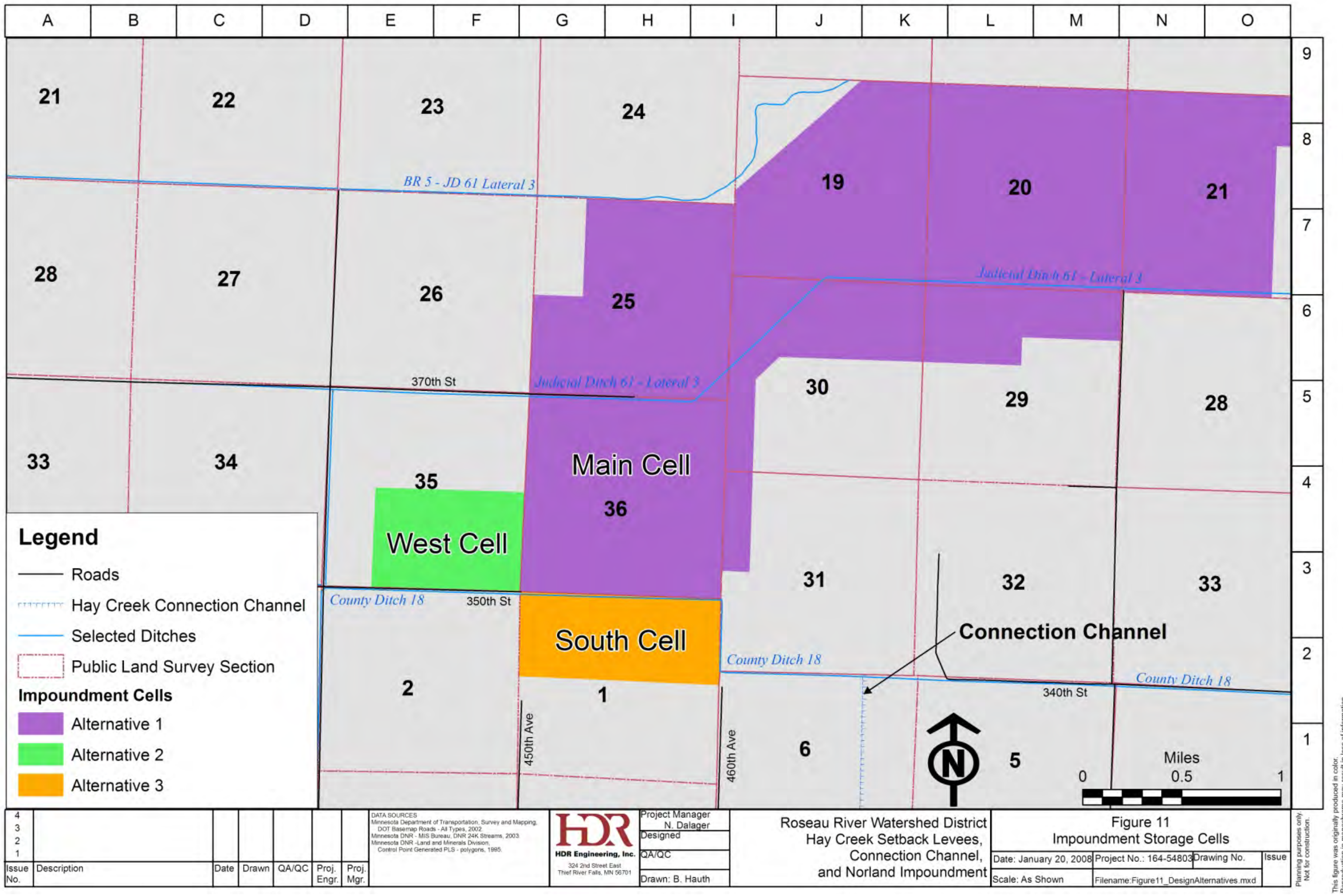


TABLE 5.
DESIGN SUMMARY

Feature	Alternative[a]					
	1-1	1-2	1-3	2-1	2-2	2-3
Top of Embankment Elevation*	1,057.5 ft					
Elevation of Drop Inlet*	1,053.8 ft	1,053.8 ft	1,053.8 ft	1,053.7 ft	1,053.8 ft	1,053.8 ft
Emergency Spillway Invert Elevation*	1,055 ft					
Project Drainage Area	41.7 mi^2 [b]			123.4 mi^2 [c]		
Gated Storage (in runoff)	6,265 acft (2.8 in)	7,710 acft (3.5 in)	7,507 acft (3.4 in)	6,037 acft (0.8 in)	7,710 acft (1.2 in)	7,507 acft (1.1 in)
Ungated (in runoff)	3,269 acft (1.5 in)	3,559 acft (1.6 in)	3,603 acft (1.6 in)	3,497 acft (0.4 in)	3,559 acft (0.5 in)	3,603 acft (0.5 in)
Total Storage (in runoff)	9,534 acft (4.3 in)	11,269 acft (5.1 in)	11,110 acft (5.0 in)	9,534 acft (1.4 in)	11,269 acft (1.7 in)	11,110 acft (1.7 in)

Notes: *Elevations are listed in NGVD29 vertical datum
[a] Alternative 1-1= Main cell impoundment without Hay Creek connection channel
Alternative 1-2 = West and Main cells impoundment without Hay Creek connection channel
Alternative 1-3 = South and Main cells impoundment without Hay Creek connection channel
Alternative 2-1 = Main cell impoundment with Hay Creek connection channel
Alternative 2-2 = West and Main cells impoundment with Hay Creek connection channel
Alternative 2-3 = South and Main cells impoundment with Hay Creek connection channel
[b] Drainage area of CD 18 and JD 61
[c] Drainage area of CD 18, JD 61, and Hay Creek

6.1.1 MAIN CELL IMPOUNDMENT

Alternatives 1-1 and 2-1 are the main cell impoundments, as shown in Figure 13. The impoundment area covers all or portions of sections 19-21, and 29-31 in Salol NE quad and sections 25 and 36 of the Salol NW quad. There are two separate low-lying areas in the impoundment. One low area is in the northern portion of the impoundment; a principal outlet structure is located on, and discharges to, Lost Creek. A second principal outlet structure is located in Section 25 and discharges to Judicial Ditch 61 (JD 61). A third principal outlet structure will be located in the south west corner of section 36 and will discharge to County Ditch 18 (CD 18). Operation of all outlets will be necessary to completely dewater the impoundment.

The shape of the main cell of the impoundment initially took the form of the parcels of land that the District owns in the Project area. Throughout the course of permitting, this shape has been slightly shifted and the size has slightly decreased to avoid impacts to high-quality wetland areas such as the Prairie Rich Fen. This shift is reflected in Figure 12.

Three inlet structures are located within the impoundment area. The northernmost inlet is in the northeast corner of Section 20, and diverts flows south through an existing ditch to JD 61. When not diverting into the impoundment, the inlet provides for local drainage through the existing ditch leading to Lost Creek. A second inlet is located on JD 61/Lateral 3 in the northeast corner of Section 29. Flows will normally pass through the impoundment interior unless the impoundment is being operated during a flood event. In this case, this inlet will drain south and west around the impoundment in an exterior ditch on the south side of the impoundment. This exterior ditch discharges to CD 18. The third inlet is located on CD 18 on the west edge of Section 31. The inlet discharges into an existing interior ditch which flows north into JD 61/Lateral 3. When not diverting flows into the impoundment, the inlet provides for local drainage through the existing CD 18.

When the primary outlets are closed, these ditches flood a maximum area of 3,013 acres storing 9,534 acre-feet. The embankment runs from the north edge of sections 20 to 19, to the west edges of sections 25 and 36, to the south edge of section 36, north through section 31 and 30, and east in the northern half of sections 30 and 29 on the south edge of the impoundment. The embankment ties into an elevation of 1,057 feet (NGVD29). Total embankment length is approximately 55,500 feet. An emergency spillway would be placed in the northern portion of section 19, which flows into Lost Creek.

6.1.2 West Cell Impoundment

Alternative 1-2 and 2-2, the west cell impoundment, adds additional storage by including a portion of section 35 of Salol NE quad. This alternative is shown in Figure 14. The total storage is 11,269 acre-feet covering 3,255 acres. The total embankment length is approximately 64,000 feet. Three principal outlets will be constructed in the impoundment area. The southern-most principal outlet will be located in the south ¼ of the south part of section 35 (Salol NW quad) and discharges into CD 18.

6.1.3 South Cell Impoundment

Alternative 1-3 and 2-3, the south cell impoundment, adds additional storage by including a portion of section 1 (Salol NW quad) and section 31 (Salol NE quad). This alternative is shown in Figure 15. The total storage is 11,110 acre-feet covering 3,292 acres. The total embankment length is approximately 56,500 feet. The impoundment will contain CD 18, necessitating the construction of an exterior ditch on the south side of the impoundment. The southern-most outlet will be located in the northwest corner of section 1 and discharges to CD 18.

6.1.4 Hay Creek Connection Channel

Alternatives 2-1, 2-2, and 2-3 have the same footprints as Alternatives 1-1, 1-2, and 1-3, respectively. A third inflow source is provided from a connection channel between CD 7/Hay Creek near the Highway 11 bridge and the impoundment. The connection channel will connect to the existing CD 18. The connection channel invert begins at an elevation of 1,050.6 feet (NGVD29) and slopes down to elevation 1,048.6 feet (NGVD29) at the connection with CD 18. The proposed channel is 20 feet wide in base width, approximately 5 feet deep, with 3:1 side slopes. A gated culvert structure will keep low flows in Hay Creek from entering the connection channel. At higher flows, a portion of Hay Creek is diverted into the connection channel and flows into the impoundment. As flood flows in Hay Creek recede, the higher elevation of the stored water can flow from the impoundment through the connection channel back into Hay Creek. Further releases from the impoundment will return to Hay Creek via the CD 18 outlet.

Figure 16 provides an alternative connection channel in which the channel is at or above the 1055.5 feet (NGVD29) contour through Section 6. This high elevation channel will significantly reduce the need for flow easements or setback levees. The total estimated channel length is 9,300 feet. An alternative alignment of this diversion channel is to briefly follow a local depression from Hay Creek to the center of Section 6, and then north to the impoundment (Figure 17). The total length of this channel is approximately 10,370 feet. Some local agricultural flooding could result when the embankment is at an elevation of 1,055 feet (NGVD29) with this option.

FIGURE 12.
SHIFT IN ALIGNMENT DUE TO WETLANDS

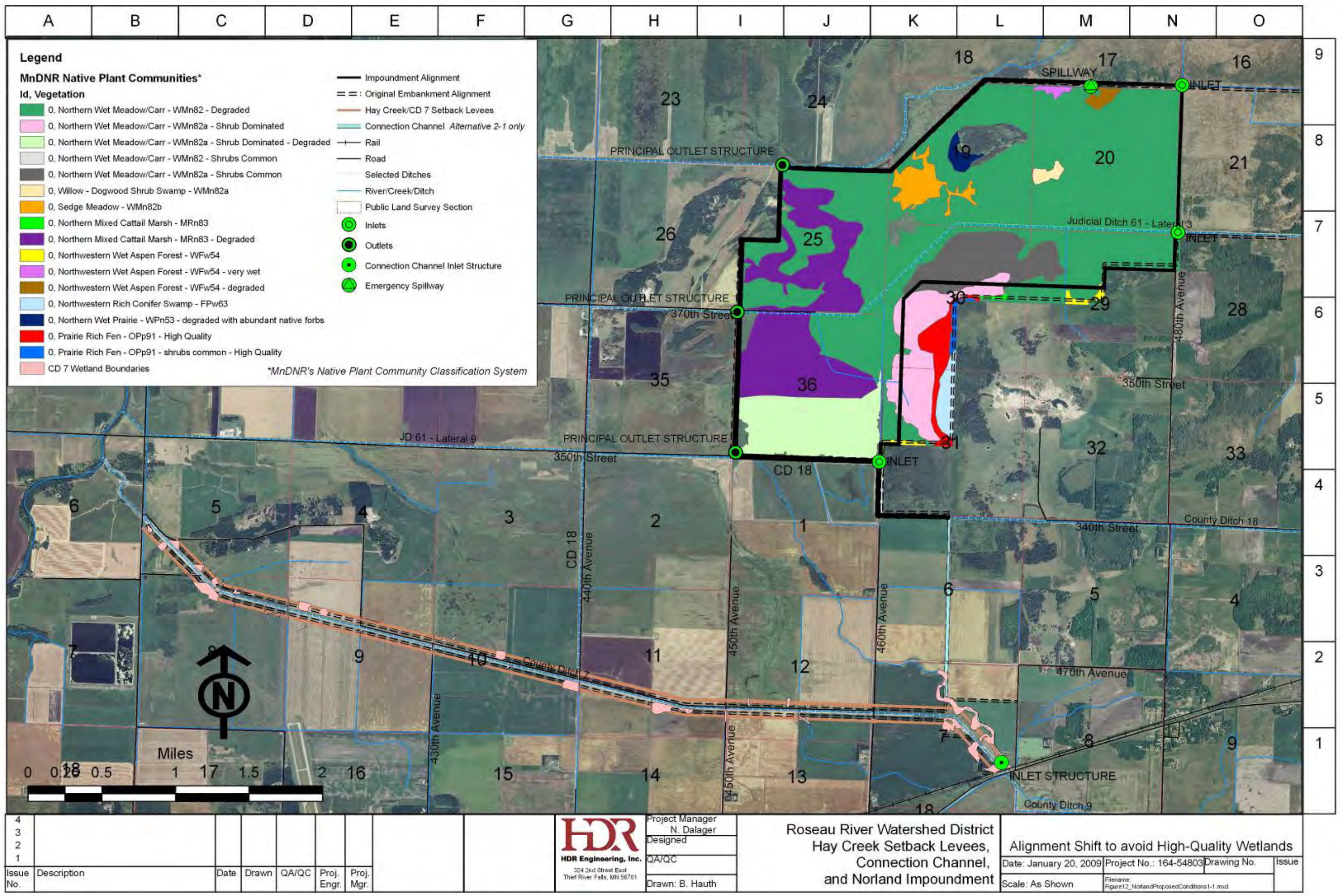


FIGURE 13.
PROPOSED CONDITIONS ALTERNATIVE 1-1 AND 2-1

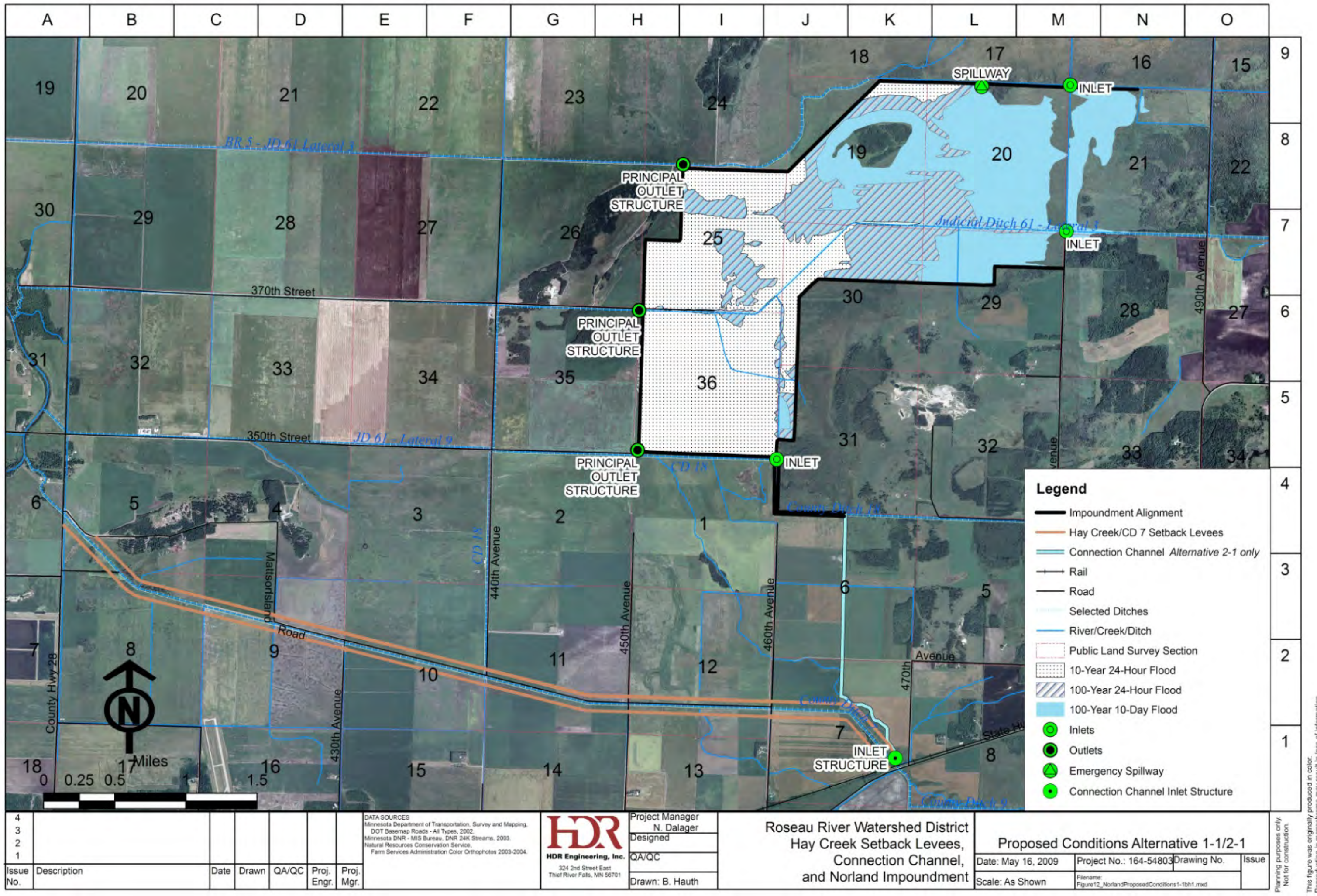


FIGURE 14.
PROPOSED CONDITIONS ALTERNATIVE 1-2 AND 2-2

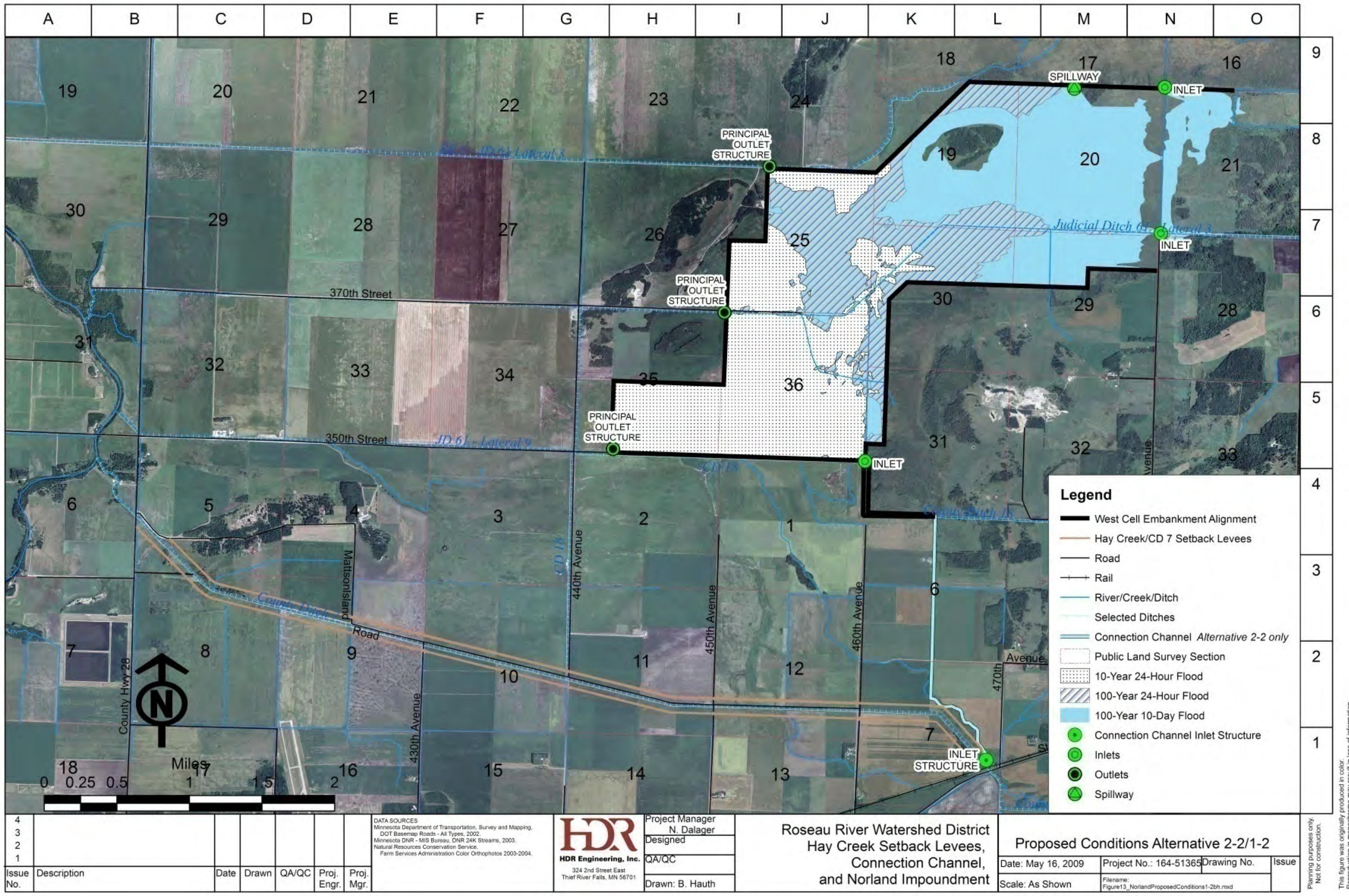


FIGURE 15.
PROPOSED CONDITIONS ALTERNATIVE 1-3 AND 2-3

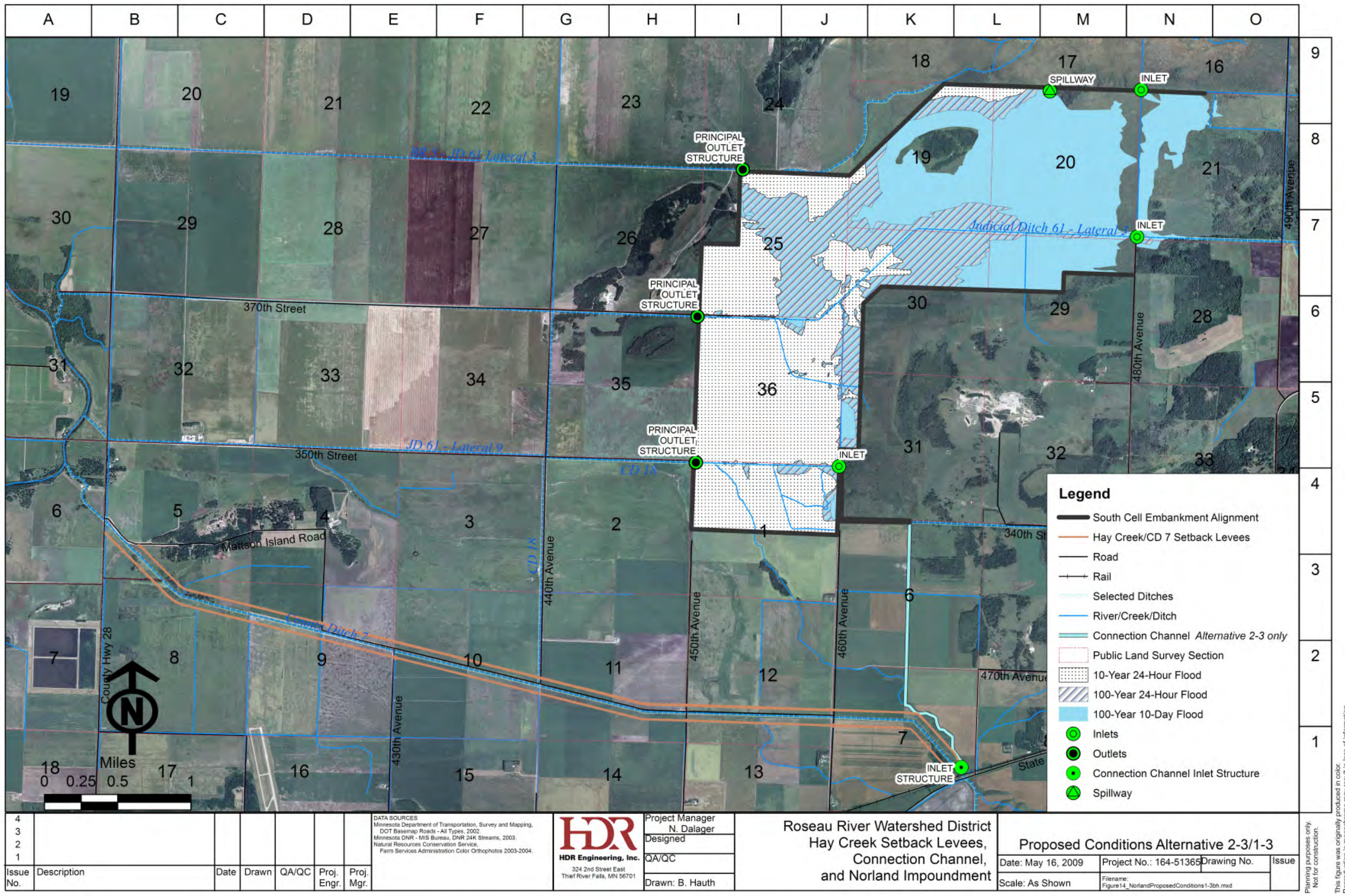


FIGURE 16.
PROPOSED CONDITIONS HAY CREEK CONNECTION CHANNEL ALTERNATIVE 1

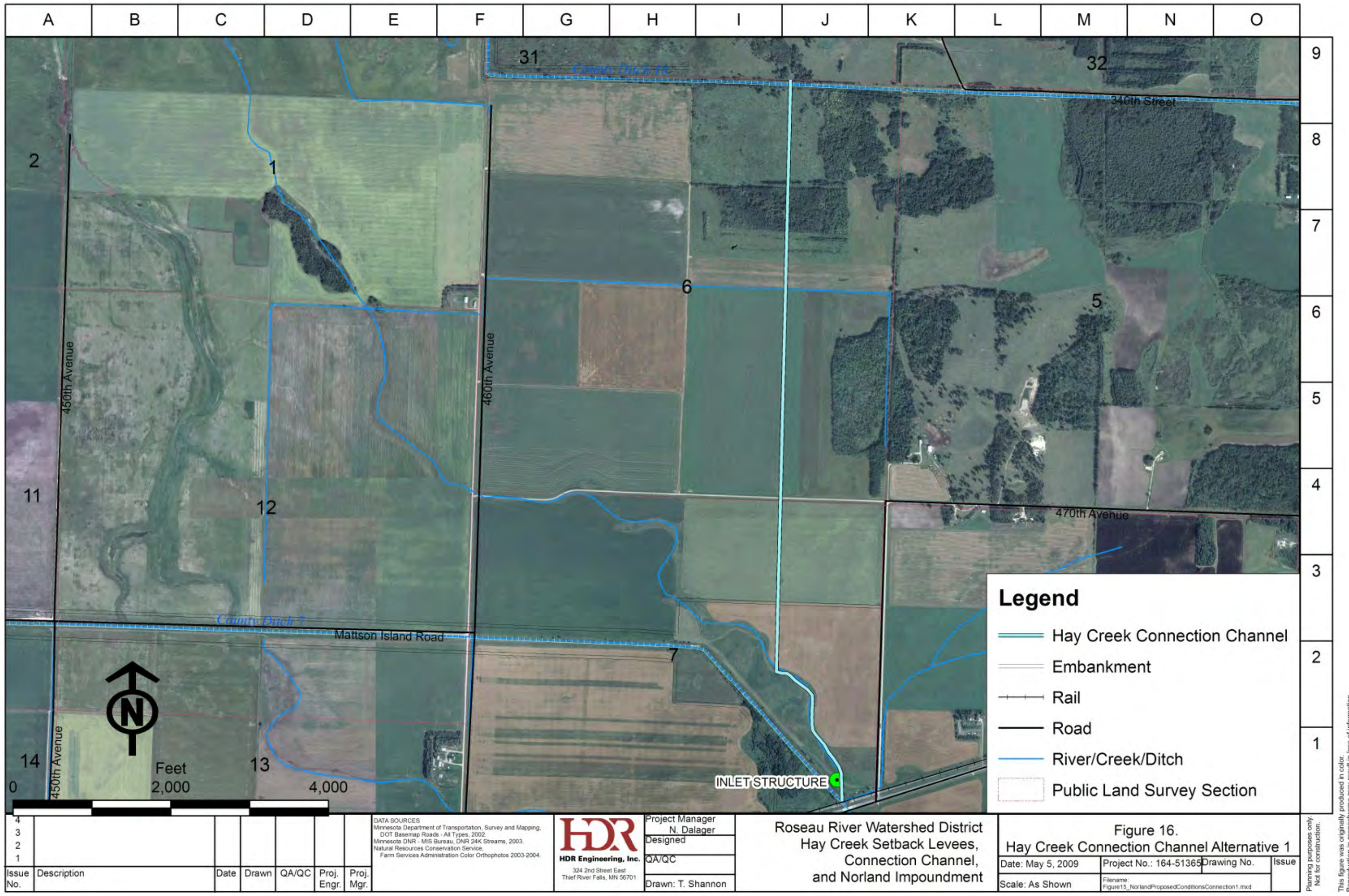
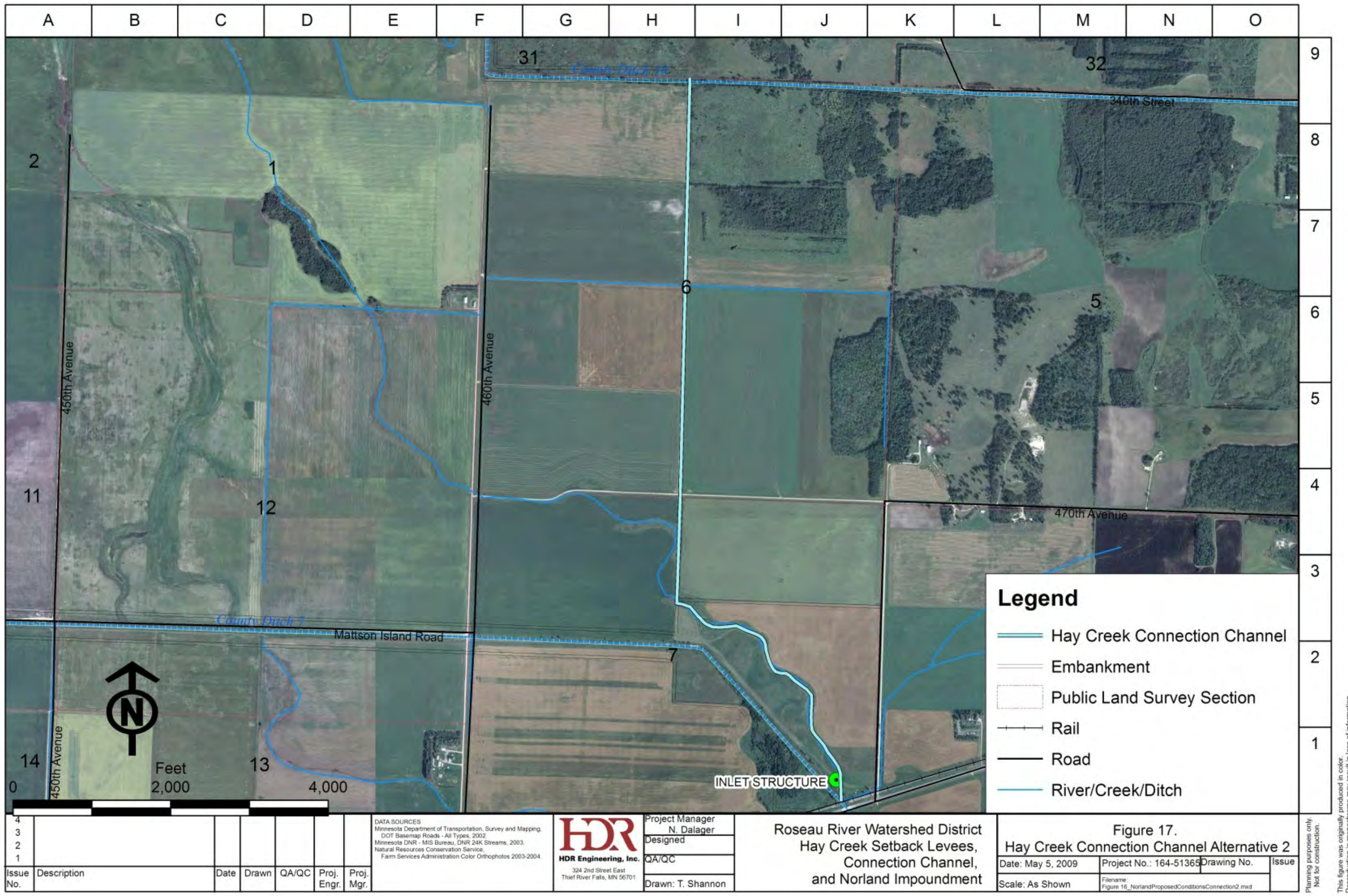


FIGURE 17.
PROPOSED CONDITIONS HAY CREEK CONNECTION CHANNEL ALTERNATIVE 2

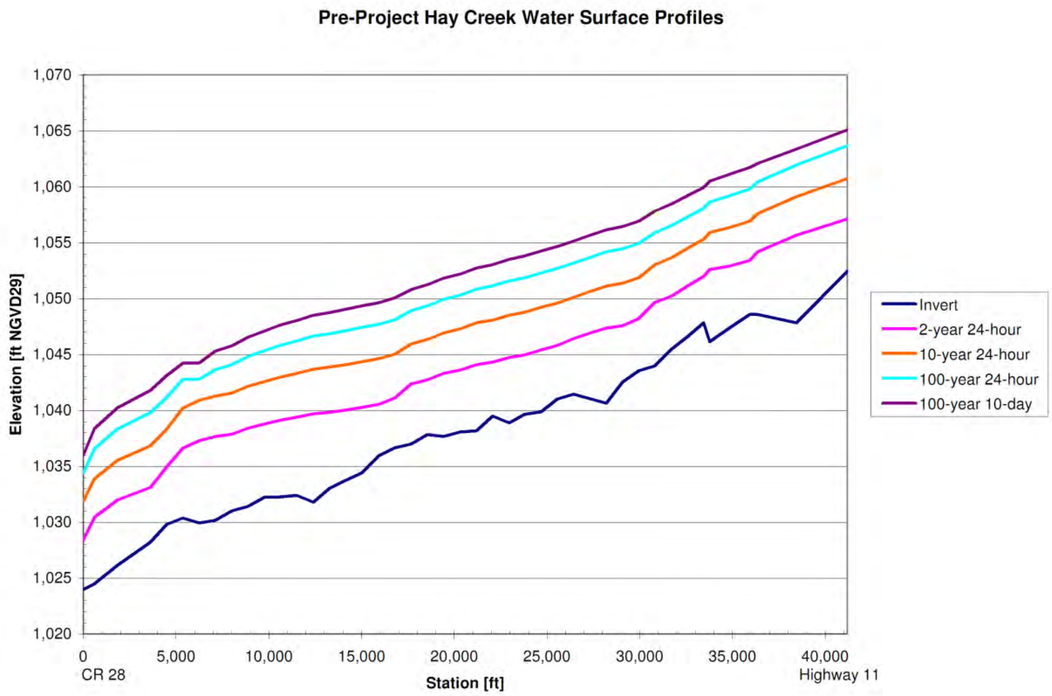


6.1.5 HAY CREEK SETBACK LEVEES

The Hay Creek Setback Levees will serve to limit flooding of Hay Creek/CD 7 on adjacent lands. The alignment of the levees is from Highway 11 to County Road 28. The interior toe of the levees are located approximately 15 feet from the left and right banks of Hay Creek. The acquired right-of-way is 325 feet on either side of the channel centerline. Exterior ditches will be placed out near the property line to provide local drainage and provide a barrier between local farmland and the Watershed District property. The initial location of the setback levees was at the perimeter of the right-of-way, but the levees were moved in near the ditch due to a County ditch repair project completed in 2009. It was no longer cost effective to move the large volume of County repair spoil out to the right-of-way limits. Near the tie-in with the rail embankment, the setback levees will end at the property boundaries of the Watershed District land. The top of the levee will range from 3 to 6 feet above the natural ground elevations with exterior ditches and side inlet culverts, with flap gates providing local drainage. About 3.5 miles of the existing township road along the north side of Hay Creek will be relocated to the top of the setback levee along Hay Creek.

The initial design of the setback levees was to be constructed to approximately the 10-year summer water surface profile plus about 1 foot of freeboard. In 2008/2009, the Roseau County project consisted of excavating the side slopes of Hay Creek to approximately 4:1 (H:V), and placing the spoil from this excavation just outside of the edge of the Creek. The level of protection from flooding is now approximately natural ground and the elevation of the bridge decks that cross Hay Creek. The proposed design is to construct the levees to the elevation of the current spoil banks; they will not be associated with any hydraulic or hydrologically determined elevations. The downstream end of the Hay Creek setback levees will still be subject to backwater flooding from the Roseau River. This Project is not designed to protect the area from flooding from high stages on the Roseau River. Figure 18 shows the water surface profiles for various storm events and ditch slope of Hay Creek/CD 7 from Highway 11 to CR 28 under pre-project conditions.

FIGURE 18
HAY CREEK/CD7 WATER SURFACE PROFILES



6.2 Design Criteria

The design of the flood storage impoundment follows normal and customary engineering approaches applied in the State of Minnesota. These include use of reference documents from the State of Minnesota, Federal agencies, and professional engineering judgment and design methods utilized on similar projects in the greater Red River basin.

6.2.1 Maximum Water Surface Elevation

The 100-year 24-hour duration, 100-year 10-day duration, and 24-hour emergency spillway hydrograph (ESH) were used to size the primary outlet. The 24-hour ESH and the 24-hour Free Board Hydrograph (FBH) was used to size the emergency spillway to prevent overtopping of the embankment crest.

6.2.2 Design Storm Data

The Project design utilized information presented in the Rainfall Frequency Atlas of the Midwest, published by the Midwest Climate Center. The probable maximum precipitation (PMP) events were obtained from National Weather Service (NWS) Technical Paper Number 40 and Hydrometeorological Report Number 51. Methods for computing the ESH and FBH from Soil

Conservation Service (SCS) National Engineering Handbook Number 4 and Natural Resources Conservation Service (NRCS) Technical Release Number 60 (2nd edition) were utilized.

TABLE 6.
DESIGN STORM RAINFALL DEPTHS

Event	Precipitation Depth [in]
2-Year 24-Hour	2.12
10-Year 24-Hour	3.50
100-Year 24-Hour	5.25
100-Year 10-Day	8.25
ESH (6-Hour)	6.42
ESH (24-Hour)	7.86
FBH (6-Hour)	10.90
FBH (24-Hour)	13.95

6.2.3 DESIGN RAINFALL DISTRIBUTION

NRCS TR-60 provides a dimensionless duration curve for use with the ESH and FBH. All other storm events utilized the SCS Type II rainfall distribution.

6.2.4 RAINFALL-RUNOFF MODEL

A rainfall-runoff model of the Roseau River basin was developed by the RRWD ("District Model"). This model was utilized, with modifications, for analysis in this report.

6.2.5 SUBWATERSHEDS

Figure 2 shows the Hay Creek Setback Levees and Norland Impoundment watershed. The total watershed area is 123.4 mi^2, divided into 23 subwatersheds. This area consists of drainage contributing to CD 18, JD 61, and Hay Creek upstream of the proposed impoundment location. Seven of these subwatersheds (an area of 41.7 mi^2) constitute drainage into CD 18 and JD 61 upstream of the proposed impoundment location.

6.2.6 SCS CURVE NUMBERS

The District Model was developed for simulation of storm events of 10-day duration. SCS curve numbers ranges from 46 to 57 within the drainage area. For this report, additional storm events of 24-hour durations or less, were required. A version of the District Model was generated in which the SCS curve numbers (CN) were increased based on TR-60 to account for the storm duration differences.

6.2.7 TIME OF CONCENTRATION

The District Model was developed using the Minnesota Hydrology Guide approaches in determining the time of concentration (T_c).

6.2.8 RAINFALL DISTRIBUTION

Several standard sources were utilized for rainfall depth information. The 100-year storm events were obtained from the Rainfall Frequency Atlas of the Midwest (Huff and Angel, 1992). Estimates of the Probable PMP were obtained from the NWS publications Technical Paper 40 (TP-40) and Hydrometeorological Report 51 (HR-51). The computed depths for the ESH and the FBH were developed based on TR-60. The temporal distribution for the 100-Year, 10-Day storm is based on the hyetograph contained in the District HEC Hydrologic Modeling System (HMS) model. The distribution for the ESH and FBH is from TR-60.

6.2.9 HYDROGRAPH SHAPE

The hydrograph transformation uses the Clark synthetic unit hydrograph. While this method is different from the basin-shape derived hydrographs utilized in the District model, the modeled differences were small. Time of concentration (T_c) and the SCS storage coefficient (R) are used as inputs to this method. The District HMS model provides ratios of $R/(T_c+R)$ between 0.58 and 0.74 in the Norland watershed.

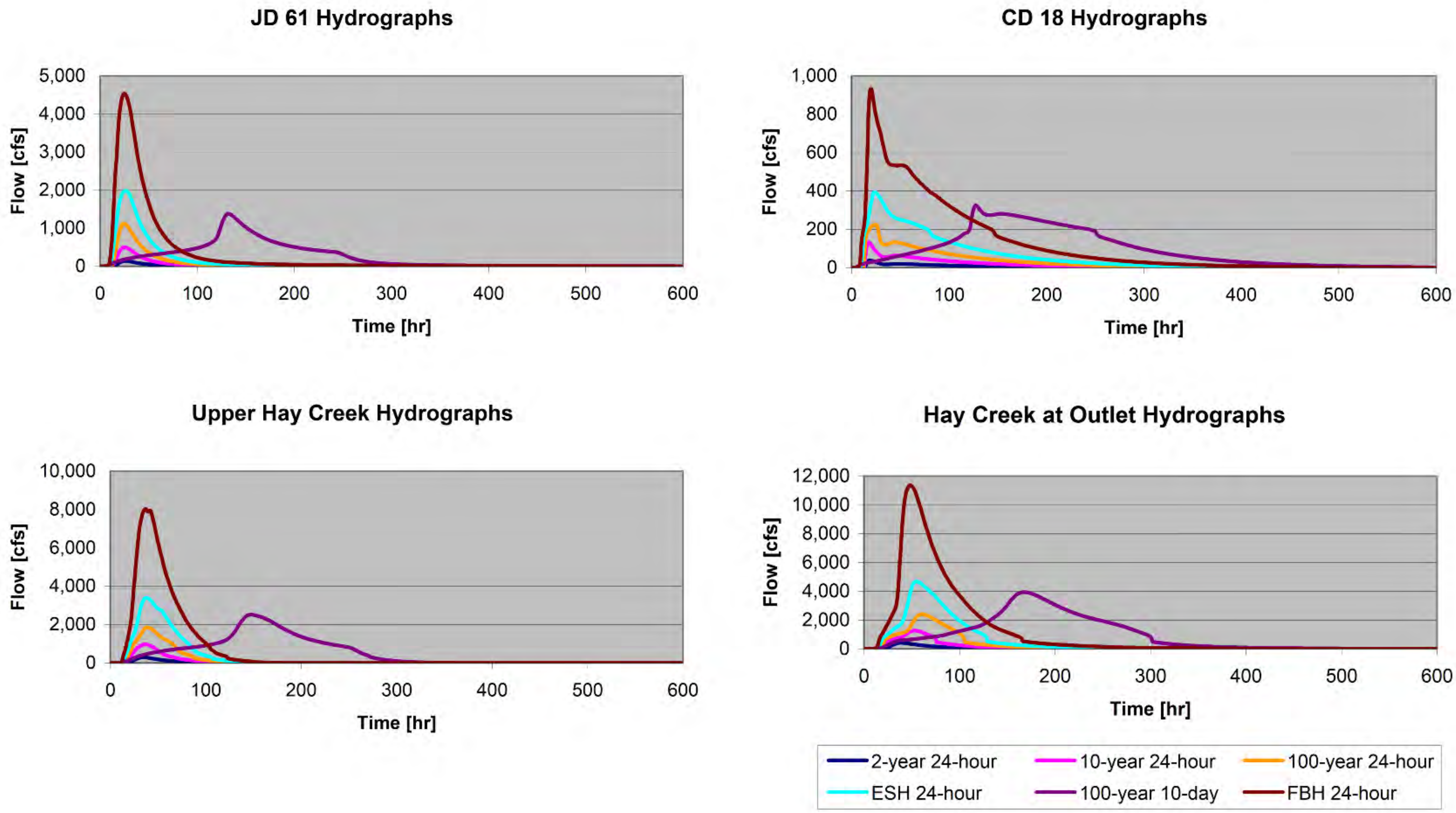
Peak Flows

Table 7 provides the peak flows and volumes generated for various storms from the District Model. Selected hydrographs are shown in Figure 19. The locations of the selected hydrographs are depicted in Figure 2.

TABLE 7.
MODELED PEAK FLOWS AND VOLUMES

Event	Judicial Ditch 61		County Ditch 18		Upper Hay Creek		Hay Creek at Outlet	
	Peak Flow [cfs]	Volume [acft]	Peak Flow [cfs]	Volume [acft]	Peak Flow [cfs]	Volume [acft]	Peak Flow [cfs]	Volume [acft]
2-year 24-hour	140	398	39	212	298	923	418	1,785
10-year 24-hour	499	1,404	132	666	972	3,129	1,269	5,939
100 year 24-hour	1,118	3,111	224	1,382	1,859	6,807	2,411	12,752
100 year 10-day	1,384	11,747	324	4,671	2,525	24,912	3,933	46,036
ESH (24-hour)	1,985	6,105	394	2,707	3,397	13,297	4,684	25,012
ESH (6-hour)	1,774	4,407	429	2,030	2,680	9,625	3,449	18,046
FBH (24-hour)	4,530	13,932	934	5,914	8,036	30,059	11,362	56,373
FBH (6-hour)	3,975	9,925	971	4,304	5,999	21,502	8,136	40,411

FIGURE 19.
SELECTED MODELED HYDROGRAPHS



7.0 HYDROLOGIC AND HYDRAULIC MODELING RESULTS

7.1 HYDRAULIC MODEL DEVELOPMENT

Hydraulic modeling of the impoundment alternatives was performed using the Environmental Protection Agency's (EPA) SWMM version 5.0.013.

7.2 HYDRAULIC DATA

All Project alternatives can store water up to an elevation of 1,055 feet (NGVD29). The stage-storage curves for the alternatives are provided in Figure 20. The discharge capacity of the primary outlet and connection channel is shown in Figure 21 and Figure 22.

Roseau County implemented channel modifications of Hay Creek independently of this project. Subsequent observations during the 2009 spring runoff event indicate that flood stages have decreased due to this channel modification. While modified cross-section details are not currently available, it was assumed that the original channel bottom was not altered and modification consists of 4:1 (H:V) side slopes for subsequent SWMM modeling in this report.

FIGURE 20.
ELEVATION- STORAGE CURVE

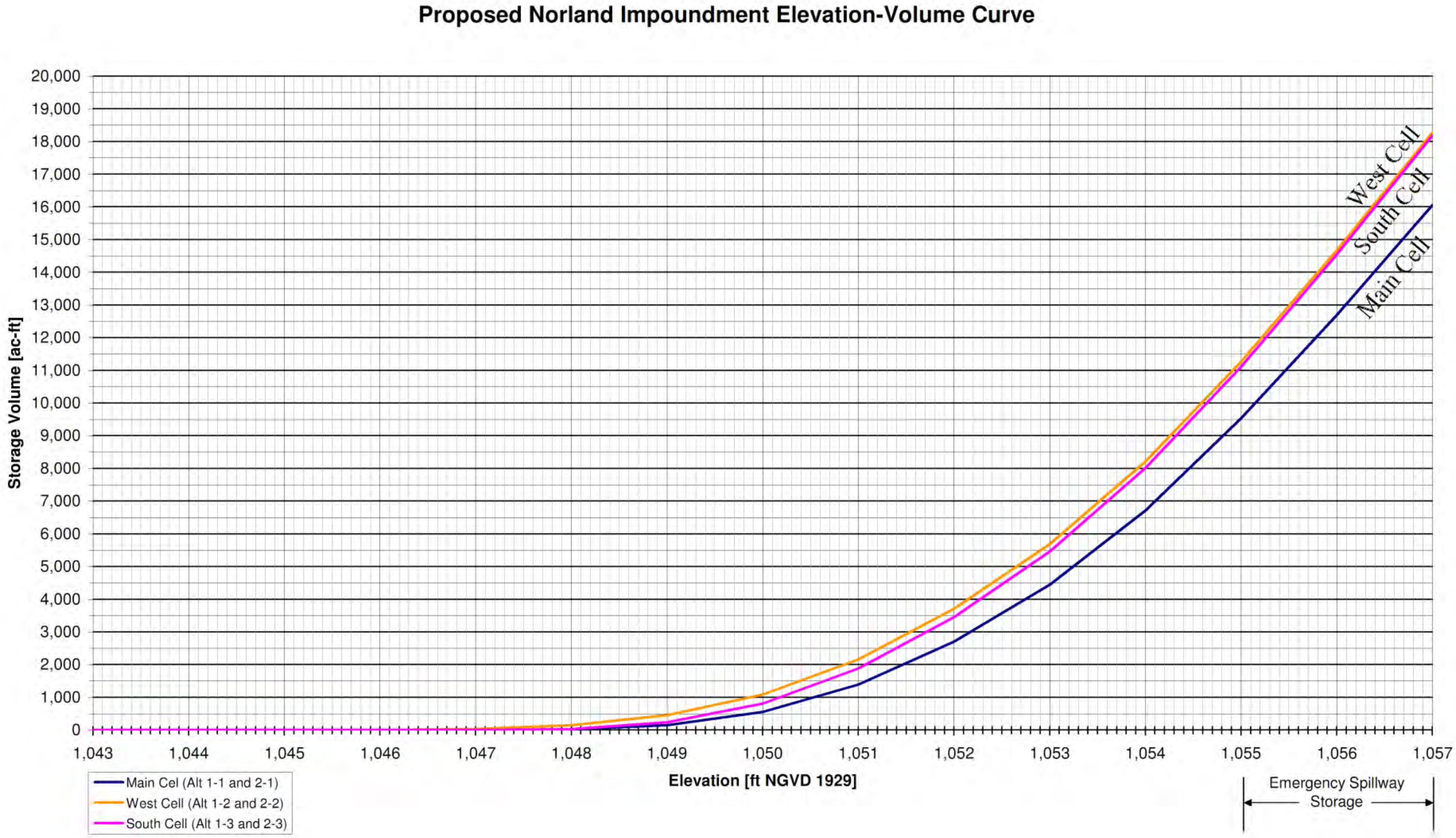


FIGURE 21.
IMPOUNDMENT ELEVATION- DISCHARGE CURVES

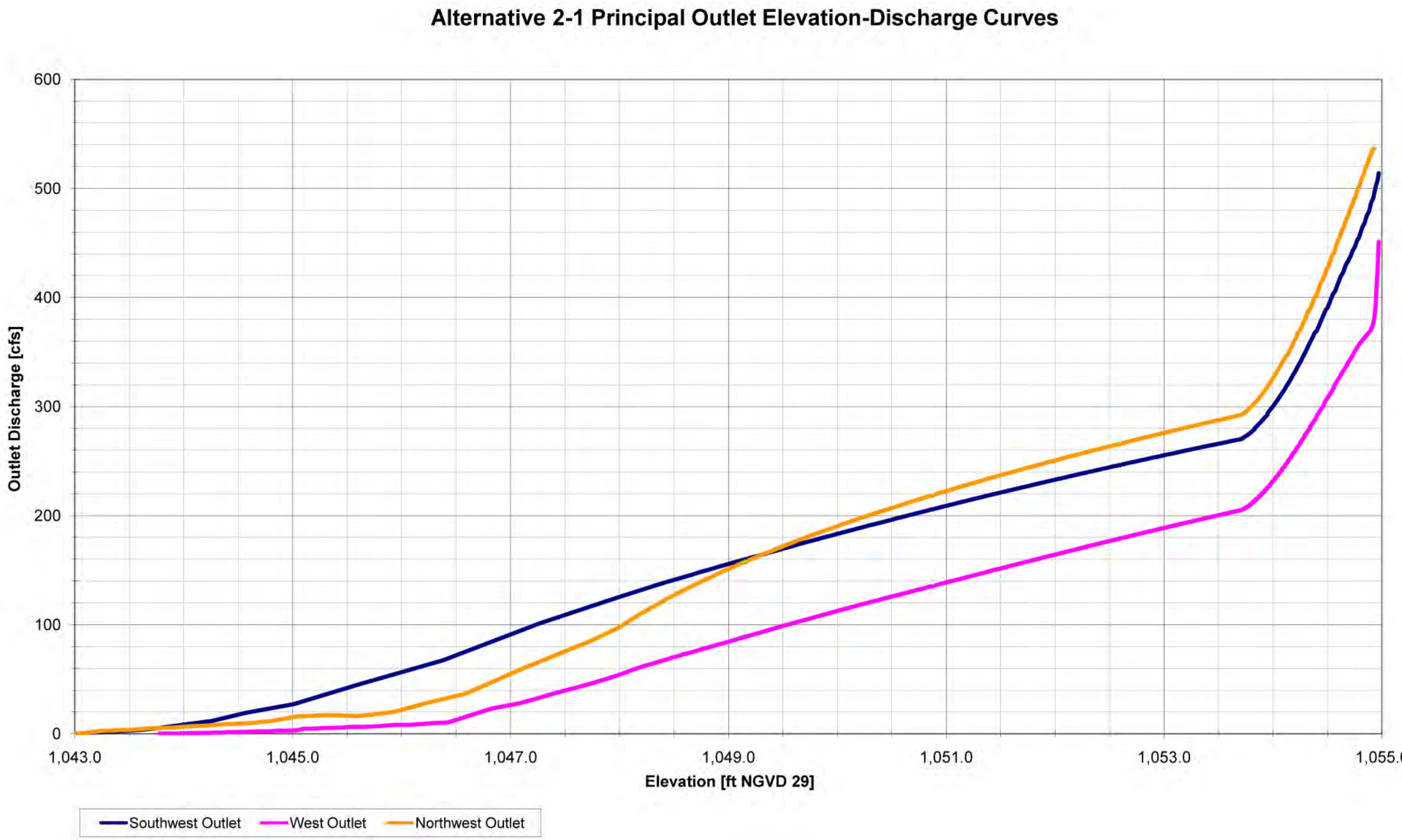
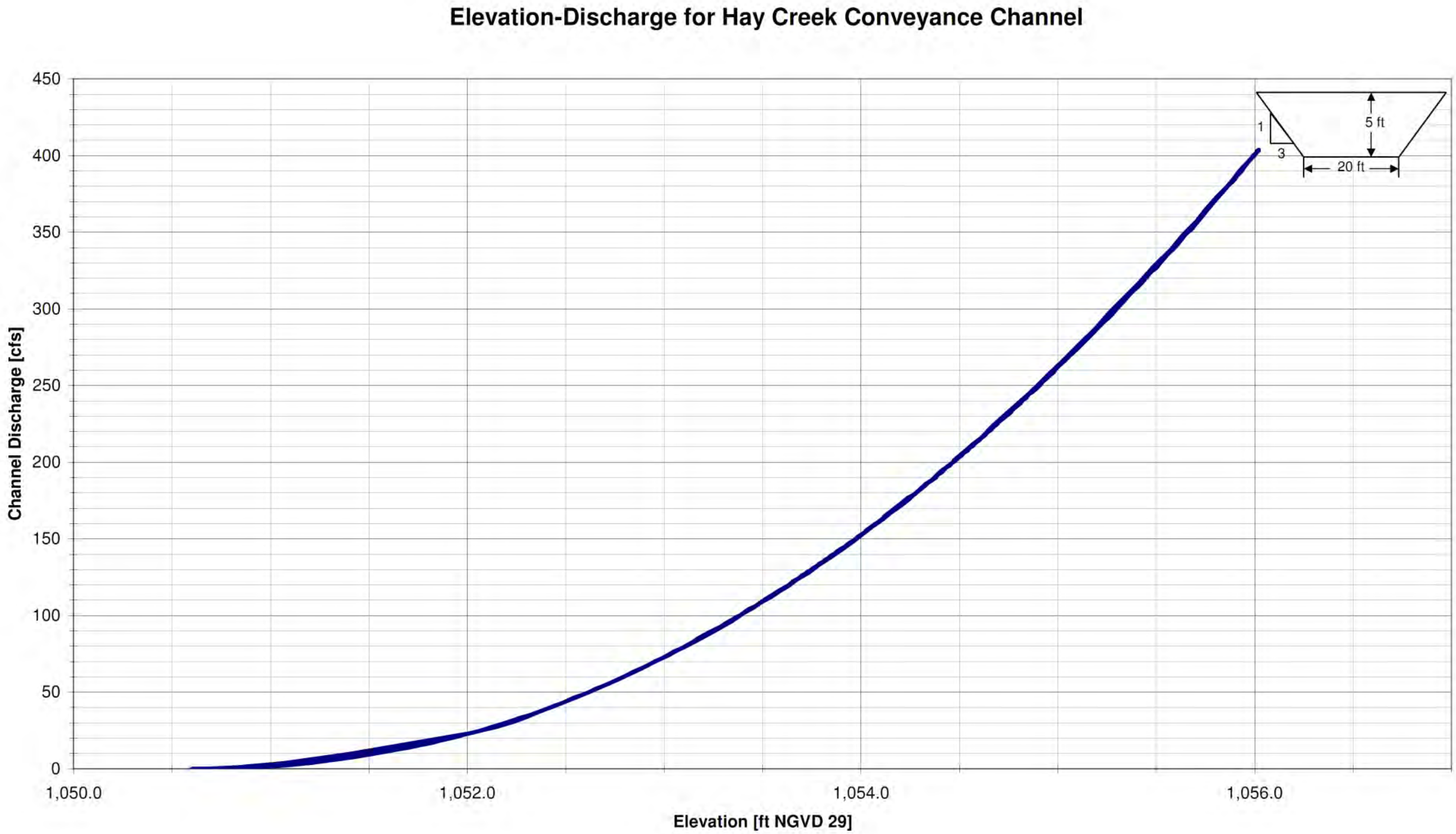


FIGURE 22.
HAY CREEK CONNECTION CHANNEL ELEVATION-DISCHARGE CURVES



Note: Assumes minimum water surface elevation in Impoundment and CD 18.

7.2.1 EMBANKMENT

The embankment top elevation for both impoundment alternatives is 1,057.5 feet (NGVD29). Two feet of freeboard is provided between the invert elevation of the emergency spillway and the top of the embankment. The embankment will also be built with a 6-inch overbuild to allow for settlement. The maximum pool elevation for the 100-year, 10-day storm event does not exceed the emergency spillway crest.

7.2.2 PRINCIPAL OUTLETS (GATED)

There are three principal outlets consisting of reinforced concrete box culverts and gates with a size of 6 feet wide and 4 feet high. These outlets are referred to as the northwest (discharging to Lost Creek), west (discharging to JD 61), and the southwest (discharging to CD 18) outlet structures. The drop inlet weir length is 80 feet set at varying crest heights depending on the alternative being considered. This weir crest height can be found in Table 9. Both the gate and drop inlet discharge to an outlet box culvert 10 feet wide by 6 feet high. The northwestern outlet invert discharging to Lost Creek will be located at an elevation of 1,043.6 feet (NGVD29). The western outlet invert, discharging to JD 61/Lateral 3, will be located at an elevation of 1,042.85 feet (NGVD29). The southwestern outlet invert, discharging to CD 18, will be located at an elevation of 1,043.6 (NGVD29). When opened, the gate in conjunction with the secondary outlet will substantially dewater the impoundment from its maximum storage within 10 to 15 days. The maximum discharge for a single principal outlet is around 500 to 530 cfs. The maximum velocities are approximately 8 to 9 feet/sec.

The sizes of the principal outlets are summarized in Table 8.

TABLE 8.
PRINCIPAL OUTLET SIZES

Alternative[a]	Gate Size	Outlet Size	Maximum Capacity [cfs] [b]	Maximum Velocity [fps] [b]
1-1	6 ft by 4 ft	10 ft by 6 ft	500	8.3
1-2	6 ft by 4 ft	10 ft by 6 ft	502	8.4
1-3	6 ft by 4 ft	10 ft by 6 ft	502	8.4
2-1	6 ft by 4 ft	10 ft by 6 ft	524	8.7
2-2	6 ft by 4 ft	10 ft by 6 ft	502	8.4
2-3	6 ft by 4 ft	10 ft by 6 ft	502	8.4

Notes:

a Alternative 1-1= Main cell impoundment without Hay Creek connection channel
Alternative 1-2 = West and Main cells impoundment without Hay Creek connection channel
Alternative 1-3 = South and Main cells impoundment without Hay Creek connection channel
Alternative 2-1 = Main cell impoundment with Hay Creek connection channel
Alternative 2-2 = West and Main cells impoundment with Hay Creek connection channel
Alternative 2-3 = South and Main cells impoundment with Hay Creek connection channel

b Maximum capacity and velocity of a single principal outlet.

7.2.3 SECONDARY OUTLET (DROP INLET)

The secondary outlet was sized using the 100-year, 10-day and ESH hydrograph as the critical storm event. The sizing requirement passes the 100-year, 10-day hydrograph with the maximum storage elevation reaching, but not exceeding, the emergency spillway elevation.

The secondary outlet structure is positioned at 1,053.8 feet (NGVD29) for Alternatives 1-1, 1-2, and 1-3. The secondary outlet structure crest is at 1,053.7 feet (NGVD29) for Alternative 2-1, 1,053.8 feet (NGVD29) for Alternatives 2-2 and 2-3. The larger storage volume in the west and south cell alternatives permits for a higher drop structure elevation.

Table 9 summarizes the drop inlet sizes.

TABLE 9.
SUMMARY OF DROP INLET SIZING

Alternative[a]	Maximum Weir Crest Height [NGVD29 ft]	Weir Length for each Drop Inlet [ft]	Number of Drop Inlets	Total Weir Length for All Drop Inlets [ft]
1-1	1,053.8	80	3	240
1-2	1,053.8	80	3	240
1-3	1,053.8	80	3	240
2-1	1,053.7	80	3	240
2-2	1,053.8	80	3	240
2-3	1,053.8	80	3	240

Notes:

a Alternative 1-1= Main cell impoundment without Hay Creek connection channel
Alternative 1-2 = West and Main cells impoundment without Hay Creek connection channel
Alternative 1-3 = South and Main cells impoundment without Hay Creek connection channel
Alternative 2-1 = Main cell impoundment with Hay Creek connection channel
Alternative 2-2 = West and Main cells impoundment with Hay Creek connection channel
Alternative 2-3 = South and Main cells impoundment with Hay Creek connection channel

7.2.4 EMERGENCY SPILLWAY

The emergency spillway is located at an elevation of 1,055.0 feet (NGVD29). The spillway will discharge into the Lost River on the north side of the impoundment for all alternatives. The spillway will convey the FBH without the water surface elevation overtopping the embankment. The minimum width of the spillway crest is 1,000 feet. Table 10 summarizes the emergency spillway sizing.

TABLE 10.
SUMMARY OF EMERGENCY SPILLWAY SIZING

Feature	Design
Spillway Elevation [ft NGVD29]	1,055.0
Spillway Length [ft]	1,000

7.2.5 HAY CREEK AND CD 18 BACKWATER EFFECTS

Roseau County implemented channel modifications of Hay Creek independently of this project. Subsequent observations during the 2009 spring runoff event indicate that flood stages have decreased due to this channel modification. While modified cross section details are not currently available, it was assumed that the original channel bottom was not altered and modification consists of 4:1 (H:V) side slopes for subsequent SWMM modeling in this report.

Comparisons of pre-project and post-project WSE along Hay Creek from Highway 11 to County Road 28 are shown in Figure 23 to Figure 26 for various storm events. Based on the presumed Hay Creek channel modification, the model shows that the 100-year, 10-day storm event does not exceed the channel capacity. As a result, the Hay Creek setback levees are not anticipated to result in a rise in water surface elevation for the storm events that were considered.

CD 18 is expected to have a pre-project to post-project increase in water surface of 1.5 feet. This increase is expected to occur just upstream of the southeast inlet, but it is contained within the spoil berms of CD 18. The backwater effect dissipates approximately 1,500 feet upstream of the southeast inlet. Figure 27 shows the comparison between pre-project and post-project WSEs along CD 18 for the 100-year, 10-day storm event.

FIGURE 23.
HAY CREEK WATER SURFACE ELEVATION INCREASE FOR THE 100-YEAR, 10-DAY STORM EVENT

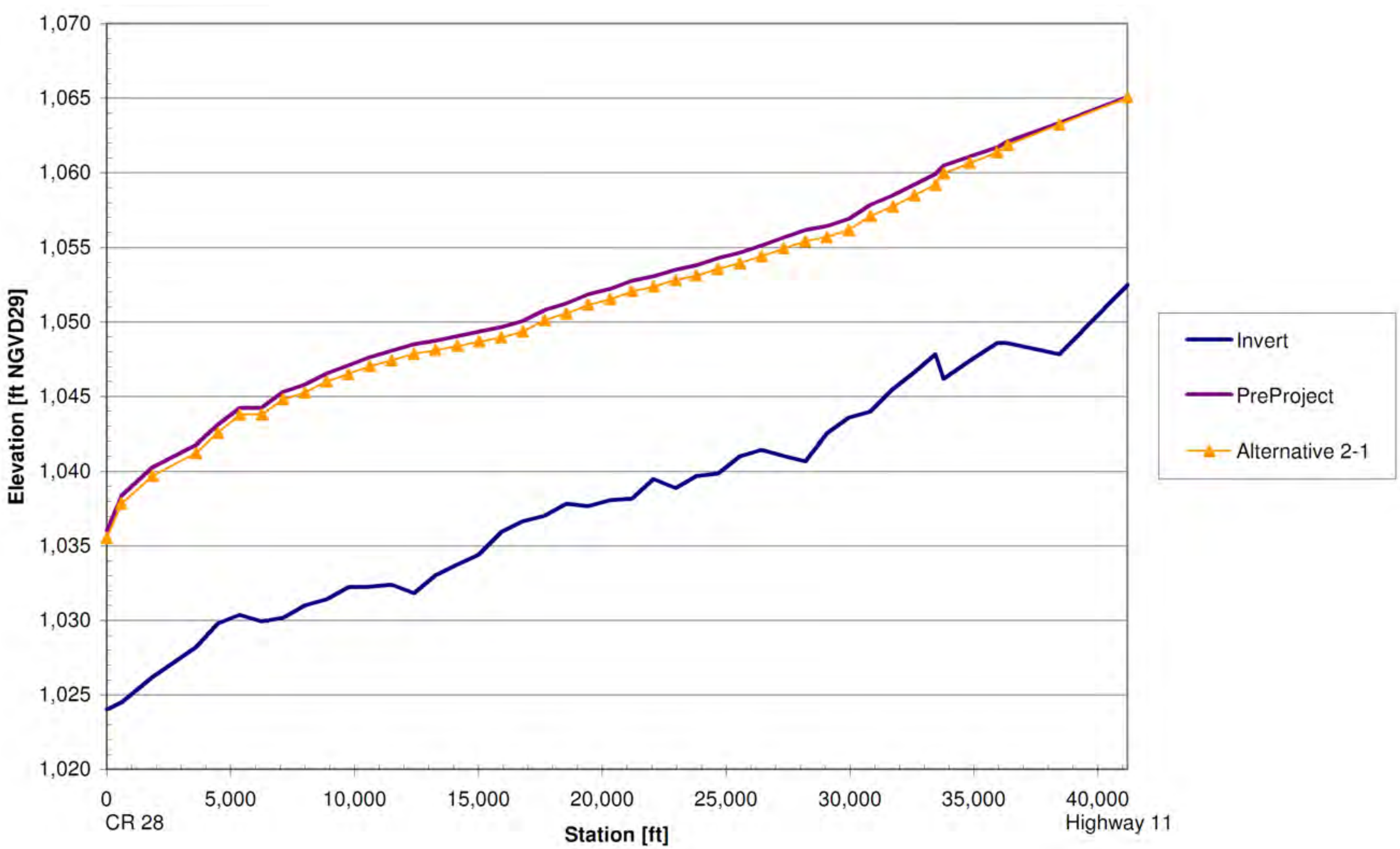


FIGURE 24.
HAY CREEK WATER SURFACE ELEVATION INCREASE FOR THE 100-YEAR 24-HOUR STORM EVENT

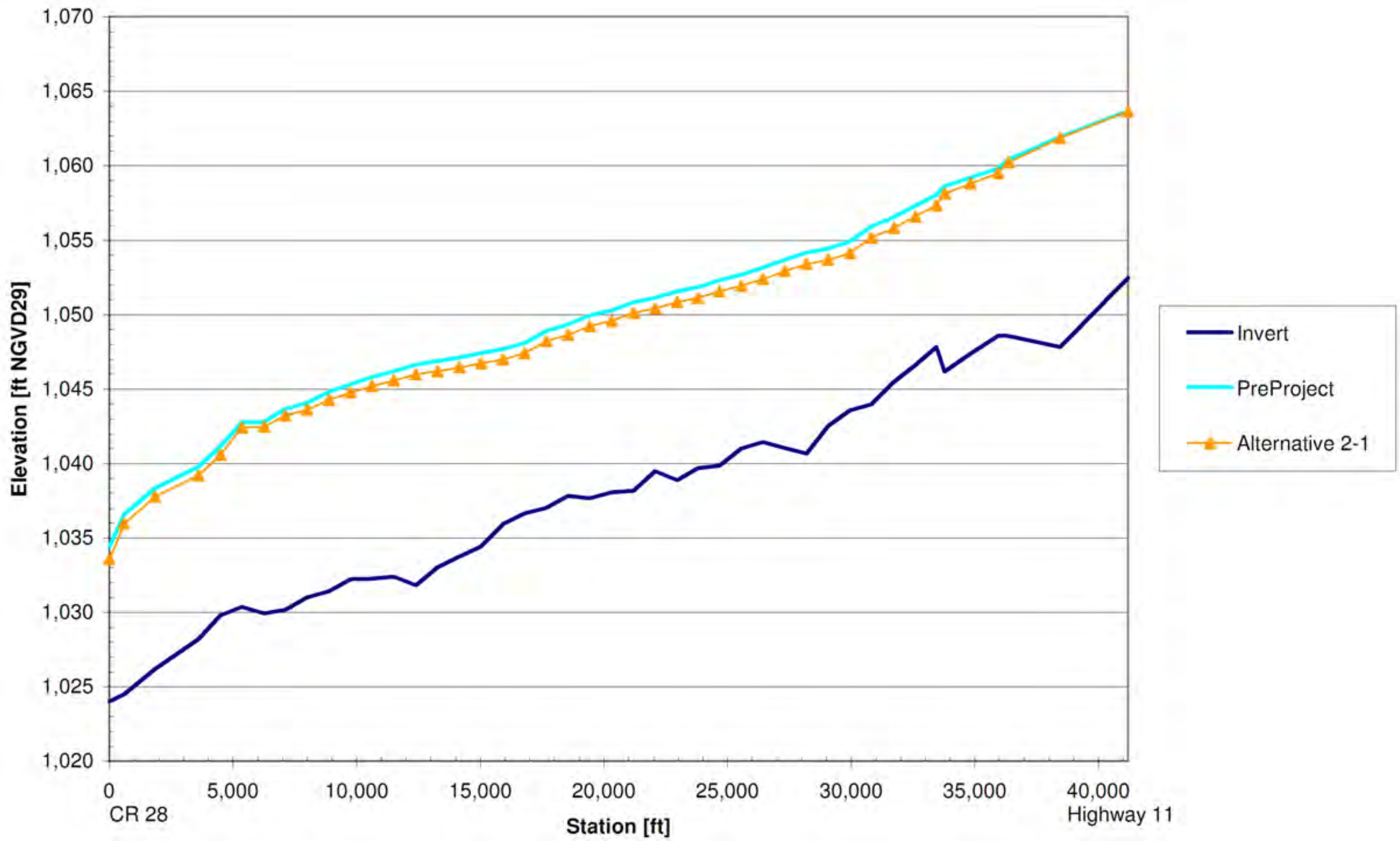


FIGURE 25.
HAY CREEK WATER SURFACE ELEVATION INCREASE FOR THE 10-YEAR 24-HOUR STORM EVENT

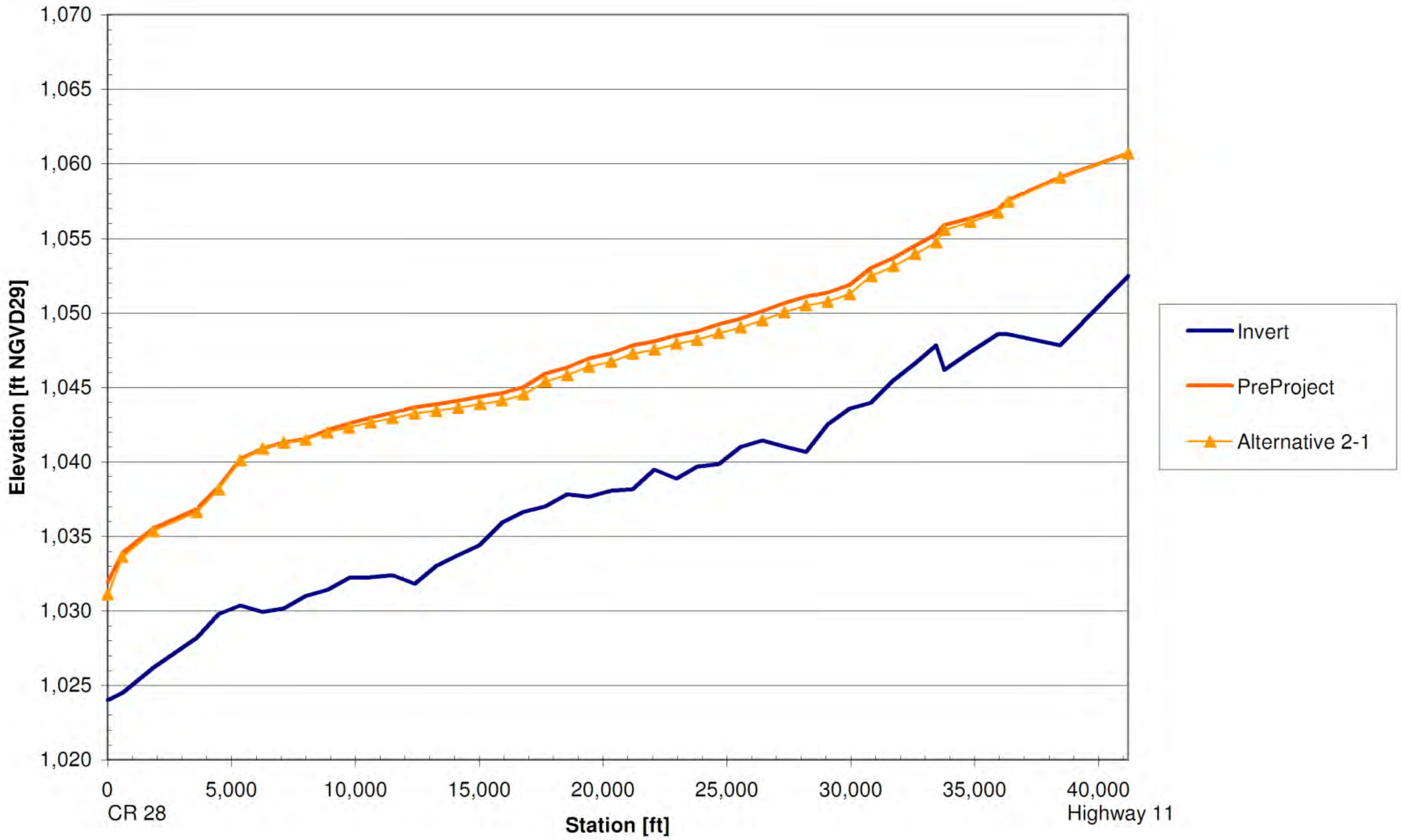


FIGURE 26.
HAY CREEK WATER SURFACE ELEVATION INCREASE FOR THE 2-YEAR 24-HOUR STORM EVENT

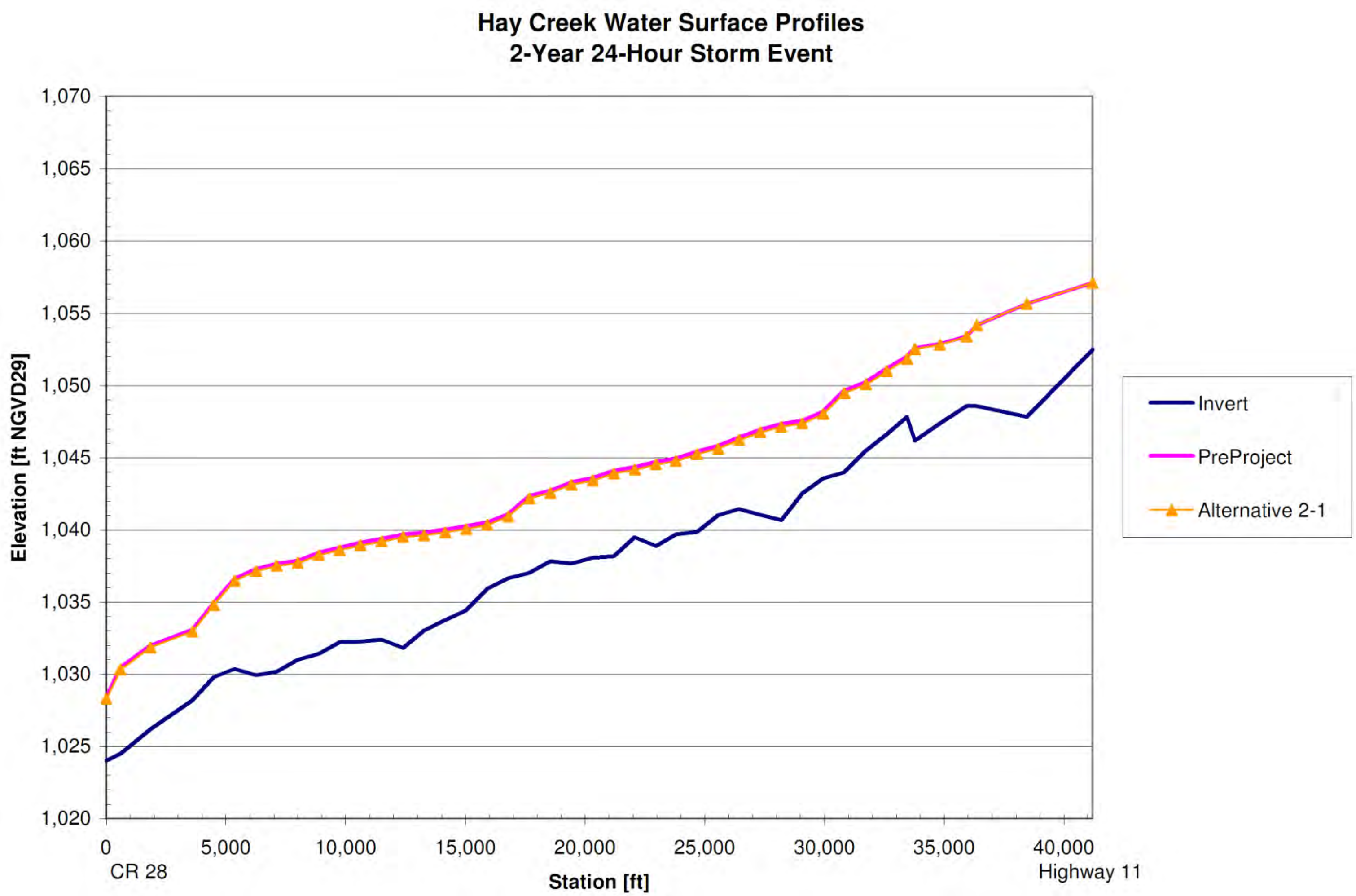


FIGURE 27.
CD 18 WATER SURFACE ELEVATION INCREASE FOR THE 100-YEAR, 10-DAY STORM EVENT

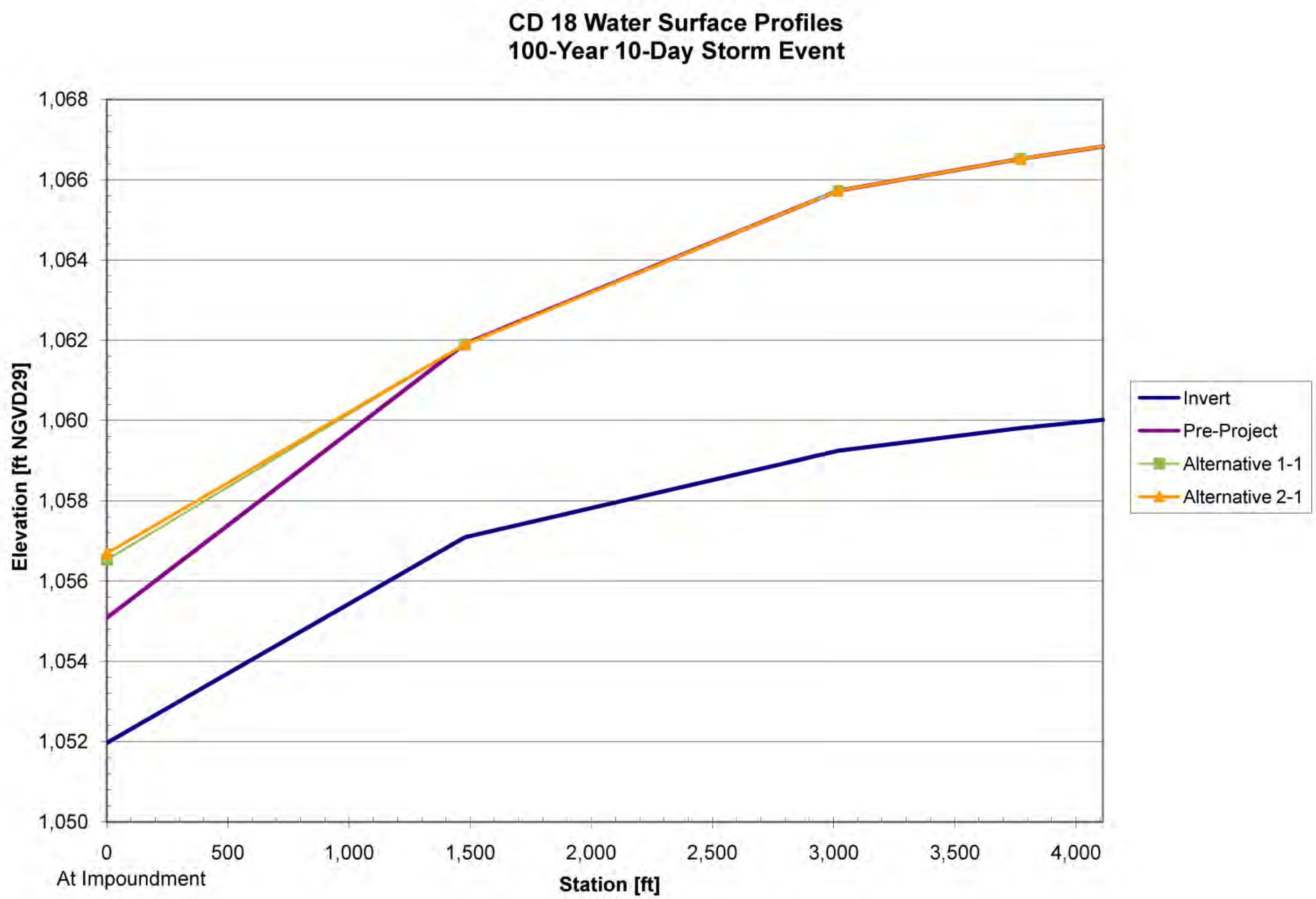


Figure 28 shows the extent of inundation that will occur when the impoundment is filled to capacity and the inlets are closed, allowing local drainage around the impoundment. Some localized flooding may occur along the southern edge of the impoundment, prior to the closing of the southern inlet which will restore drainage. Figure 29 shows areas that are expected to be flooded with the Project, areas that are currently flooded and flooded with the Project, and areas where flooding would be mitigated with the Project.

7.2.6 EFFECTS ON MAINSTEM FLOODING

Table 11 compares the existing, pre-project conditions to all alternatives using the various storm events. Refer to Figure 13 to Figure 15 for the maximum extent of the inundated areas for each storm event and impoundment alternative. Figure 30 shows the effect of the Project on stages at the upstream limit of the modeling just downstream of the City of Roseau. The graph shows the Roseau River flow hydrograph plotted as a line against the scale on the right axis. Stage reduction is shown as a bar graph referenced to the left axis. The Project may have more of an effect on reducing the duration of the higher stages by allowing stages to rise and fall more quickly.

FIGURE 28.
INUNDATION PLAN AND PROFILE FOR 100-YEAR, 10-DAY EVENT

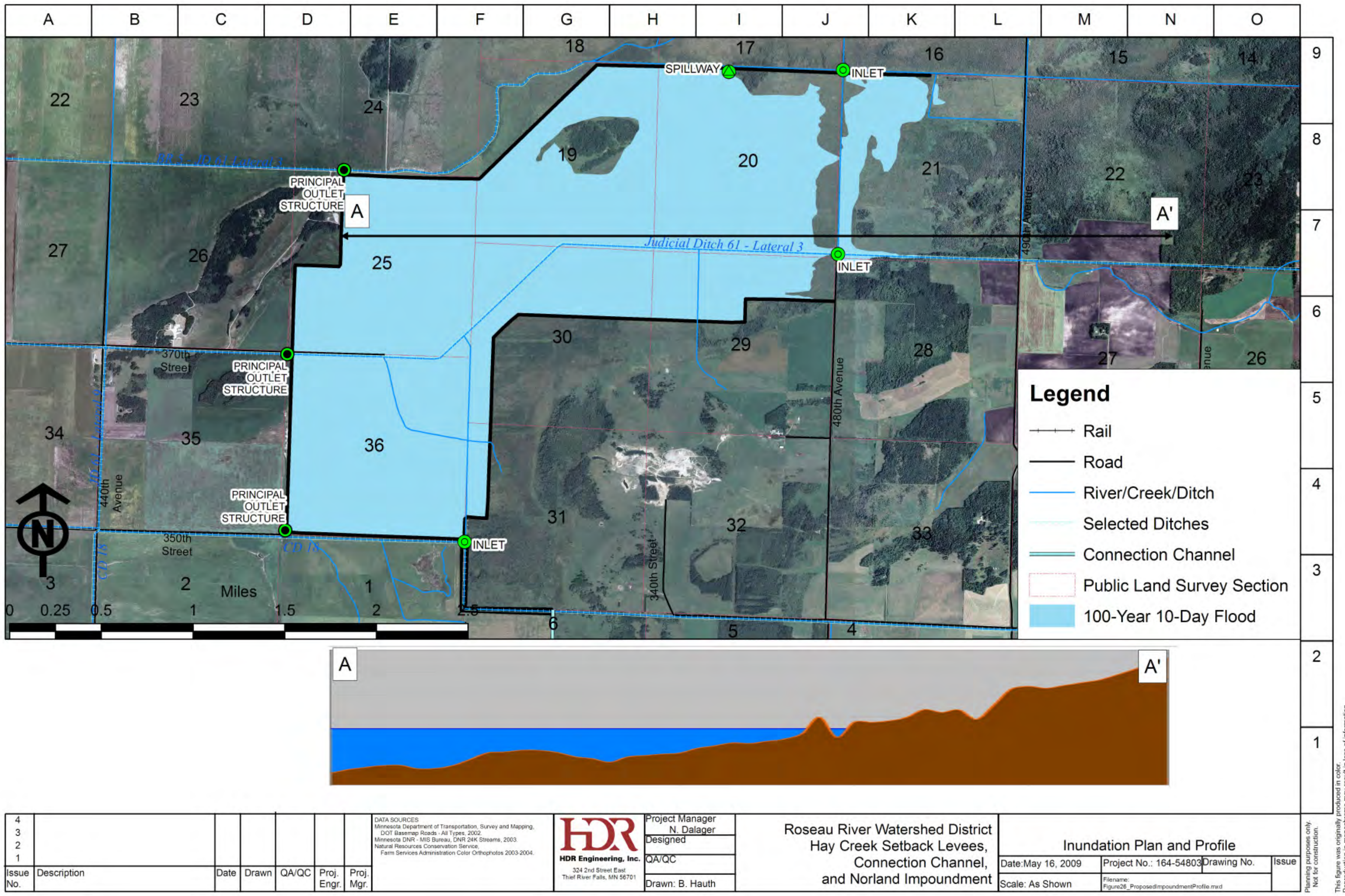


FIGURE 29.
FLOODED AREAS

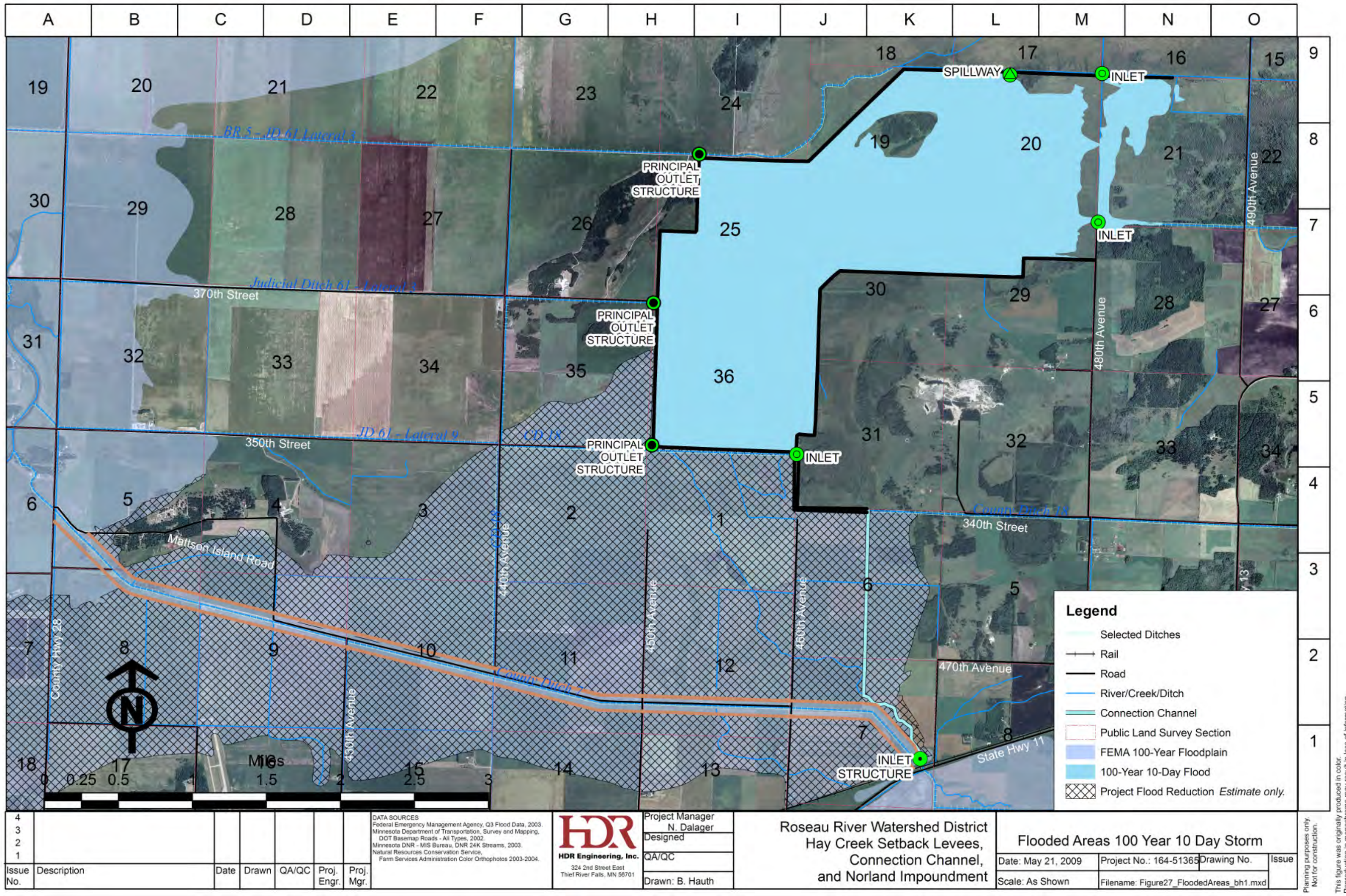
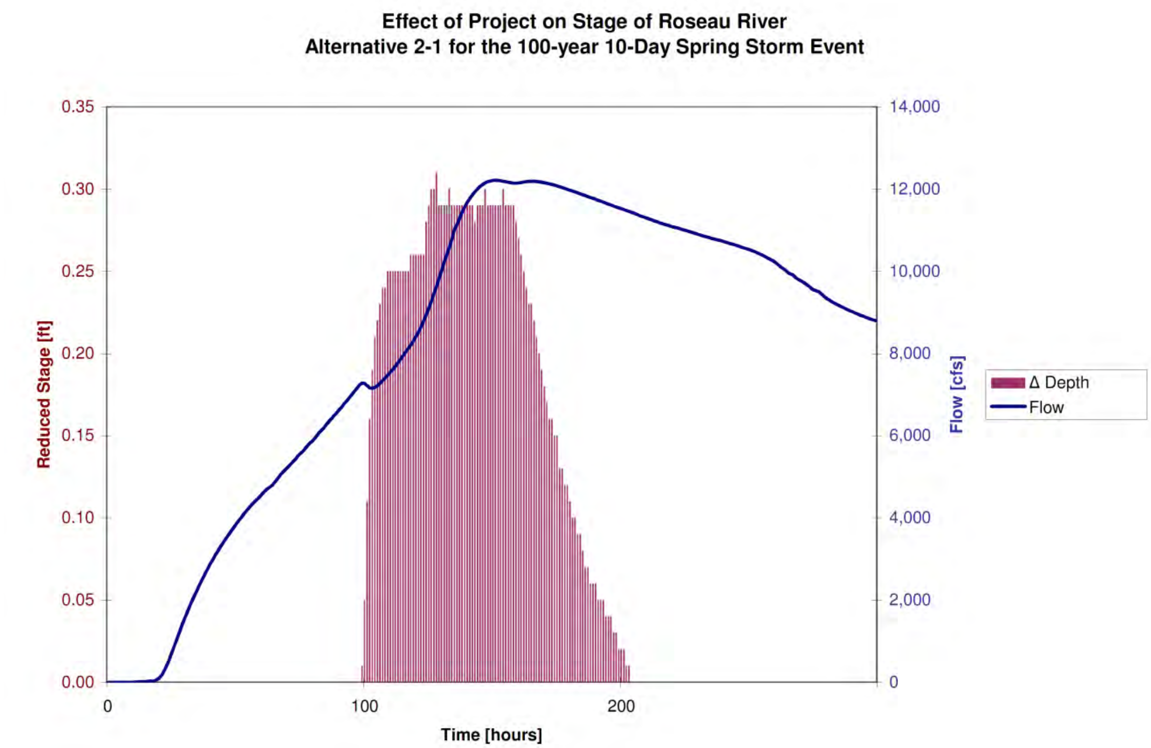


TABLE 11.
HYDROLOGIC AND HYDRAULIC DATA

Alternative[a]	Impoundment Peak Values			Roseau River Peak Flow [cfs] (Reduction)
	Inflow [cfs]	Elevation [ft NGVD 29]	Storage [ac-ft]	
100-Year 10-Day Event				
PRE-PROJECT	n/a	n/a	n/a	13,328
ALT 1-1	1,672	1,054.74	8,759	12,635 (5%)
ALT 1-2	1,729	1,054.63	10,088	12,633 (5%)
ALT 1-3	1,716	1,054.63	9,923	12,634 (5%)
ALT 2-1	1,978	1,054.96	9,417	12,215 (8%)
ALT 2-2	1,982	1,054.94	11,060	12,212 (8%)
ALT 2-3	1,981	1,054.94	10,901	12,213 (8%)
100-Year 24-Hour Event				
PRE-PROJECT	n/a	n/a	n/a	10,773
ALT 1-1	1,275	1,053.00	4,438	10,241 (5%)
ALT 1-2	1,278	1,052.39	4,446	10,241 (5%)
ALT 1-3	1,273	1,052.52	4,444	10,241 (5%)
ALT 2-1	1,441	1,053.49	5,482	9,966 (7%)
ALT 2-2	1,444	1,052.92	5,524	9,966 (7%)
ALT 2-3	1,440	1,053.02	5,516	9,966 (7%)
10-Year 24-Hour Event				
PRE-PROJECT	n/a	n/a	n/a	5,932
ALT 1-1	569	1,051.52	2,014	5,482 (8%)
ALT 1-2	571	1,050.89	2,021	5,482 (8%)
ALT 1-3	568	1,051.10	2,019	5,482 (8%)
ALT 2-1	667	1,051.82	2,428	5,330 (10%)
ALT 2-2	671	1,051.21	2,451	5,330 (10%)
ALT 2-3	667	1,051.39	2,445	5,330 (10%)
2-Year 24-Hour Event				
PRE-PROJECT	n/a	n/a	n/a	1,855
ALT 1-1	161	1,050.02	569	1,731 (7%)
ALT 1-2	161	1,049.25	577	1,731 (7%)
ALT 1-3	161	1,049.67	573	1,731 (7%)
ALT 2-1	161	1,050.08	607	1,708 (8%)
ALT 2-2	161	1,049.32	615	1,708 (8%)
ALT 2-3	161	1,049.73	611	1,708 (8%)

[a] Alt. 1-1= Main cell impoundment, no connection channel; Alt. 1-2 = West and Main cells impoundment, no connection channel; Alt. 1-3 = South and Main cells impoundment, no connection channel; Alt. 2-1 = Main cell impoundment with connection channel; Alt. 2-2 = West and Main cells impoundment with connection channel; Alt. 2-3 = South and Main cells impoundment with connection channel

FIGURE 30.
PROJECT EFFECTS ON ROSEAU RIVER



Notes: Impoundment outlet gates close 54 hours prior to Roseau River peak flows.

8.0 OTHER CONSIDERATIONS

8.1 GEOTECHNICAL

The geology of the Hay Creek/Norland area is a product of Pleistocene and recent sedimentation and erosion. Glaciers advanced over the area several times during the Pleistocene Epoch and deposited a thick mantle of drift estimated to be over 150-200 feet thick. The last glacial period ended approximately 9,000 years ago with the retreat of the last glacier and draining of glacial Lake Agassiz, which occupied most of northwestern Minnesota, northeastern North Dakota, and central Canada. Since the recession of Lake Agassiz, streams such as the Roseau River and Hay Creek established meandering courses over the relatively flat till and lake plain, eroding and depositing alluvial sediments; and shallow depressions filled with organic deposits to create marshes and expansive peat lands typical of the pre-drainage Norland area.

Ten borings ranging in depth from 7 to 35 feet obtained in the Project Area in December 2000 revealed soils consistent with the geologic history and manmade changes. In addition, 26 borings ranging in depth from 11 to 21 feet were obtained in the Project Area in April 2008. For discussion purposes, materials were grouped into six units, based on engineering properties and geologic origin: fill, alluvium, marsh, lacustrine, glacio-lacustrine, and glacial drift. The fill overlies the other soils, primarily in the form of roadways and side-cast materials along drainage ditches. Fill typically comprises a mixture of locally-derived clayey glacial drift, alluvium, and lacustrine soils; organic soils are common.

Recent marsh deposits consist of a highly compressible peat layer up to 6 feet thick sandwiched between highly compressible, less-than-2-foot-thick layers of clay, silt, and organics with poor engineering properties.

Undifferentiated alluvial sand, silt, and clay soils are evident along past and present corridors of Hay Creek. Glacio-lacustrine sand, silt, and clay and lacustrine clays are sandwiched between the alluvial and glacial drift soils. Glacial drift underlies the lacustrine soils. The alluvium consists of 1- to 3-feet-thick fluvial deposits of undifferentiated sand, silt, and clay from the Roseau River and Hay Creek floodplains. This unit lacks the organics present in the marsh deposits.

The lacustrine and glacio-lacustrine soils consist of shallow lake bottom sediments mostly derived from underlying glacial till. These soils include fat clays and sandy, gravelly "lake-washed" tills interbedded in some areas, likely a result of fluctuating glacial lake levels. Some samples had preexisting slickensides, or formed slickensides when sheared. The glacial drift is a medium-stiff to stiff, unsorted, silty, sandy clay with scattered cobbles and boulders. The upper 1 to 4 feet is typically less stiff and has abundant randomly spaced iron stained joints.

Availability of borrow immediately adjacent to the alignment of the proposed Norland embankment (dam) is in question. Based on the most recent soil borings, a borrow plan has been developed to address the questionable soils and will be shown in detail in the specifications. Borings show thin layers of interbedded suitable and unsuitable materials (e.g. peat) that could make it difficult to efficiently excavate sufficient quantities of good quality fill. In addition, the high water table in the Norland site could hamper borrow operations adjacent to the embankment alignment, and the saturated material would require substantial working and drying time to reach optimal moisture content for compaction.

Poor foundation materials (e.g. peat) in some reaches of the Norland embankment may (a) require staged construction to allow for differential settlement and stabilization and (b) force incorporation of a stability berm when the design of the Norland embankment exceeds a critical height which, in turn, increases costs.

The soil boring information analyzed for this report was developed by the USACE during the EA phase. The findings and conclusions from the USACE study are generally applicable and can be extrapolated to the site of the proposed Hay Creek levees and the Norland Impoundment. The subsurface conditions and recommended embankment configurations can be assumed to be similar to those recommended in the USACE study. The recommended embankment section from the USACE study for the Hay Creek levees consisted of a 4-foot high embankment with 3:1 side slopes and a 10-foot crest. For the Norland levees, the embankment consisted of a 10-foot high embankment with 3:1 slopes with good quality fill and 5:1 slopes with poor quality fill.

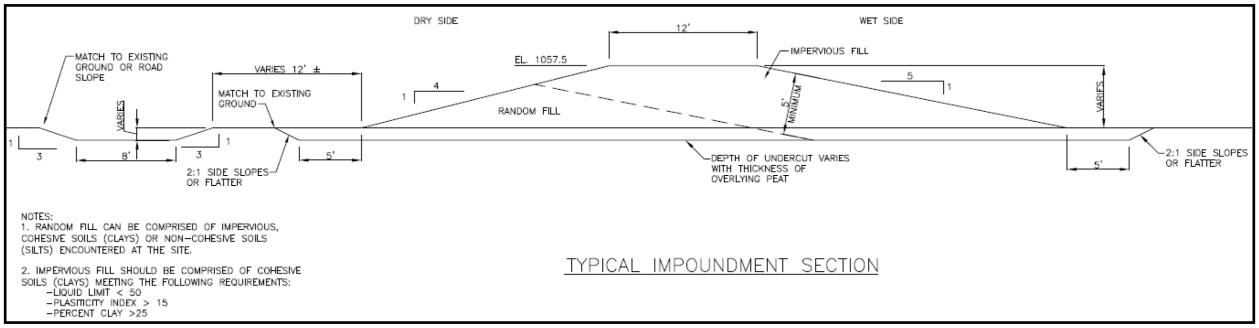
The USACE study did not completely investigate the site of the proposed levees and impoundment. Only the western limits of the site were investigated with test borings. Additionally, the scope of the USACE study did not include a laboratory testing program to assess the material properties of the foundation soils and new fill. The properties were based on several factors, including published correlations and the results of past testing of similar soils. The values of the properties selected for use in the stability analyses are considered reasonable and conservative for the materials present at the site. The results of the stability analyses indicated that acceptable factors of safety can be achieved and that stable embankments for the proposed levees and impoundment can be constructed at the site.

It should be noted that analyses of underseepage and settlement were not performed as a part of the USACE study. From the available geotechnical data, underseepage does not appear to be an issue since the foundation soils are primarily clayey and relatively impervious, and any pervious sands are present at depths of 20 feet or more. Regarding settlement, an overbuild of 6 inches was predicted for the 9-foot high embankment. If higher embankments are constructed, it can be reasonably assumed that the overbuild will increase proportionally.

The soil borings gathered in April of 2008 were tested by Braun Intertec of Hibbing, MN. HDR Engineering, Inc. also evaluated the borings and boring tests and were able to assess engineering characteristics of the embankment and foundation soils, evaluate slope stability of the embankment and foundation soils, estimate settlements of the embankment crest and recommend an overbuild, evaluate foundation and embankment underseepage, and make recommendations for construction. A full overview of these soil borings, tests, and evaluations can be found in Appendix B.

Figure 31 shows the embankment cross-section consisting of an impermeable layer of clay on the wet side of the embankment, with random fill on the dry side of the embankment, and peat topsoil.

FIGURE 31
EMBANKMENT CROSS-SECTION



Note: For planning purposes only. Not for construction. Refer to engineering plan sets.

8.2 EMBANKMENT ACCESS

Sufficient turning radius will be provided at the principal outlet structures. Embankment access points will be designed with sufficient width and turning radius and will be provided as necessary around the perimeter of the Project. Access to all of the principal inlet and outlet structures will also be provided with sufficient turning radius.

8.3 TIMING OF FLOWS AND OPERATING PLAN

The Hay Creek Setback Levees, Connection Channel, and Norland Impoundment will necessarily include considerable operable parameters. A dam tender or other person authorized by the RRWD Board will conduct these operations according to the Operating Plan. A flood control plan primarily consists of determination of gate closure and initiation of impoundment filling based on flood conditions. The safety of impounding water in order to prevent overtopping of the embankment is one consideration, as well as the potential of flood damages in the Project Area.

The establishment of control points and trigger WSEs will be refined by experience in operation of the Project. An initial estimate of these conditions can be made based on hydrologic modeling.

Three outlet structures, and four inlet structures, including the connection channel, will be operated according to the Operating Plan. When established triggering elevations are reached downstream, inlet structures will be operated to allow flows into the storage elements of the Project. During an operating event, outlet structures will also be closed in as simultaneous a fashion as is practicable. When flood flows subside downstream, flows will be released in a similar fashion by closing the inlets and opening the outlets. Flows will be released down CD 18 and two laterals of JD 61 in a fashion that does not contribute to downstream flooding, and also maintains a proportionate share of flows commensurate with the upstream drainage area of the particular system.

Currently, the alignment of CD 18 flows south into CD 7. However, CD 18 is ineffective in conveying all of the flow from the southwest outlet down this alignment due to size and grade limitations. Instead, approximately 40% of the flow is proposed to continue down CD 18, south into CD 7, and 60% of flows will travel west down Lateral 9/JD 61 using culvert sizing. As part of this project, the RRWD will petition the County Board (Ditch Authority) for its impacts on the County ditch systems. Alternatives, such as improving the CD 18 outlet system or the JD 61/Lateral 9 outlet system to carry all of the flow from the southwest outlet have been considered, but these alternatives would be much more costly than dividing the flow between the CD 18 and the JD 61/Lateral 9 outlet systems.

8.3.1 Flood Control Considerations

Development of an appropriate operating plan requires a good understanding of local and regional flood conditions and the types of flood damages that are prevalent. This Project has the potential to affect urban, agricultural, and Red River flood damages.

It is also important to understand the limits of safe storage within the reservoir. Reservoir safety is primarily associated with freeboard. Extended periods of operation with limited freeboard would increase the risk of damage to the embankment, due to wave action, and increase the probability of overtopping, due to follow-on storm events.

Agricultural damages occur much more frequently and at lower stages than urban damages. The greatest damage potential is during the growing season when there is potential for crop loss. Spring flooding frequently results in erosion damage and losses due to delayed planting. The Project has the ability to reduce agricultural damages in several areas.

The local agricultural damages can be addressed by establishing triggering elevations at critical locations downstream. These can best be selected by experience. Note that optimum target flood control elevations may be lower during the growing season than during spring runoff. Therefore, some degree of latitude should be afforded the gate controller with a goal of lowering the pool levels as quickly as possible without causing damages to agricultural crops or land. To accomplish this, the gates should be adjusted to keep the ditches flowing at or near flood stage. Local flood durations are relatively short. As experience is gained, these operating parameters should be fine tuned where necessary to accomplish the desired goals.

Floods on the Red River are characterized by long duration. Spring floods often extend well into the growing season. Because it is desirable to increase freeboard against wave action and to reestablish storage capacity, releases may have to be made while the Red River is still above flood stage. Table 12 outlines the proposed operating plan.

8.3.2 Operating Plan

The WSEs at specific control points in downstream channels will be used to determine whether or not discharge from the impoundment is appropriate. If flows at any control point exceed the maximum allowed elevation, the flows must be reduced to levels that are appropriate for channel capacities.

In accordance with RRWMB criteria for the Red River, the impoundment will normally hold water for up to 30 days while the Red River is above flood stage.

There are three gaging stations on the Roseau River, near Roseau. They are the Roseau River below South Fork near Malung (Malung), the Roseau River at Ross (Ross), and the Roseau River at Roseau (Roseau). The Malung and Ross gages each have a period of record of 78 years, while the Roseau gage has a period of record of about 22 years.

Based upon discussions with landowners, local officials, and gaging station information, the river stage at the Roseau gage where major urban flood damages may begin to occur is about 19.5 feet. The impoundment gates will be closed in advance of this predicted stage.

By comparing this 19.5 feet stage with the same event at the Malung and Ross gages, as well as comparing other historical flooding events, a correlation can be determined between all three gages. Below are the predicted stages at which the impoundment will be operated, based on this correlation:

Malung:	21.0 feet (~4,350 cfs)
Ross:	16.0 feet (~3,500 cfs)
City of Roseau:	19.5 feet (~5,700 cfs)

TABLE 12. OPERATING PLAN CONSIDERATIONS

<table>
<tr><td colspan="5">NORMAL GATE POSITION   5 sq ft</td></tr>
<tr><td rowspan="2">Gate Control Operation Close and Open Gates to Control Floods at Threshold Levels</td><td colspan="4">Operating Thresholds at Gage Locations</td></tr>
<tr><td>Upstream</td><td colspan="3">Downstream</td></tr>
<tr><td>Pool Elevation (NGVD29)</td><td>Malung Stage</td><td>Roseau Stage</td><td>Ross Stage (Predicted)</td><td>Red River at Pembina Stage (Predicted)</td></tr>
<tr><td>Below 1055.0</td><td>21.0 ft</td><td>19.5 ft</td><td>16 ft</td><td>50 ft</td></tr>
</table>

In order to determine the frequency of impoundment operation, the Malung and Ross gages were used for analysis because they contain the longer period of record. The number of events exceeding the stages listed above were identified. The number of years of record was then divided by the number of events occurring above the referenced stages to result in the operational frequency. Operation of the impoundment, based upon how frequently these stages have been reached or exceeded for the period of record, would occur approximately:

Malung: 1 out of 8 years
Ross: 1 out of 8 years
City of Roseau: 1 out of 8 years

The duration of gate operation and resulting impoundment flood pool (including drawdown), will range from about 7 days for an 8-year flood event to as long as 6 weeks for a 100-year, 10-day flood event. Gate opening and release of floodwaters from the impoundment would occur after stages have receded below the operational threshold.

Gate operation will occur based upon the NWS "predicted" stages at Ross and Pembina gages, in order to better address the timing of flows from the Roseau River watershed affecting these downstream areas.

The Roseau River Watershed District reserves the right to modify the operational parameters and locations of the trigger points as operational experience is gained.

8.3.3 Growing Season Operational Considerations

One concern is whether or not the embankment will be operated during the growing season. For the purpose of discussion, the assumed start of the growing season is May 15th. The number of 8-year events occurring after May 15th (during the growing season) can be divided by the total number of 8-year events, and multiplied by the 1 out of 8 year frequency to determine the frequency at which the impoundment will be operated during the growing season. The operational frequency of the impoundment during the growing season will be approximately as follows:

Malung:	(4 out of 10) * (1 out of 8) = **1 out of 20 years**
Ross:	(4 out of 11) * (1 out of 8) = **1 out of 22 years**
City of Roseau:	(2 out of 5) * (1 out of 8) = **1 out of 20 years**

The following pages contain a plot of the annual peak flows occurring at each gage before or after the growing season. The timing of each event is highlighted with respect to the May 15th assumed growing season start dates.

FIGURE 32. MALUNG GAGE – OPERATIONAL FREQUENCY BEFORE AND DURING GROWING SEASON

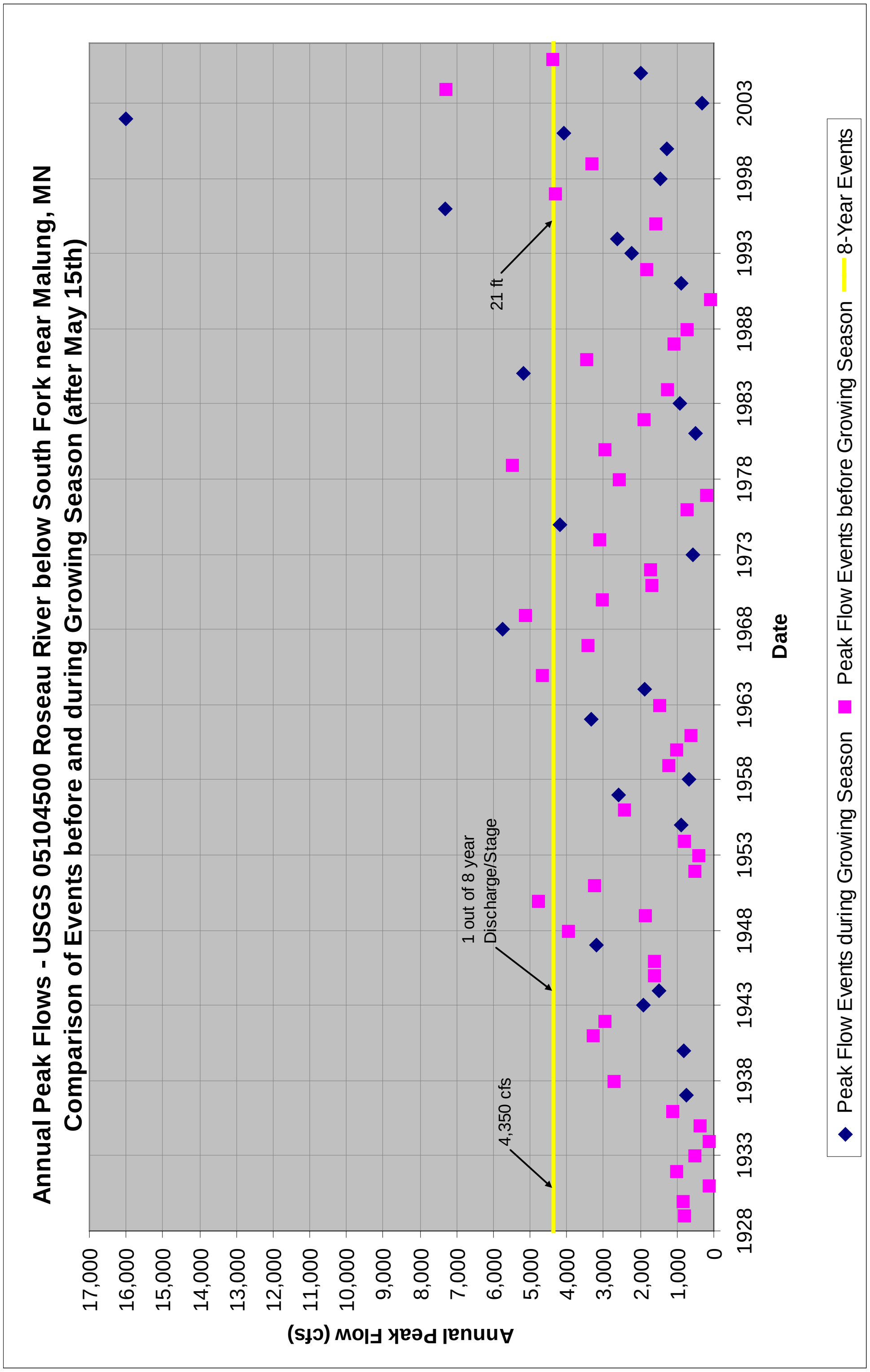


FIGURE 33. ROSS GAGE – OPERATIONAL FREQUENCY BEFORE AND DURING GROWING SEASON

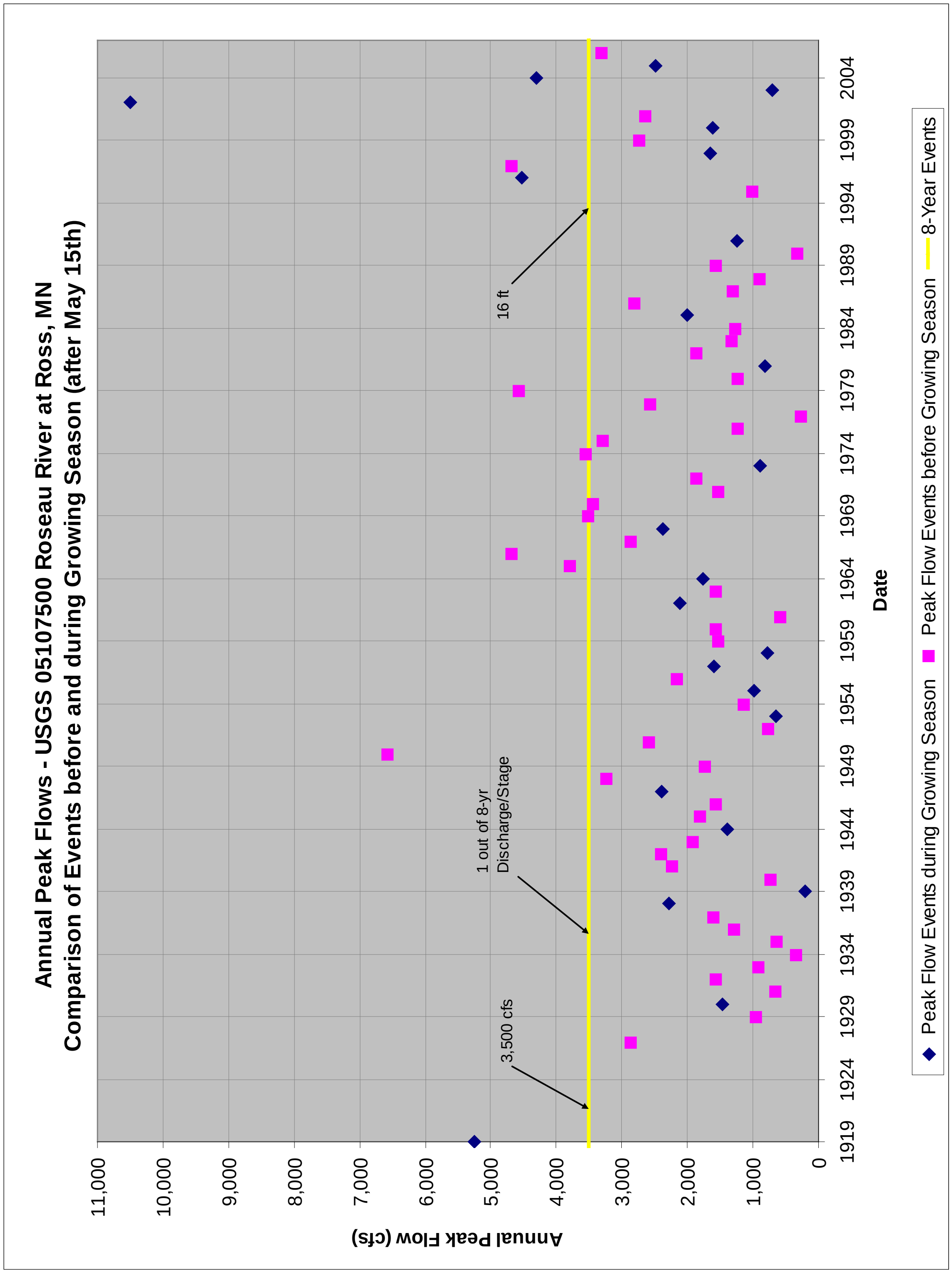
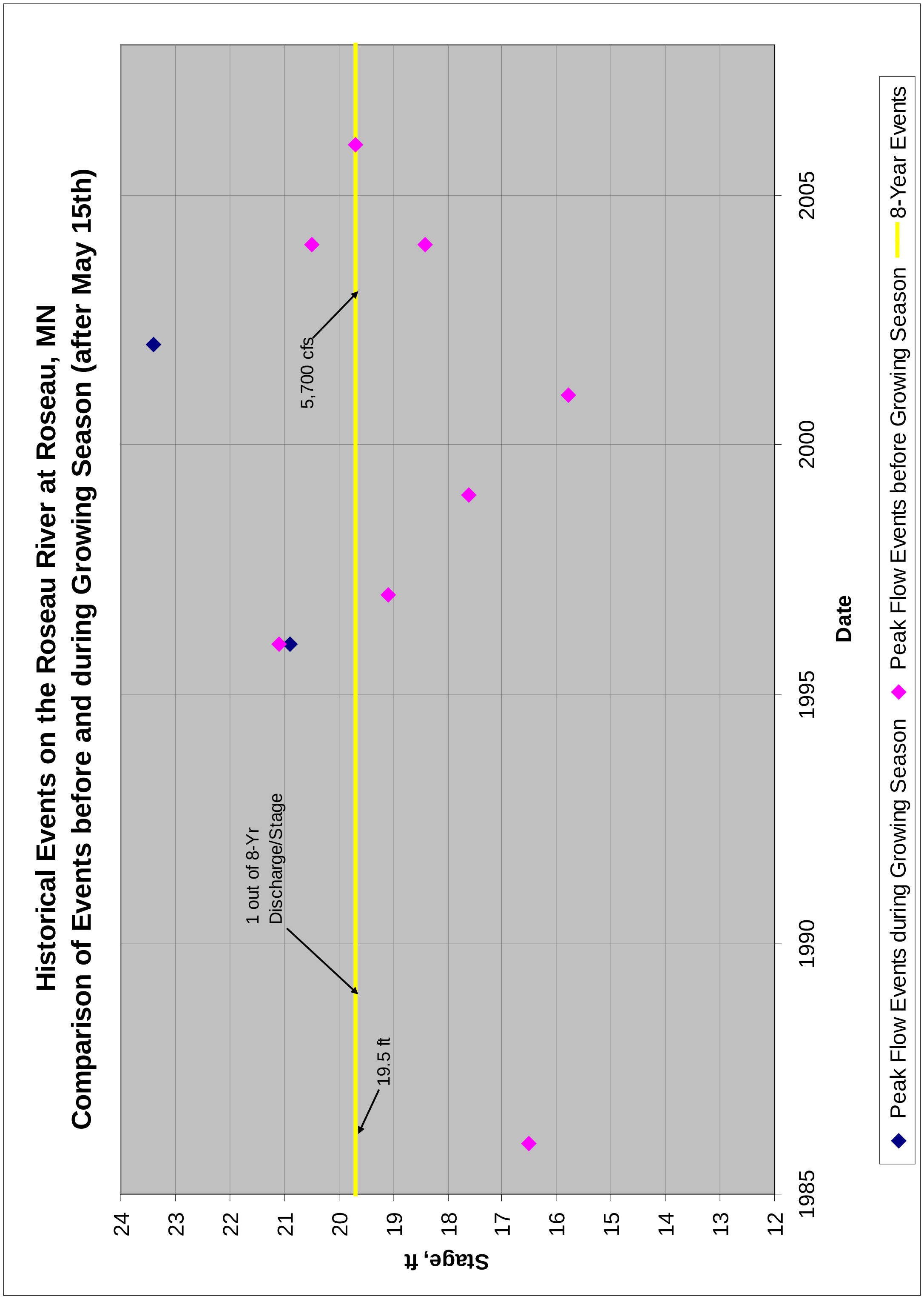


FIGURE 34. ROSEAU GAGE – OPERATIONAL FREQUENCY BEFORE AND DURING GROWING SEASON



8.4 Potential Groundwater Impacts

It is not anticipated that this project will have widespread effects on local or regional groundwater patterns. Groundwater levels are generally high in this area, and the occasional storage of surface water is not expected to change this.

8.5 Environmental Consequences

This Project is not expected to cause significant negative environmental consequences. The Project gates may be expected to close with an annual probability of about 12 or 13 percent. Impounded water would be retained for a limited number of days. At other times, the present land use of cropland would be maintained.

This Project is not expected to cause significant negative environmental consequences. The primary purpose of this Project is flood damage reduction. However, there is potential to enhance natural resource features in this Project Area. These natural resource enhancements may include promoting erosion control and/or enhanced riparian corridors along ditches, land use treatments, and wetland restorations in the upper watershed, and incorporating Natural Resource Enhancement (NRE) features into the flood control impoundments. The potential to add NREs to this Project will be evaluated by the Project Work Team (PWT) as the Project moves forward.

Specific enhancements include rock chutes downstream of each outlet to enhance oxygenation of discharge waters.

8.5.1 Water Quality

There is limited water quality monitoring information available for the drainage area. The PWT will be developing a monitoring plan for this Project.

8.5.2 Fish and Wildlife

It is anticipated that this Project will enhance fish and wildlife habitat. Wetland and upland habitats exist on the Project Site. Actual delineation of wetlands, mitigation, and coordination with permitting agencies is underway, and construction will not begin until all permits are received.

Upland habitats will be subjected to periodic inundation in accordance with the Project Purpose and Operating plan. Historically, these habitats have been under agricultural production.

8.6 LAND OWNERSHIP, LAND USE AND RIGHT-OF-WAY

Figure 35 shows the land ownership for the project as of January 2009. Meetings have been held with landowners about the project concepts, and rights-of-way have been acquired for the impoundment, setback levees, and the connection channel portions of the Project. Additional right-of-way is required for the West Cell and South Cell Alternatives if these alternatives are selected. Right-of-way has been purchased for the setback levees, approximately 325 feet on either side of the CD 7 ditch centerline. Right-of-way has also been purchased for the Connection Channel and will entail a corridor approximately 125 feet wide for the length of the channel.

9.0 OPINION OF MOST PROBABLE COST

Table 13 outlines the estimated costs for 4 separate alternatives based on 2009 rates.

TABLE 13. PROBABLE COSTS

Roseau River Watershed District	Alternative 1-1			
Hay Creek Setback Levees and Norland Impoundment Project	**Engineer's Opinion of Most Probable Cost**			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$100,000.00	$100,000.00
FIELD LABORATORY - TYPE D	EACH	1	$15,000.00	$15,000.00
CLEARING & GRUBBING	LS	1	$50,000.00	$50,000.00
REMOVE/SALVAGE CS PIPE CULVERTS	LF	844	$12.00	$10,128.00
SETBACK LEVEES COMMON EXCAVATION (P)	CY	172,296	$1.70	$292,903.20
IMPOUNDMENT COMMON EXCAVATION (P)	CY	554,337	$1.70	$942,372.90
SETBACK LEVEES COMMON BORROW (CV) (P) - EMBANKMENT	CY	57,300	$3.25	$186,225.00
IMPOUNDMENT COMMON BORROW (CV) (P) - EMBANKMENT	CY	991,357	$3.25	$3,221,910.25
GEOTEXTILE FABRIC - TYPE 5 (ROADWAY) (P)	SY	49,312	$2.00	$98,624.00
AGGREGATE SURFACING (CV) (P)	TON	10,193	$11.00	$112,123.00
AGGREGATE BASE (CV) (P), CLASS 3	TON	9,769	$10.00	$97,690.00
PRINCIPAL INLET AND OUTLET STRUCTURES	EACH	6	$275,000.00	$1,650,000.00
AGGREGATE BEDDING (CV)	TON	796	$15.00	$11,940.00
12" CS PIPE CULVERT	LF	34	$25.00	$850.00
18" CS PIPE CULVERT	LF	1,064	$30.00	$31,920.00
24" CS PIPE CULVERT	LF	878	$35.00	$30,730.00
30" CS PIPE CULVERT	LF	374	$45.00	$16,830.00
36" CS PIPE CULVERT	LF	392	$50.00	$19,600.00
42" CS PIPE CULVERT	LF	880	$65.00	$57,200.00
48" CS PIPE CULVERT	LF	360	$80.00	$28,800.00
72" CS PIPE CULVERT	LF	70	$110.00	$7,700.00
84" CS PIPE CULVERT	LF	78	$125.00	$9,750.00
12" GS PIPE APRON	EACH	2	$120.00	$240.00
18" GS PIPE APRON	EACH	15	$180.00	$2,700.00
24" GS PIPE APRON	EACH	11	$235.00	$2,585.00
30" GS PIPE APRON	EACH	3	$350.00	$1,050.00
36" GS PIPE APRON	EACH	5	$500.00	$2,500.00
42" GS PIPE APRON	EACH	9	$700.00	$6,300.00
48" GS PIPE APRON	EACH	1	$850.00	$850.00
72" GS PIPE APRON	EACH	2	$1,200.00	$2,400.00
FLAPGATE FOR 18" CS PIPE CULVERT (3 CMP)	EACH	11	$300.00	$3,300.00
FLAPGATE FOR 24" CS PIPE CULVERT (3 CMP)	EACH	9	$500.00	$4,500.00
FLAPGATE FOR 30" CS PIPE CULVERT (3 CMP)	EACH	3	$600.00	$1,800.00
FLAPGATE FOR 36" CS PIPE CULVERT (3 CMP)	EACH	3	$700.00	$2,100.00
FLAPGATE FOR 42" CS PIPE CULVERT (3 CMP)	EACH	9	$875.00	$7,875.00
FLAPGATE FOR 48" CS PIPE CULVERT (3 CMP)	EACH	3	$950.00	$2,850.00
4 INCH PE PERFORATED PIPE DRAIN	LF	8,817	$4.50	$39,676.50
RANDOM RIPRAP, CLASS 3	CY	1,320	$60.00	$79,200.00
RANDOM RIPRAP, CLASS 4	CY	731	$70.00	$51,170.00
TRAFFIC CONTROL	LS	1	$10,000.00	$10,000.00
TEMPORARY DITCH CHECK, TYPE 3 (12" BIO ROLLS)	LF	1,980	$5.00	$9,900.00
SEEDING	ACRE	571	$100.00	$57,100.00
SEED MIXTURE	POUND	39,970	$7.00	$279,790.00
MULCH MATERIAL TYPE 1	TON	1,142	$110.00	$125,620.00
DISC ANCHORING	ACRE	571	$30.00	$17,130.00
EROSION CONTROL BLANKET, CATEGORY 1	SY	3,168	$2.00	$6,336.00
COMMERCIAL FERTILIZER, ANALYSIS 17-17-17	TON	58	$1,400.00	$81,200.00
Subtotal				$7,709,268.85
Land/Building Acquisition and Easements				$450,000.00
Mitigation				$350,000.00
Engineering and Administration		12	%	$925,112.26
Materials Testing (Construction)				$25,000.00
Total Construction				**$9,459,381.11**

Note: For planning purposes only. Not for construction or bid. Refer to engineering plan sets.

Roseau River Watershed District	Alternative 2-1			
Hay Creek Setback Levees and Norland Impoundment Project	**Engineer's Opinion of Most Probable Cost**			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$100,000.00	$100,000.00
FIELD LABORATORY - TYPE D	EACH	1	$15,000.00	$15,000.00
CLEARING & GRUBBING	LS	1	$50,000.00	$50,000.00
REMOVE/SALVAGE PIPE CULVERTS	LF	932	$12.00	$11,184.00
SETBACK LEVEES COMMON EXCAVATION (P)	CY	172,296	$1.70	$292,903.20
IMPOUNDMENT COMMON EXCAVATION (P)	CY	554,337	$1.70	$942,372.90
CONNECTION CHANNEL COMMON EXCAVATION (P)	CY	67,458	$1.70	$114,678.60
SETBACK LEVEES COMMON BORROW (CV) (P) - EMBANKMENT	CY	57,300	$3.25	$186,225.00
IMPOUNDMENT COMMON BORROW (CV) (P) - EMBANKMENT	CY	991,357	$3.25	$3,221,910.25
CONNECTION CHANNEL COMMON BORROW (CV) (P) - EMBANKMENT	CY	1,342	$3.25	$4,361.50
GEOTEXTILE FABRIC - TYPE 5 (ROADWAY) (P)	SY	49,419	$2.00	$98,838.00
AGGREGATE SURFACING (CV) (P)	TON	10,330	$11.00	$113,630.00
AGGREGATE BASE (CV) (P), CLASS 3	TON	9,769	$10.00	$97,690.00
PRINCIPAL INLET AND OUTLET STRUCTURES	EACH	7	$275,000.00	$1,925,000.00
AGGREGATE BEDDING (CV)	CY	796	$15.00	$11,940.00
12" CS PIPE CULVERT	LF	34	$25.00	$850.00
18" CS PIPE CULVERT	LF	1,482	$30.00	$44,460.00
24" CS PIPE CULVERT	LF	878	$35.00	$30,730.00
30" CS PIPE CULVERT	LF	374	$45.00	$16,830.00
36" CS PIPE CULVERT	LF	392	$50.00	$19,600.00
42" CS PIPE CULVERT	LF	880	$65.00	$57,200.00
48" CS PIPE CULVERT	LF	360	$80.00	$28,800.00
72" CS PIPE CULVERT	LF	70	$110.00	$7,700.00
84" CS PIPE CULVERT	LF	78	$125.00	$9,750.00
57" x 38" CS PIPE-ARCH CULVERT	LF	268	$100.00	$26,800.00
12" GS PIPE APRON	EACH	2	$120.00	$240.00
18" GS PIPE APRON	EACH	22	$180.00	$3,960.00
24" GS PIPE APRON	EACH	11	$235.00	$2,585.00
30" GS PIPE APRON	EACH	3	$350.00	$1,050.00
36" GS PIPE APRON	EACH	5	$500.00	$2,500.00
42" GS PIPE APRON	EACH	9	$700.00	$6,300.00
48" GS PIPE APRON	EACH	1	$850.00	$850.00
72" GS PIPE APRON	EACH	2	$1,200.00	$2,400.00
FLAPGATE FOR 18" CS PIPE CULVERT (3 CMP)	EACH	18	$300.00	$5,400.00
FLAPGATE FOR 24" CS PIPE CULVERT (3 CMP)	EACH	9	$500.00	$4,500.00
FLAPGATE FOR 30" CS PIPE CULVERT (3 CMP)	EACH	3	$600.00	$1,800.00
FLAPGATE FOR 36" CS PIPE CULVERT (3 CMP)	EACH	3	$700.00	$2,100.00
FLAPGATE FOR 42" CS PIPE CULVERT (3 CMP)	EACH	9	$875.00	$7,875.00
FLAPGATE FOR 48" CS PIPE CULVERT (3 CMP)	EACH	3	$950.00	$2,850.00
4 INCH PE PERFORATED PIPE DRAIN	LF	8,817	$4.50	$39,676.50
RANDOM RIPRAP, CLASS 3	CY	1,585	$60.00	$95,100.00
RANDOM RIPRAP, CLASS 4	CY	731	$70.00	$51,170.00
TRAFFIC CONTROL	LS	1	$10,000.00	$10,000.00
TEMPORARY DITCH CHECK, TYPE 3 (12" BIO ROLLS)	LF	2,208	$5.00	$11,040.00
SEEDING	ACRE	606	$100.00	$60,600.00
SEED MIXTURE	POUND	42,420	$7.00	$296,940.00
MULCH MATERIAL TYPE 1	TON	1,212	$110.00	$133,320.00
DISC ANCHORING	ACRE	606	$30.00	$18,180.00
EROSION CONTROL BLANKET, CATEGORY 1	SY	3,504	$2.00	$7,008.00
COMMERCIAL FERTILIZER, ANALYSIS 17-17-17	TON	62	$1,400.00	$86,100.00
Subtotal				$8,281,998.00
Land/Building Acquisition and Easements				$500,000.00
Mitigation				$350,000.00
Engineering and Administration		12	%	$993,840.00
Materials Testing (Construction)				$25,000.00
Total Construction				**$10,150,838.00**

Note: For planning purposes only. Not for construction or bid. Refer to engineering plan sets.

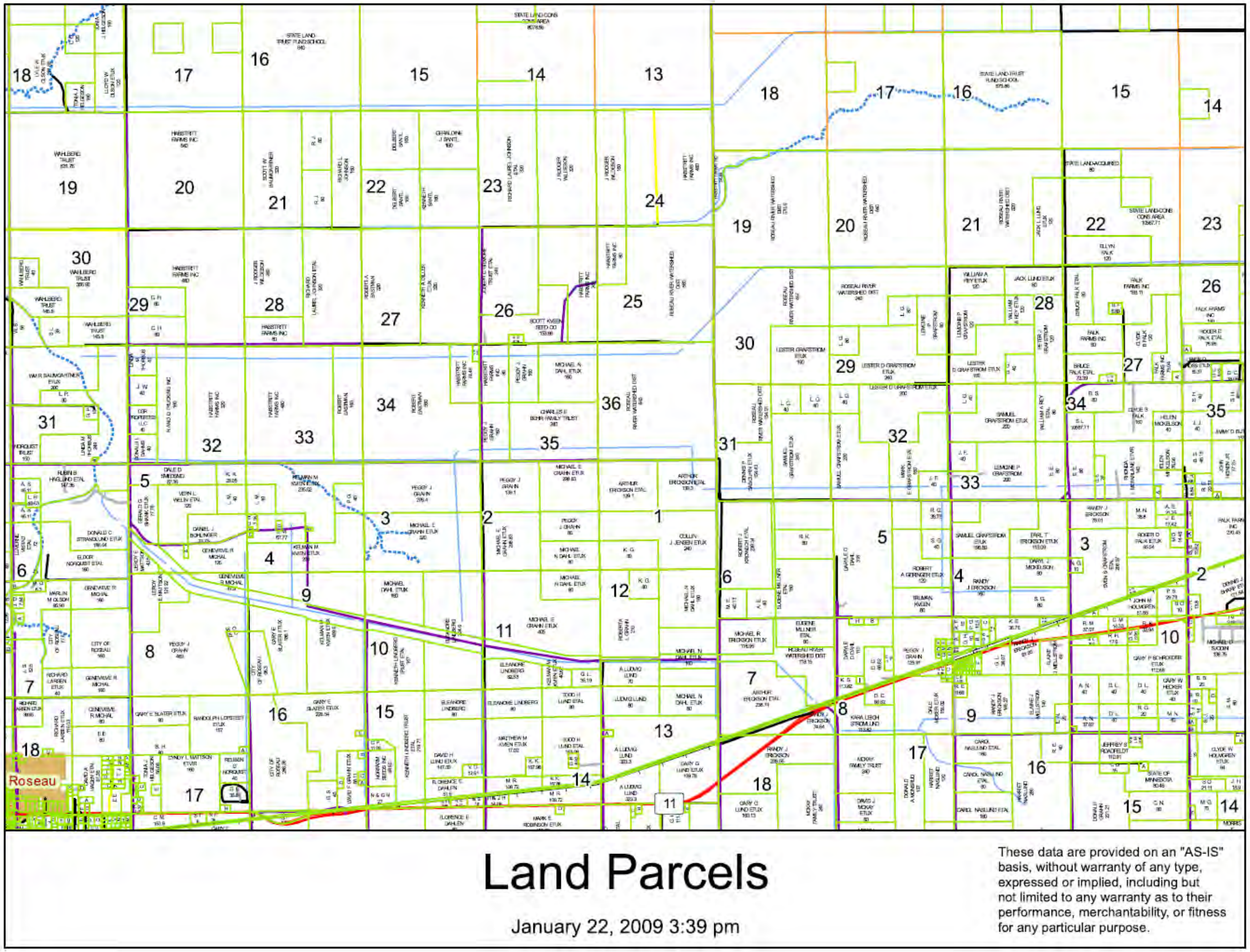
Roseau River Watershed District	Alternative 2-2			
Hay Creek Setback Levees and Norland Impoundment Project	Engineer's Opinion of Most Probable Cost			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$100,000.00	$100,000.00
FIELD LABORATORY - TYPE D	EACH	1	$15,000.00	$15,000.00
CLEARING & GRUBBING	LS	1	$50,000.00	$50,000.00
REMOVE/SALVAGE PIPE CULVERTS	LF	932	$12.00	$11,184.00
SETBACK LEVEES COMMON EXCAVATION (P)	CY	172,296	$1.70	$292,903.20
IMPOUNDMENT COMMON EXCAVATION (P)	CY	637,488	$1.70	$1,083,728.84
CONNECTION CHANNEL COMMON EXCAVATION (P)	CY	67,458	$1.70	$114,678.60
SETBACK LEVEES COMMON BORROW (CV) (P) - EMBANKMENT	CY	57,300	$3.25	$186,225.00
IMPOUNDMENT COMMON BORROW (CV) (P) - EMBANKMENT	CY	1,140,061	$3.25	$3,705,196.79
CONNECTION CHANNEL COMMON BORROW (CV) (P) - EMBANK	CY	1,342	$3.25	$4,361.50
GEOTEXTILE FABRIC - TYPE 5 (ROADWAY) (P)	SY	49,419	$2.00	$98,838.00
AGGREGATE SURFACING (CV) (P)	TON	10,330	$11.00	$113,630.00
AGGREGATE BASE (CV) (P), CLASS 3	TON	9,769	$10.00	$97,690.00
PRINCIPAL INLET AND OUTLET STRUCTURES	EACH	7	$275,000.00	$1,925,000.00
AGGREGATE BEDDING (CV)	CY	796	$15.00	$11,940.00
12" CS PIPE CULVERT	LF	34	$25.00	$850.00
18" CS PIPE CULVERT	LF	1,482	$30.00	$44,460.00
24" CS PIPE CULVERT	LF	878	$35.00	$30,730.00
30" CS PIPE CULVERT	LF	374	$45.00	$16,830.00
36" CS PIPE CULVERT	LF	392	$50.00	$19,600.00
42" CS PIPE CULVERT	LF	880	$65.00	$57,200.00
48" CS PIPE CULVERT	LF	360	$80.00	$28,800.00
72" CS PIPE CULVERT	LF	70	$110.00	$7,700.00
84" CS PIPE CULVERT	LF	78	$125.00	$9,750.00
57" x 38" CS PIPE-ARCH CULVERT	LF	268	$100.00	$26,800.00
12" GS PIPE APRON	EACH	2	$120.00	$240.00
18" GS PIPE APRON	EACH	22	$180.00	$3,960.00
24" GS PIPE APRON	EACH	11	$235.00	$2,585.00
30" GS PIPE APRON	EACH	3	$350.00	$1,050.00
36" GS PIPE APRON	EACH	5	$500.00	$2,500.00
42" GS PIPE APRON	EACH	9	$700.00	$6,300.00
48" GS PIPE APRON	EACH	1	$850.00	$850.00
72" GS PIPE APRON	EACH	2	$1,200.00	$2,400.00
FLAPGATE FOR 18" CS PIPE CULVERT (3 CMP)	EACH	18	$300.00	$5,400.00
FLAPGATE FOR 24" CS PIPE CULVERT (3 CMP)	EACH	9	$500.00	$4,500.00
FLAPGATE FOR 30" CS PIPE CULVERT (3 CMP)	EACH	3	$600.00	$1,800.00
FLAPGATE FOR 36" CS PIPE CULVERT (3 CMP)	EACH	3	$700.00	$2,100.00
FLAPGATE FOR 42" CS PIPE CULVERT (3 CMP)	EACH	9	$875.00	$7,875.00
FLAPGATE FOR 48" CS PIPE CULVERT (3 CMP)	EACH	3	$950.00	$2,850.00
4 INCH PE PERFORATED PIPE DRAIN	LF	8,817	$4.50	$39,676.50
RANDOM RIPRAP, CLASS 3	CY	1,585	$60.00	$95,100.00
RANDOM RIPRAP, CLASS 4	CY	731	$70.00	$51,170.00
TRAFFIC CONTROL	LS	1	$10,000.00	$10,000.00
TEMPORARY DITCH CHECK, TYPE 3 (12" BIO ROLLS)	LF	2,208	$5.00	$11,040.00
SEEDING	ACRE	632	$100.00	$63,210.00
SEED MIXTURE	POUND	44,247	$7.00	$309,729.00
MULCH MATERIAL TYPE 1	TON	1,264	$110.00	$139,062.00
DISC ANCHORING	ACRE	632	$30.00	$18,963.00
EROSION CONTROL BLANKET, CATEGORY 1	SY	3,696	$2.00	$7,392.00
COMMERCIAL FERTILIZER, ANALYSIS 17-17-17	TON	64	$1,400.00	$89,880.00
Subtotal				$8,932,728.42
Land/Building Acquisition and Easements				$650,000.00
Mitigation				$350,000.00
Engineering and Administration		12	%	$1,071,927.41
Materials Testing (Construction)				$25,000.00
Total Construction				**$11,029,655.83**

Note: For planning purposes only. Not for construction or bid. Refer to engineering plan sets.

Roseau River Watershed District	Alternative 2-3			
Hay Creek Setback Levees and Norland Impoundment Project	Engineer's Opinion of Most Probable Cost			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$100,000.00	$100,000.00
FIELD LABORATORY - TYPE D	EACH	1	$15,000.00	$15,000.00
CLEARING & GRUBBING	LS	1	$50,000.00	$50,000.00
REMOVE/SALVAGE PIPE CULVERTS	LF	932	$12.00	$11,184.00
SETBACK LEVEES COMMON EXCAVATION (P)	CY	172,296	$1.70	$292,903.20
IMPOUNDMENT COMMON EXCAVATION (P)	CY	609,771	$1.70	$1,036,610.19
CONNECTION CHANNEL COMMON EXCAVATION (P)	CY	67,458	$1.70	$114,678.60
SETBACK LEVEES COMMON BORROW (CV) (P) - EMBANKMENT	CY	57,300	$3.25	$186,225.00
IMPOUNDMENT COMMON BORROW (CV) (P) - EMBANKMENT	CY	1,090,493	$3.25	$3,544,101.28
CONNECTION CHANNEL COMMON BORROW (CV) (P) - EMBANK	CY	1,342	$3.25	$4,361.50
GEOTEXTILE FABRIC - TYPE 5 (ROADWAY) (P)	SY	49,419	$2.00	$98,838.00
AGGREGATE SURFACING (CV) (P)	TON	10,330	$11.00	$113,630.00
AGGREGATE BASE (CV) (P), CLASS 3	TON	9,769	$10.00	$97,690.00
PRINCIPAL INLET AND OUTLET STRUCTURES	EACH	7	$275,000.00	$1,925,000.00
AGGREGATE BEDDING (CV)	CY	796	$15.00	$11,940.00
12" CS PIPE CULVERT	LF	34	$25.00	$850.00
18" CS PIPE CULVERT	LF	1,482	$30.00	$44,460.00
24" CS PIPE CULVERT	LF	878	$35.00	$30,730.00
30" CS PIPE CULVERT	LF	374	$45.00	$16,830.00
36" CS PIPE CULVERT	LF	392	$50.00	$19,600.00
42" CS PIPE CULVERT	LF	880	$65.00	$57,200.00
48" CS PIPE CULVERT	LF	360	$80.00	$28,800.00
72" CS PIPE CULVERT	LF	70	$110.00	$7,700.00
84" CS PIPE CULVERT	LF	78	$125.00	$9,750.00
57" x 38" CS PIPE-ARCH CULVERT	LF	268	$100.00	$26,800.00
12" GS PIPE APRON	EACH	2	$120.00	$240.00
18" GS PIPE APRON	EACH	22	$180.00	$3,960.00
24" GS PIPE APRON	EACH	11	$235.00	$2,585.00
30" GS PIPE APRON	EACH	3	$350.00	$1,050.00
36" GS PIPE APRON	EACH	5	$500.00	$2,500.00
42" GS PIPE APRON	EACH	9	$700.00	$6,300.00
48" GS PIPE APRON	EACH	1	$850.00	$850.00
72" GS PIPE APRON	EACH	2	$1,200.00	$2,400.00
FLAPGATE FOR 18" CS PIPE CULVERT (3 CMP)	EACH	18	$300.00	$5,400.00
FLAPGATE FOR 24" CS PIPE CULVERT (3 CMP)	EACH	9	$500.00	$4,500.00
FLAPGATE FOR 30" CS PIPE CULVERT (3 CMP)	EACH	3	$600.00	$1,800.00
FLAPGATE FOR 36" CS PIPE CULVERT (3 CMP)	EACH	3	$700.00	$2,100.00
FLAPGATE FOR 42" CS PIPE CULVERT (3 CMP)	EACH	9	$875.00	$7,875.00
FLAPGATE FOR 48" CS PIPE CULVERT (3 CMP)	EACH	3	$950.00	$2,850.00
4 INCH PE PERFORATED PIPE DRAIN	LF	8,817	$4.50	$39,676.50
RANDOM RIPRAP, CLASS 3	CY	1,585	$60.00	$95,100.00
RANDOM RIPRAP, CLASS 4	CY	731	$70.00	$51,170.00
TRAFFIC CONTROL	LS	1	$10,000.00	$10,000.00
TEMPORARY DITCH CHECK, TYPE 3 (12" BIO ROLLS)	LF	2,208	$5.00	$11,040.00
SEEDING	ACRE	623	$100.00	$62,340.00
SEED MIXTURE	POUND	43,638	$7.00	$305,466.00
MULCH MATERIAL TYPE 1	TON	1,247	$110.00	$137,148.00
DISC ANCHORING	ACRE	623	$30.00	$18,702.00
EROSION CONTROL BLANKET, CATEGORY 1	SY	3,632	$2.00	$7,264.00
COMMERCIAL FERTILIZER, ANALYSIS 17-17-17	TON	63	$1,400.00	$88,620.00
Subtotal				$8,627,198.27
Land/Building Acquisition and Easements				$650,000.00
Mitigation				$350,000.00
Engineering and Administration		12	%	$1,035,263.79
Materials Testing (Construction)				$25,000.00
Total Construction				**$10,687,462.06**

Note: For planning purposes only. Not for construction or bid. Refer to engineering plan sets.

FIGURE 35.
LAND OWNERSHIP IN THE PROJECT AREA



10.0 COMPATIBILITY WITH EXISTING PLANS, STATUTES, RULES AND PERMIT NEEDS

10.1 ROSEAU RIVER WATERSHED DISTRICT PLAN

It is the intention of the Board to manage the waters and related resources within the Watershed District in a reasonable and orderly manner to improve the general welfare and public health of the residents of the Watershed District.

The Managers of the RRWD accept the responsibilities with which they are charged as a governing body by Minnesota Statutes. Said Board of Managers, in the conduct, duties, and responsibilities conferred upon them, do not intend to usurp the authority or responsibilities of other agencies or governing bodies; however, said Board of Managers will not avoid their responsibilities and obligations.

The overall goals for the RRWD include:

Flood Damage Reduction (FDR) Goals

- Provide 100-year flood protection for the City of Roseau and rural homesteads in the district.
- Provide 10-year flood protection for agricultural lands.
- Reduce flood damage to roads and crossings.
- Reduce drought damages.
- Preserve ground water supply and recharge areas.

Natural Resource Enhancement (NRE) Goals

- Protect, restore, enhance, and manage lakes and streams in the RRWD to support sustainable aquatic communities.
- Manage wetland and upland habitats to support sustainable wildlife communities.
- Preserve, protect, and restore unique natural resource communities and other features in the watershed.
- Increase and promote outdoor recreational activities related to fish, wildlife, and other natural resources in the watershed.
- Improve water quality in the RRWD.

The Project will contribute to several of these RRWD goals.

10.2 LOCAL MUNICIPAL PLANS

In response to the June 2002 flood, the City of Roseau and the USACE began planning for various flood mitigation projects for the City. Based on a draft feasibility report, the desired mitigation project is construction of a high flow channel that would divert Roseau River through the east side of the City. The channel would be utilized during major flood events. The Norland Impoundment project can serve to supplement the channel. The impoundment may reduce the increase in WSE generated by the proposed flood channel.

Roseau County staff and commissioners have participated in project planning throughout the PWT process. The proposed Project's flood control and natural resource benefits are supported by the County Water Plan goals and objectives.

10.3 MINNESOTA STATUTES AND RULES

Section 103D of Minnesota Statutes pertains to Watershed Districts. Section 103D.335, Subd. 5 enables watershed districts to exercise the power to "…make necessary surveys or utilize other reliable surveys and data and develop projects to accomplish the purposes for which the district is organized." Section 103D.335, Subd. 8 gives the watershed district the power to "…construct, clean, repair, alter, abandon, consolidate, reclaim, or change the course or terminus of any public ditch, drain, sewer, river, watercourse, natural or artificial, within the district." In addition, Section 103D.335, Subd. 9 give the power to "…acquire, operate, construct, and maintain dams, levees, reservoirs, and appurtenant works."

Also required by Section 103D.711 is the preparation of an "Engineer's Report". Requirements relative to the content of the report include:

- A scaled map of the area to be improved.
- Location of the proposed improvements; location of respective outlets.
- The watershed of the Project Area; the location of existing highways, bridges and culverts
- All lands, highways, and utilities affected, together with the names of the owners thereof, so far as known; the outlines of any public lands and public bodies of water affected; potential benefiting lands; easement maps; and principal Project features.

This report is intended to satisfy the requirements of 103D.605, 701, and 711.

Additional Statutory requirements include interaction with Statute 103E (Roseau County Ditch Authority). Several of the ditches involved with the design of this project are Roseau County

Ditches, such as CD 18, CD 7, JD 61 and associated branches and laterals. The RRWD will need the approval of the County Ditch Authority to proceed with the work as described. The process will likely involve a petition from the RRWD to the Roseau County Board, after which a public hearing will be held to review and evaluate the proposal.

10.4 STATE ENVIRONMENTAL REVIEW

Minnesota Rules Chapter 4410 require the preparation of an Environmental Assessment Worksheet (EAW). An EAW was completed in May 2003, after review of the USACE EA project, and the proposed Hay Creek Norland Project is substantially similar to the USACE plan, for which no Environmental Impact Statement was ordered. The mandatory preparation of an EAW (Minnesota Rules 4410.4300, subpart 24) is necessary for "Construction of a dam with an upstream drainage area of 50 square miles or more" or "permanent impoundment of water creating additional water surface of 160 or more acres". The total drainage area of the proposed impoundment is 124 square miles, and the proposed impoundment will be "dry," not permanently impounding water. The anticipated dam classification is Class III. Stream diversion (subpart 26) may temporarily result from the Connection Channel between Hay Creek and the Norland Impoundment, and the public waters (subpart 27) that are impacted include Hay Creek and Lost River.

10.5 SECTION 404 OR SECTION 10

Meetings have been held with USACE permitting authorities regarding the proposed Project. It is understood that an individual wetland permit may be required from the USACE, which will include a review of operational parameters, such as wetland inundation, bounce, flood frequency, and water depth, in addition to wetland impacts from the construction footprint. Construction will not begin until all permits are received.

10.6 MINNESOTA DEPARTMENT OF NATURAL RESOURCES

The proposed project requires a dam safety permit from the MnDNR in accordance with Minnesota Rules 6115.0300. The purpose of these rules is to regulate the construction and enlargement of dams, as well as the repair, alteration, maintenance, operation, and abandonment, in such a manner as to best provide for public health, safety, and welfare.

The Norland Impoundment will likely be classified as a Class III (TR 60 Class A) low hazard dam. Issuance of the dam safety permit follows a thorough review of the dam design by the MnDNR.

A MnDNR Public Water Permit, in accordance with Minnesota Rules 6115.015, is also required for possible changes to the course, current, and cross section of Hay Creek and the Lost River.

10.7 WETLAND CONSERVATION ACT (WCA)

Meetings have been held with Wetland Conservation Act (WCA) permitting authorities regarding the proposed Project. It is understood that an individual wetland permit will be required from the local government unit (LGU), which will include a review of operational parameters, such as wetland inundation, bounce, flood frequency, and water depth, in addition to wetland impacts from the construction footprint. Construction will not begin until all permits are received.

10.8 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM REQUIREMENTS

A storm water permit is required for the construction of this Project. The permittee must develop storm water pollution prevention plans (SWPPPs) to address their storm water discharges from the site. Each regulated party determines the appropriate pollution prevention practices, or best management practices, to minimize pollution for the specific site. The final engineering plans for the Project will address the SWPPP for the site by means of seeding, mulch, fiber rolls, silt fence, filter fabric, and riprap.

11.0 RECOMMENDATIONS

The hydrologic and hydraulic data indicates that the project should contribute to the reduction of downstream flood levels and the duration of flooding. The timing of flood peaks in CD 18, JD61, and the Roseau River will not be negatively affected. The benefit of constructing the setback levees, impoundment, and connection channel, is the cumulative benefit of additional Flood Damage Reduction in the City of Roseau, improvement in agricultural production downstream of the proposed impoundment due to reduced flooding, and the ability to provide gated storage for use during regional events.

Several alternatives were considered, and the recommendations are based upon an assessment of each project feature and its overall effectiveness in reducing flood damages. HDR recommends that the following alternative be considered:

RECOMMENDATIONS

- Hay Creek Setback Levees
- Norland Impoundment Alternative 2-1 (Main Cell with Alternative 2 Connection Channel)
- County Ditch System Improvements

The rationale for this recommendation is fundamentally based on the RRWD goals to provide constituents with the following protection:

Flood Damage Reduction (FDR) Goals

- Provide 100-year flood protection for the City of Roseau and rural homesteads in the district.
- Provide 10-year flood protection for agricultural lands.
- Reduce flood damage to roads and crossings.
- Reduce drought damages.
- Preserve ground water supply and recharge areas.

This alternative will provide the maximum incremental and cumulative benefit of the alternatives considered in the vicinity of the site. The primary difference between the recommended alternative and the remaining alternatives is:

- Increased gated and ungated flood storage volume
- Allow for more frequent use and provide additional storage control for a larger drainage area

The recommended alternative is the most feasible and practicable alternative.

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APPENDIX A
RRWMB STAR VALUE WORKSHEET

Star Value Computation Worksheet
Red River Watershed Management Board

Enter values only in the cells that have been shaded. All other values are computed from these values.

Project Name:	**Hay Creek Norland**		**Step 2**	Enter Project Name. (Status eg Step)
Watershed District:	**Roseau River Watershed District**			Enter Name of Watershed District.
Project Location:	**Spruce Twsp, Roseau County**			Enter Project Location.
Estimated Total Cost:	**$ 10,150,838**			Enter the estimated project costs. These are used to compute the cost per star value.
RRWMB Cost:	**$ 1,268,855**	CPI (1984=100)	CPI (2009=100)	
Year of Estimate:	**2009**			Ratios of the Consumer price index read from the CPI worksheet.
Adj. to SummaryAll Base Yr:				
Drainage Area (square miles)	**124.0**	Enter the drainage area in square miles used to compute the runoff volume.		
Storage Volume(s):	**Acre-feet**	**Inches**	**Adj. Storage (ac-ft)**	The adjusted storage is total storage is multiplied by the Volume Adjustment Factor which can reduce the storage. Storage is removed 1st from the ungated storage, 2nd from the gated (2) storage, 3rd from the gated (1) storage and last from the drawdown st
Drawdown		0.00	0	
Gated (1)	**6,037**	0.91	6,037	
Gated (2)		0.00	0	
Ungated (to emergency spillway)	**3,497**	0.53	3,497	
Total Storage (8.1 inches Max.)	9,534	1.44	9,534	
Volume Adjustment Factor	1.00	0		
Est. of Ungated Detention Time	**Volume (ac-ft)**	**Elevation (ft)**	**Discharge (cfs)**	Note: this section is provided for reference only. The values are not used in the calculations.
Emergency Spillway	**9,534**	0	0	
10% of Ungated	**953**	0	0	
90% of Ungated Volume	8,581			
	Average Discharge (cfs)		0	
	Discharge in AF per day		0	
	Average Detention Time (days)		not applicable	
Detention Time:				
Gated (1) from Operation plan	**30.0**	Enter gated detention time for the 1st category of gated storage.		
Gated (2) from Operation plan	**0.0**	Enter gated detention time for the 2nd category of gated storage.		
UnGated (from Operation Plan or above)	**6.0**	Enter ungated detention time. (Center of Mass to Center of mass)		
Ungated Storage Offset	**0.0**	Offset of center of mass of inflow hydrogragh to center of mass of storage.		
Average Time Interval between Routed Site Peak and Red River Peak (days). (Negative is ahead of peak, positive is after peak)	**10.0**	**Existing Relative T**	9.01	Existing Relative T is based on the average time interval between routed site peak flows and the RRN.
Calculation of Star Value	**Routed Relative T**	**Adj. Storage (Ac-ft)**	**Star Value**	
Drawdown Storage (30 - 9.05)	20.95	0	0	Routed relative T is the value of the detention times computed using the regression equations given in figure 3. The Existing Relative T is subtracted from the project Relative T.
Gated (1) Storage (28.00 - 9.05)	18.95	6,037	114,416	
Gated (2) Storage (9.05 - 9.05)	0.00	0	0	
Ungated) Storage (16.00 - 9.05)	6.95	3,497	24,312	
Star Value		**9,534**	**138,728**	STAR VALUE
		2009 dollars	**0 dollars**	
Total Cost per Star Value		**$ 73.17**	**$ -**	Total Cost divided by STAR Value
RRWMB Cost per Star Value		**$ 9.15**	**$ -**	RRWMB Cost divided by STAR Value
Prepared By:	Nate Dalager			Enter name of preparer
Source of Data:	Step 2			Enter source data.
Frequency/Date of Preparation:	100 Year 10 Day		15-May-09	Enter frequency and date.

APPENDIX B
SOILS REPORT

Hay Creek Section 206 Study

GEOTECHNICAL APPENDIX
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I. Geology

1. <u>Physiography and Topography</u>: The Project site lies in the Red River Lowland Subdivision of the Central Lowland geographic province. Following the last glaciation of Pleistocene time a huge inland melt water lake called Glacial Lake Agassiz covered this area, including most of northwestern Minnesota. The abandoned shoreline forms the boundaries of the Red River Lowland. The physiographic areas within this Red River Lowland include the Glacial Moraine, Glacial Washed Till Plain, and the Glacial Lake Plain. The Glacial Moraine lies to the south of the Upper and Lower Red Lakes and is characterized by gently rolling to hilly landscape with local relief up to 150 feet. The Project lies in the Glacial Washed Till Plain, which extends approximately 50 to 60 miles west, north and east and is characterized by flat to gently rolling landscape, with local relief up to 15 feet and abundant peat deposits. The Glacial Lake Plain borders the Till Plain to the west extending into North Dakota and Canada, and is characterized by poorly drained nearly level landscape.

2. The altitude of the land surface ranges from approximately 1,600 feet above mean sea level (msl) in the moraine area south of the site to 800 feet where the Roseau River meets the Red River of the North. Natural ground surface elevations at the site range from 1045 to 1060 feet.

3. <u>General Geology</u>: The geology influencing the Hay Creek area is a product of Pleistocene and recent sedimentation and erosion. Glaciers advanced over the area several times during the Pleistocene Epoch and deposited a thick mantle of drift on top of an eroded Precambrian crystalline bedrock surface. The Cretaceous and Paleozoic bedrock has been eroded in this area. The thickness of glacial drift is estimated to be over 150-200 feet, although very limited deep subsurface data is available for the area. The last glacial period ended approximately 9000 years ago with the retreat of the last glacier and the draining of Glacial Lake Agassiz. Lake Agassiz occupied an area of approximately 200,000 square miles including most of northwestern Minnesota, northeastern North Dakota and central Canada. The Upper and Lower Red Lakes are remnants of the huge Glacial Lake Agassiz. Since the recession of the glacial lake the local streams such as the Roseau River and Hay Creek established their meandering course over the relatively flat till and lake plain eroding and depositing alluvial sediments. The shallow depressions in the ancient lake bottom have since filled with organic deposits to create marshes and expansive peat lands typical of the area north and east of Hay Creek.

4. <u>Subsurface Exploration Program</u>: Ten soil borings were obtained at the site in December 2000. The borings were done to determine the thickness and distribution of organic deposits, the foundation conditions, the source of borrow, and the as-built conditions of the existing embankments. The boring locations are shown on the map on Plate 1. The three boring log profiles are shown on Plates 2 through 4. Plates 5 through 7 show the drafted boring logs. The borings are numbered in sequence as they were taken. The numbering system 00-1M through 00-10M refer to borings done on this Project in 2000 by machine (M). The depth of borings ranged from 7 to 35 feet. The target depth for most was glacial drift, since this is a good foundation. A field geologist logged the soils as the borings progressed using the Unified Soils Classification System. Jar samples were taken and will be stored in the Corps of Engineers (COE) sample warehouse for at least two years, in the event that laboratory testing is needed. Original boring logs are on file at the St. Paul District Office.

5. The borings were continuously sampled with split spoon samplers and a Standard Penetration Test (SPT) was conducted at least every 5 feet.

6. Site Geology: Project borings revealed soils consistent with the geologic history and man-made changes to the area. For discussion purposes the soils have been grouped into six units based on engineering properties and geologic origin: fill, alluvium, marsh, lacustrine, glacio-lacustrine and glacial drift. Most borings encountered only two or three of the units; fill overlies the other soils; primarily adjacent to the ditches. The fill used for the existing embankments consists of a mixture of the sandy, silty, clayey soils typical of the underlying native soils. Recent marsh, deposits consist of peat and organic soils. Undifferentiated alluvial sand, silt and clay soils are evident along past and present corridors of Hay Creek. Glacio-lacustrine sand, silt and clay and lacustrine clays are sandwiched between the alluvial and glacial drift soils. Glacial drift underlies the lacustrine soils.

7. Fill: The fill consists of predominately brown to black, loose and medium stiff, silty sandy clay. Organic soils are common. This fill is typical of a mixture of the locally derived clayey glacial drift, alluvium, and lacustrine soils. Most of the fill occurs on the roadways and in the small side-cast embankments created near the drainage ditches.

8. Marsh: The recent marsh deposits consist of a sequence of fibrous peat composed of slightly decomposed plant fragments and roots approximately 1 to 6 feet in thickness. The peat is highly compressible.

9. A thin less than 2-foot thick organic silt and clay layer classified as OH and OL is common at the top and base of the fibrous peat. This unit is black and consists of clay, silt and amorphous organics. This unit has poor engineering properties and is highly compressible.

10. Alluvium: The alluvial sand, silt and clay lack the organics present in the marsh deposits and show no similarities to the underlying lacustrine soils. This unit consists of undifferentiated recent fluvial deposits, from the Roseau River and Hay Creek floodplain. These soils are gray to brown, soft to medium stiff silty clays. These soils are common but usually only 1 to 3-feet thick.

11. Lacustrine and Glacio-Lacustrine: The lacustrine and glacio-lacustrine soils consist of fat clays and soft to medium stiff sandy gravelly "lake-washed" tills or material slumped off of melting glacial ice. These units occur interbedded in some areas, likely a result of fluctuating glacial lake levels. The clayey beds commonly consist of blocky textured clays that appear to have been desiccated. Some samples formed slickensides when sheared some samples had preexisting slickensides. This unit may be underlain by sandy phases under artesian conditions. These soils consist of shallow lake bottom sediments most of which were derived from the underlying glacial till. This unit is typically gray colored, and loose or soft to medium stiff.

12. Glacial Drift: The glacial drift is a medium-stiff to stiff, unsorted, silty, sandy clay with scattered cobbles and boulders. The upper 1 to 4 feet is typically brown or buff colored, less stiff, and has abundant randomly spaced iron stained joints.

13. Groundwater: The regional groundwater flow is from the highlands just south toward the lake plain to the north and west. Artesian conditions and springs have been noted in geologic literature. Boring 00-3M flowed at the ground surface once the sandy glacio-lacustrine unit was encountered approximately 20-feet below ground surface. Wet organic soils in the Norland area are likely a consequence of clayey soils, springs or high groundwater levels.

14. Sources of Construction Materials:

15. Riprap and Bedding: Fieldstone and oversized rock from the area gravel pits are viable sources for the riprap and bedding needs of the Project.

16. Borrow Sites: Local

II. Geotechnical Evaluation

1. Boring Data Base: Ten borings were acquired for the Hay Creek Section 206 Study in December of 2000. Additional borings obtained for the Roseau River General Design Memorandum (GDM) dated November of 1970 were also evaluated as necessary to supplement the Project database.

2. Sampling and Testing: Jar samples were obtained from the ten borings completed in December of 2000. The table below summarizes the samples taken and testing performed on them. Unit weights were not obtained for these borings.

Jar Samples

	Atterbergs	**Moisture Content**	**Sieve Analyses**
97	44	39	22

3. Soil Parameters: Soil parameters used in the geotechnical analysis were obtained from a number of sources and are summarized in the table below. Each parameter is discussed in detail in the paragraphs following the table.

SOIL PARAMETERS USED FOR THE HAY CREEK ENVIRONMENTAL RESTORATION REPORT

			S (5) (CD)		Q (UU)	
Soil Type	γ_{moist} (pcf)	$\gamma_{sat.}$ (pcf)	c' (psf)	ϕ' (deg.)	c (psf)	ϕ (deg.)
Embankment Fill	111	116	500	30	1000	10
Alluvium	110	110	0	27	470	0
Lacustrine	-	97	0	23	380	0
Glacio-Lacustrine	-	116	0	30	240	0
Peat	98	98	0	44	250	0
Till	103	122	0	32	0	32

4. Unit Weight: Since no unit weight information was available for the ten borings obtained in December of 2000, this information was taken from other sources. Unit weights for the alluvial and lacustrine units were obtained from boring 67-1M of the Roseau River GDM. Only saturated unit weights were available since sampling and testing was below the water table. The design profile on Plate B-2 of the GDM indicates that the moist unit weight of the fluvial unit is approximately equal to the saturated unit weight. Therefore it is assumed the moist unit weight and saturated unit weights are approximately equal for the alluvial unit at Hay Creek. The moist unit weight for the lacustrine unit was not required since it is below the water table. The glacio-lacustrine unit weight was assumed to be similar to the Sherack Unit as defined in the Grand Forks/East Grand Forks Alignment Design Documentation Report (GF/EGF DDR) as they have similar drained strengths. Determination of the moist unit weight was not necessary as this unit is below the water table for conditions modeled. The embankment fill was assumed to have the same unit weight as embankment fill defined in the GF/EGF DDR. Unit weights for the peat were developed using an estimated dry unit weight from Table 3.30 in *Geotechnical Engineering Investigation Manual* by Hunt in conjunction with water contents derived from boring 00-6M. The unit weight for the till was determined using blow count and soil type information from the boring 00-2M in conjunction with the chart on Figure 3-5 of EM 1110-2-1913.

5. Drained Strengths: Drained strengths were developed from several sources. The embankment strengths defined in the GF/EGF DDR were used for the Hay Creek Setback Levee and Norland Embankment. Drained strengths for the alluvial, lacustrine, and glacio lacustrine units were developed from test results for plasticity index (PI) used in conjunction with the Figure 19.7 plot of friction angle vs. PI in *Soil Mechanics in Engineering Practice*, written by Terzaghi, Peck, and Mezri. Due to lack of information available, drained strengths for the peat were developed from triaxial test results for three peat specimens obtained for the Bassett Creek Flood Control Project in 1980. Drained strengths for the till were developed from boring data for 00-2M used

with the chart on Figure 3-5 of EM 1110-2-1913 discussed in the previous paragraph. Additional borings and testing should be obtained in the next phase of the Project to better define the site specific strengths.

6. Undrained Strengths: Undrained strengths were also developed from a number of sources. Embankment strengths were obtained from the GF/EGF DDR. Undrained strengths for the alluvial, lacustrine, and glacio lacustrine units were obtained from the Roseau River GDM. The strengths defined in the GDM for the superglacial till unit were used for the glacio-lacustrine unit. Drained strengths were used for the till unit due to the preponderance of granular materials (silts, sands, and gravels) observed in the borings. Undrained strengths for the peat were obtained from Table 3.30 in *Geotechnical Engineering Investigation Manual* for organic material.

7. Slope Stability: Slope stability was evaluated using the UTEXAS3 computer program. A levee section was modeled along Hay Creek and an embankment section was modeled along the Norland Embankment. In addition to soil parameters, information related to cross section geometry and design water surface was required for the stability models.

8. Cross Section Geometry: Cross sections for the stability models were developed using available topographic information in conjunction geometries defined for the proposed Project features.

9. Subsurface Geometry: The subsurface has been divided into the major soil type units as discussed in Part 1 of this Appendix. Geologic profiles were developed using the December 2000 borings.

10. Groundwater Profiles: Due to the limited data available in the study area groundwater profiles used in the models were predominantly based the water levels defined in the December 2000 borings. Boring 00-2M was used for the Hay Creek section and boring 00-6M was used for the Norland Embankment section.

11. Design Water Surface: The design water surface was different for the two sections modeled. The levee section at Hay Creek was modeled assuming the water surface was at the base of the channel for both end of construction and long-term stability conditions. For the section modeled at the Norland Impoundment, the water level observed in boring 00-6M was assumed for end of construction. For the steady state seepage with maximum storage pool a water surface elevation of 1056 feet was assumed. This correlates with the elevation of a ½ PMF event. For partial pool conditions the water surface on the upstream side of the embankment was varied from the ½ PMF elevation down to ground surface.

12. Design Criteria: Slope stability criteria and guidance as defined in EM 1110-2-1913, "Design and Construction of Levees" and EM 1110-2-1902, "Stability of Earth and Rockfill Dams" were used to evaluate slope stability for the levees and embankments of the Hay Creek and the Norland Impoundment..

13. Design Conditions: The above information was used to develop stability models for several design conditions. For the levee section at Hay Creek, end of construction and long-term

stability for drained conditions were evaluated. The low permeability of native soils and the rates of rise and fall of Hay Creek result in conditions that eliminate the need to evaluate the sudden draw down condition. For the Norland Embankment end of construction, steady state seepage with maximum storage pool, and partial pool conditions were modeled.

14. End Of Construction: Stability models for this condition simulate the response of the soils immediately after the construction of the channel, levee, or embankment. This is considered an unconsolidated and undrained condition since the soils have not had sufficient time to consolidate or to drain off the excess pore pressures that result from the additional loading. Failure is modeled on the channel side for the Hay Creek levee. For the Norland Embankment, failure was modeled on both sides. This was necessary due to the presence of an erosion berm on the permanent pool side of the embankment. The critical failure surface was on the downstream slope.

15. Long Term Stability: Stability models for this condition simulate the response of the soils to steady state seepage conditions in the absence of excess pore pressures. Drained soil strengths are used for this analysis. Failure was modeled on the channel side for the Hay Creek levee.

16. Steady State Seepage with Maximum Storage Pool: This condition was modeled for the Norland Embankment only. It assumes a steady state phreatic surface has developed within the embankment for a ½ PMF level flood event. Water levels on the downstream side of the impoundment are assumed to coincide with ground surface.

17. Partial Pool: Partial pool conditions were modeled for the upstream slope of the Norland Embankment. Water surface elevations in the pool were varied from the ground surface to ½ of the PMF to determine the critical condition corresponding to a minimum factor of safety.

18. Factor of Safety: Two criteria were used to evaluate the levee/embankment features at Hay Creek. The levee bounding Hay Creek was evaluated using the Corps of Engineers' criteria for levees as defined in EM 1110-2-1913. It states that a minimum factor of safety of 1.3 is required for the end of construction condition. For the long term stability condition a factor of safety of 1.4 is required. The end of construction condition was the most critical condition for design, although all factors of safety determined for the embankment were well above minimum requirements. The Norland Embankment is designed as a dam and as such requires a higher factor of safety for certain conditions. For end of construction a factor of safety of 1.3 is required. For the steady state seepage with maximum storage pool and partial pool conditions the required factor of safety is 1.5.

19. Stability Analysis for Hay Creek Levee: Slope stability was evaluated for one section along the levee alignment adjacent to Hay Creek. Selection of the location of the design section was based on the geologic profile developed from borings 00-1M through 00-4M. The section modeled was at the location of boring 00-2M.

20. The hydraulic analysis for the channel restoration dictated the levee and channel geometry and minimum levee setback requirements. The design levee section is 4 feet high with a 10-foot top width and 1V on 3H side slopes. The levee has a minimum setback distance of 75 feet from the

edge of the channel. The design channel requires 1V on 3H side slopes with an 8-foot base width.

21. Slope stability was evaluated for the Hay Creek levee section for end of construction and long-term stability conditions. Due to the relatively large offset of the levee from the channel both circular and noncircular failure modes were examined. The end of construction conditions modeled were more critical than long term stability for failure surfaces involving the levee section, although all factors of safety calculated were well above minimum requirements. For end of construction the minimum factor of safety determined was 2.96 for a noncircular failure. For long-term stability the minimum factor of safety determined was 3.51, also for a noncircular failure.

22. In addition to evaluating stability for the levee section, it was necessary to evaluate localized slope stability along the channel slope. Circular failure surfaces were modeled for long-term stability and end of construction. These models resulted in calculated factors of safety of 1.18 and 3.70 respectively. Although the end of construction factor of safety is well above the minimum 1.3 required the long-term stability factor of safety is slightly below the required value of 1.4. A factor of safety below levels defined in the EM is justified here for two reasons. First, the levee section is set back a minimum of 75 feet from the channel and has a factor of safety well in excess of what is required for both conditions modeled. Second, cross sections obtained for the existing Hay Creek channel indicate that side slopes steeper than 1V on 3H are common along the alignment. Plate 8 shows the results of the stability analysis.

Condition Modeled	FACTOR OF SAFETY: CIRCULAR FAILURE AT CHANNEL BANK	FACTOR OF SAFETY: CIRCULAR FAILURE AT LEVEE	FACTOR OF SAFETY: NONCIRCULAR FAILURE AT LEVEE
End Of Construction	3.70	4.42	2.96
Long Term Stability	1.18	4.77	3.51

23. <u>Stability Analysis for Norland Embankment</u>: Slope stability for the Norland Embankment was evaluated at a location along the alignment that coincided with the western boundary of Section 1 of T162N, R39W. This portion of the alignment was selected for modeling since the crest of the proposed embankment is approximately 9 feet above the existing ground. Subsurface stratigraphy and groundwater levels for the modeling were developed from boring 00-6M, which is located about four tenths of a mile to the north.

24. The design for the proposed embankment has an assumed top elevation of 1057 feet with a 10-foot top width and 1V on 3H side slopes. In addition to the embankment prism an erosion berm is proposed for the upstream slope to provide erosion protection for the permanent pool. The top of the berm is at elevation 1052 adjacent to the embankment. It extends out horizontally 10 feet at which point it slopes down at 1V on 10 H for twenty feet. It then slopes down at 1V on

3H over a distance of 6 feet to the point at which it intersects the existing ground surface. The size of the berm will be variable along the alignment, depending on the elevation of the existing ground. It is assumed that the berm will be constructed of soils in the area adjacent to the embankment, exclusive of highly organic material. Although some compaction will be performed on the berm it is assumed compaction and quality of material will be below that which is required for the embankment prism. The most important factor concerning the berm is establishing a vegetative cover that is effective in resisting erosion. The overall size of the berm will allow for some minor erosion at its outer limits.

25. Since the berm will be constructed of soils readily available in the area and only minimal compaction is assumed, native soil strengths were used for drained and undrained conditions. For each condition modeled the strength used correlated with the weakest soil unit for that condition. For undrained conditions the strength for the glacio lacustrine unit was used. For drained conditions the strength of the lacustrine unit was used. This may be somewhat conservative; especially since there will be compactive effort applied to the berm.

26. The modeling for all three conditions resulted in factors of safety that exceeded minimum requirements. For the end of construction condition a minimum factor of safety of 1.67 was calculated for a failure surface extending downstream of the embankment. A minimum failure surface was also examined for the upstream slope but this resulted in a higher factor of safety.

27. The steady state seepage with maximum pool elevation condition was evaluated for an upstream water surface at elevation 1056 feet. This equates to a ½ PMF event. For this condition, drained strengths for the soils were used. The phreatic surface is assumed to have developed to a condition approaching steady state. This is conservative for an event on the order of a ½ PMF as the water surface will not stay at these levels for more than a few days. The phreatic surface was assumed to be at ground level downstream of the stability berm. The minimum factor of safety determined was 2.04, which is well above the required value of 1.5.

28. The final condition to be examined for the embankment is partial pool. For this condition failure surfaces are determined on the upstream side of the embankment for various pool elevations. Various upstream water surface elevations were evaluated from the ground surface up to the ½ PMF. The critical failure surface was determined to be for a water surface at 1050 feet, although the factor of safety for the water surface at ground level is only slightly higher. This minimum factor of safety is 3.87, which is well above the required 1.5. The table below summarizes the results of the stability analyses. Plate 9 shows the stability section.

END OF CONSTRUCTION	STEADY STATE SEEPAGE WITH MAXIMUM POOL	PARTIAL POOL WITH UPSTREAM POOL = 1050'
1.67	2.04	3.87

Results of the Norland Embankment stability analysis.

29. <u>Seepage</u>: Seepage was not evaluated for the ERR. This will be evaluated for the Norland Embankment during the plans and specs phase of the Project.

30. Annular Drainage Fill: Corps criteria require that an 18-inch thick ring of annular drainage fill be placed around the landside one third of all pipes extending through a levee/embankment. This allows any seepage that develops along the pipe to exit on the landside without causing piping of material. Design details for drainage fill for all pipes passing through levees and embankments will be developed during plans and specs.

31. Settlement: The analysis of settlement of the levees, embankments, and gated culverts has not been completed for the ERR. This issue will be addressed in the plans and specs phase of the Project and will likely result in overbuilding of at least a portion of the levee/embankment system. For the purposes of preliminary estimates, a six inch overbuild section is assumed for embankment heights 10 feet or greater.

32. Scour Analysis: Scour protection will be required at culvert inlets and outlets. Rock quantities are anticipated to be small and design details will be developed in the plans and specifications phase of the Project. Rock protection will also be required along the right bank and across the bottom of the new Hay Creek Channel in the vicinity of the diversion overflow structure. Details will be designed in plans and specs.

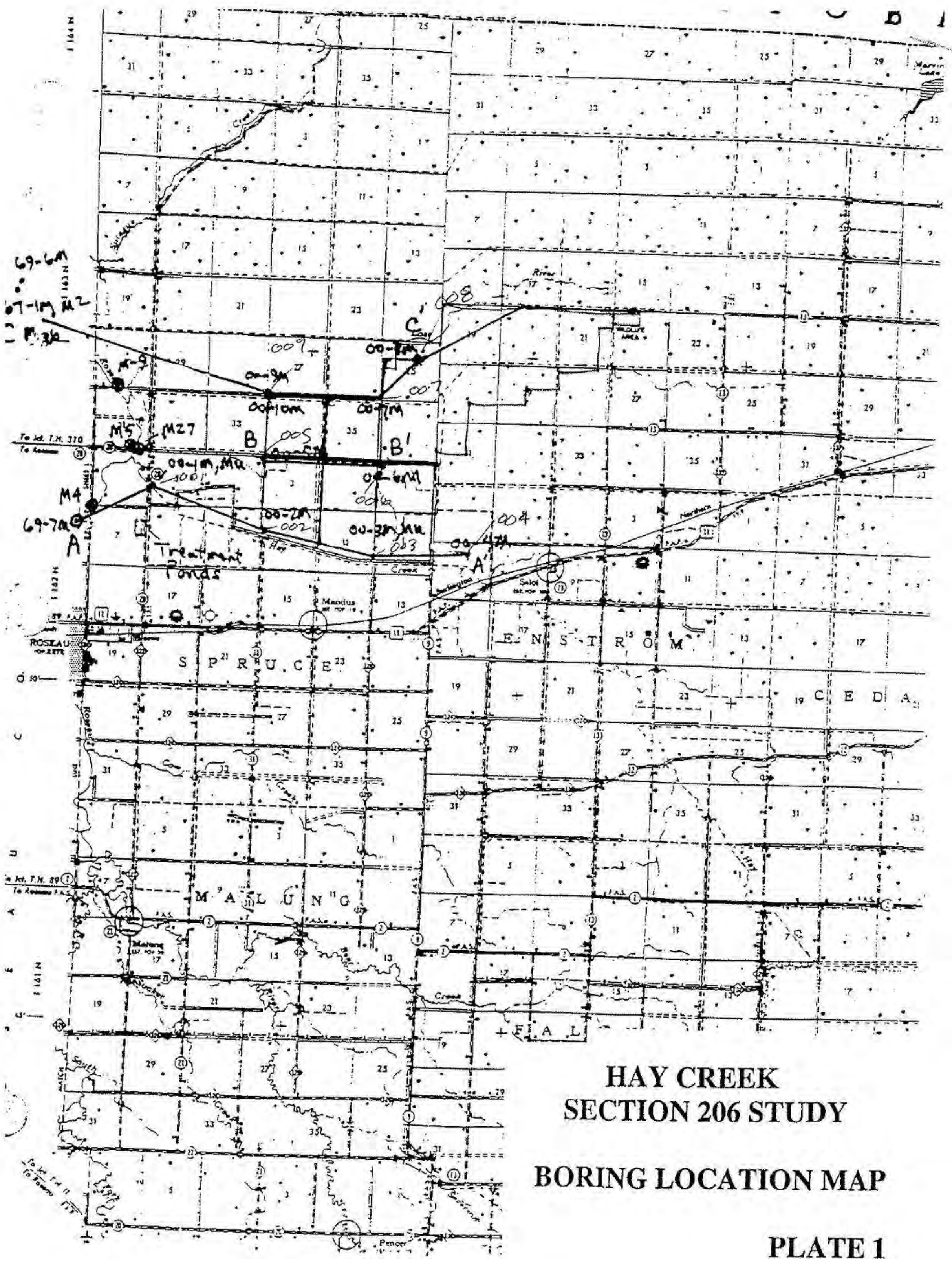
33. Hazardous Toxic Radioactive Waste (HTRW)- A Phase I Environmental Site Assessment (ESA) was completed along the proposed alignment of the Project features in October of 2000. The purpose of the ESA was to identify sites with potential environmental concerns associated with the construction of the Project features. Construction activities that could encounter contaminated materials include stripping, grubbing, and inspection trenches for levees and embankments.

34. At the time the ESA was conducted only one area was identified as potentially impacting Project features. This was an agricultural site located at the northeast corner of Section 34. Conditions at the site indicated the potential for contamination of the subsurface in the vicinity of proposed storage embankments. Since that time these storage embankments have been removed from the Project thereby eliminating HTRW concerns. No additional investigations are recommended.

35. Additional Work- Additional geotechnical work will be required if this Project advances to the plans and specifications phase.

36. Norland Embankment: Additional field investigations and testing will be required along the embankment alignment to better define subsurface conditions and soil strengths. This will be most critical in the reaches where the embankment is highest or where subsurface materials appear to be of concern. Obtaining and testing undisturbed samples is recommended to more accurately define the shear strength of the native soils along the alignment and to define settlement parameters. This will allow for more accurate stability analyses along the embankment as well as settlement analyses for the embankment and the proposed gated culverts passing through the ditches. A seepage analysis will be completed for normal and flood conditions. Scour protection will be designed for overflow structures, inlets and outlets for all culverts passing through the embankment, and for wave action on the embankment. Drainage fill will be designed for culverts passing through embankments.

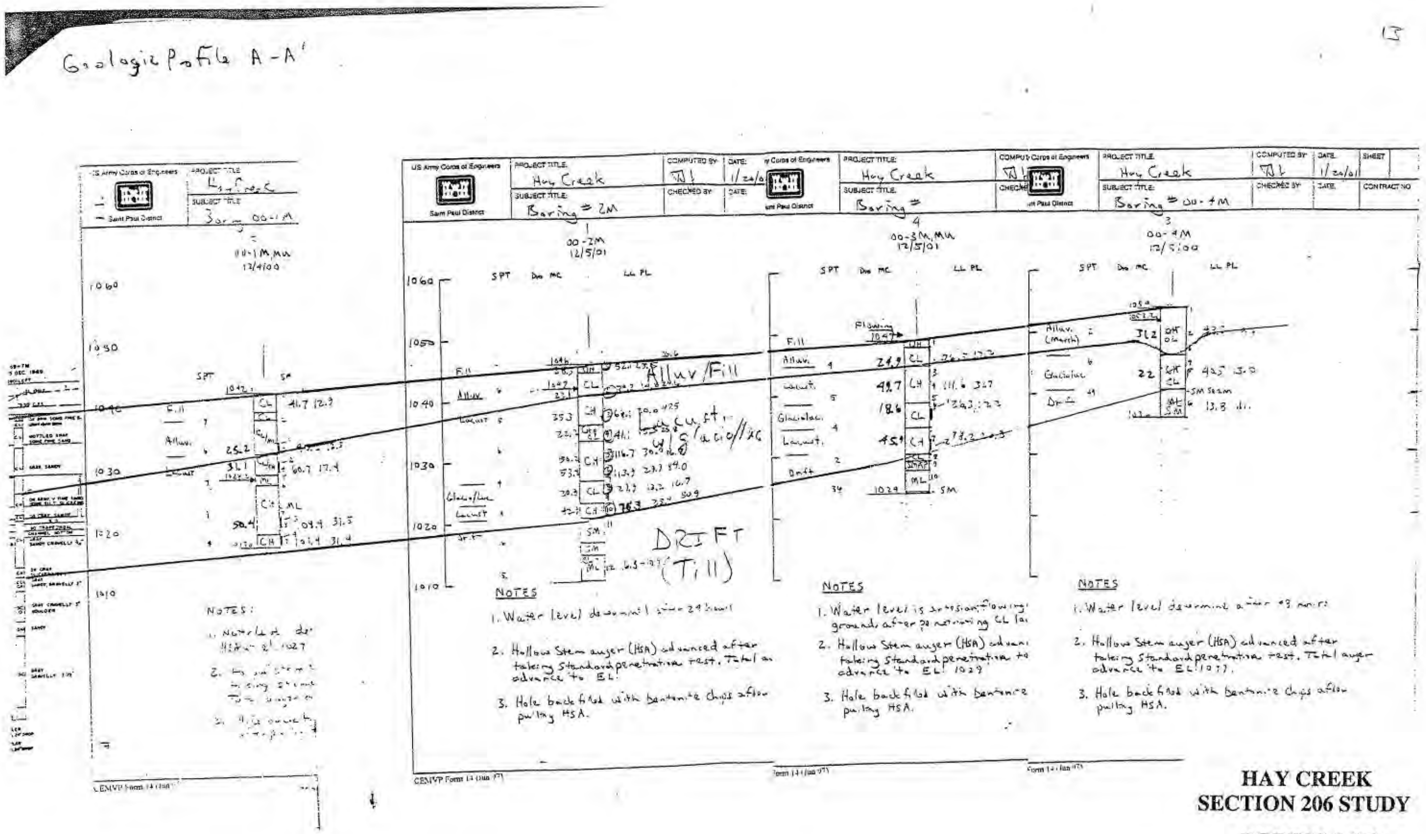
37. Hay Creek: Additional assessments may be required for the Hay Creek channel. Such work might include defining minimum levee setback requirements, design of scour protection for the channel, levee, or bridge crossings. Deviations in the levee and channel design identified in the ERR could necessitate a reassessment of stability.



HAY CREEK
SECTION 206 STUDY

BORING LOCATION MAP

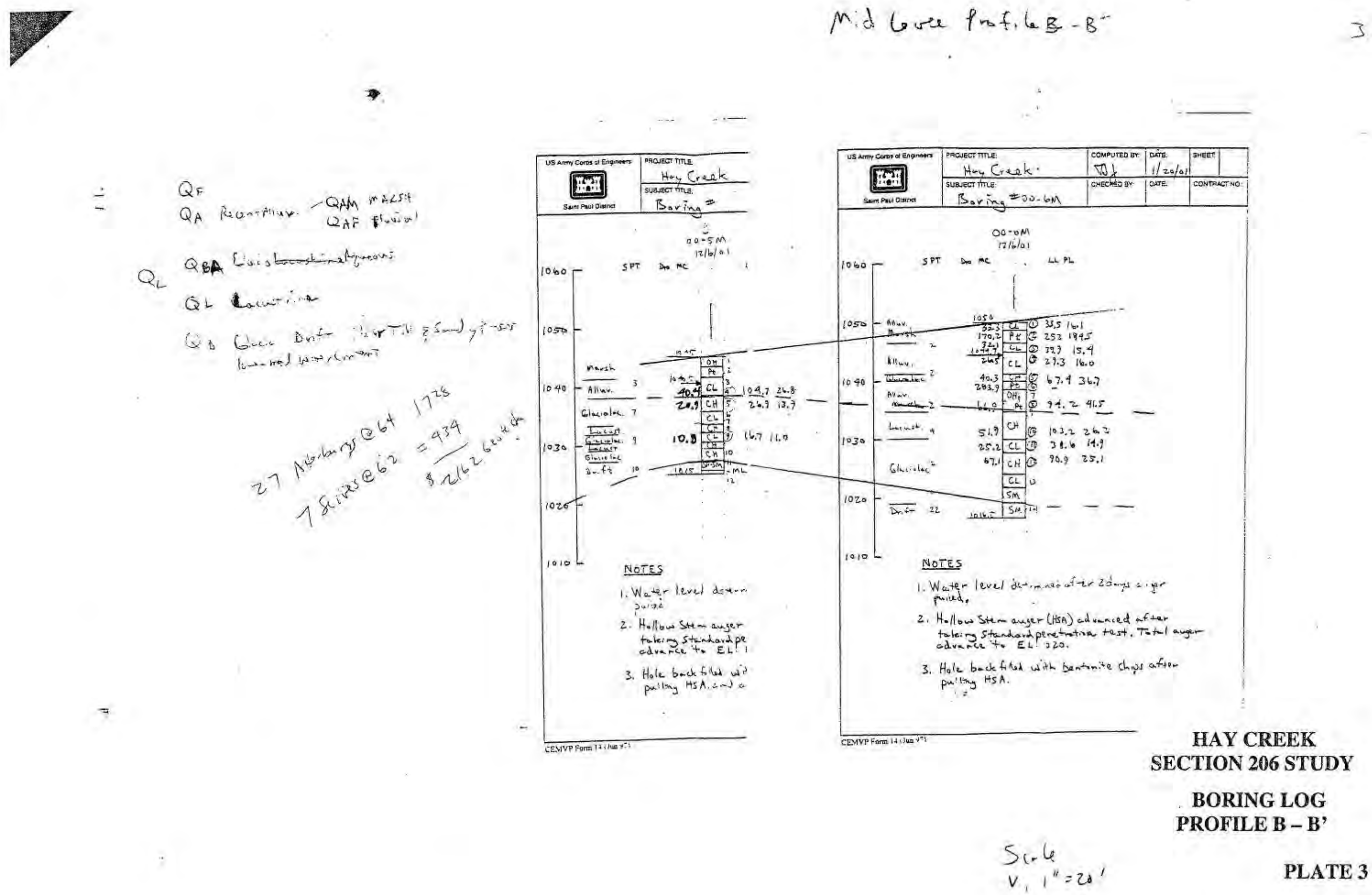
PLATE 1



HAY CREEK
SECTION 206 STUDY

BORING LOG
PROFILE A – A'

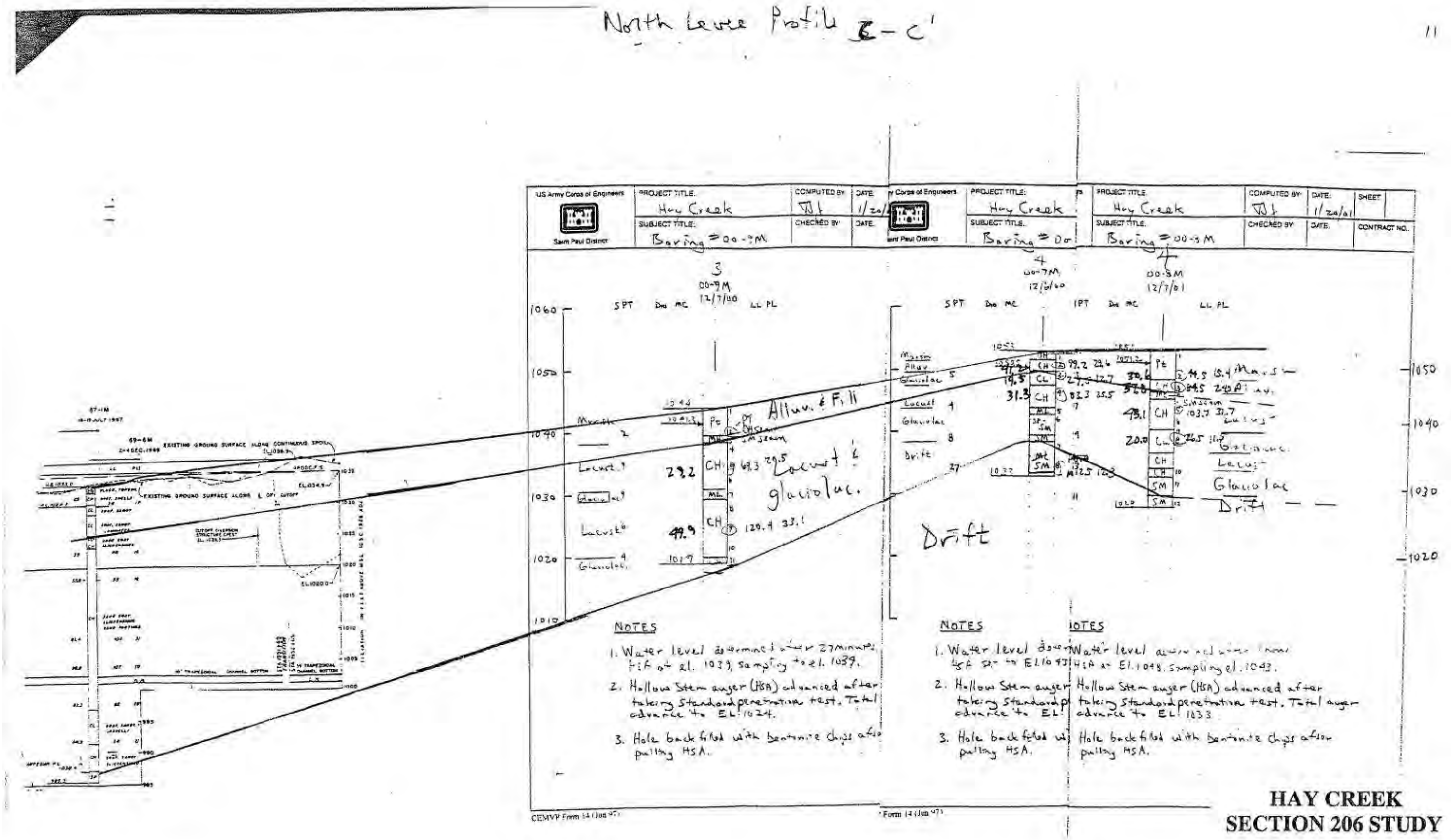
PLATE 2



HAY CREEK
SECTION 206 STUDY

BORING LOG
PROFILE B – B'

PLATE 3



HAY CREEK
SECTION 206 STUDY

BORING LOG
PROFILE C – C'

PLATE 4

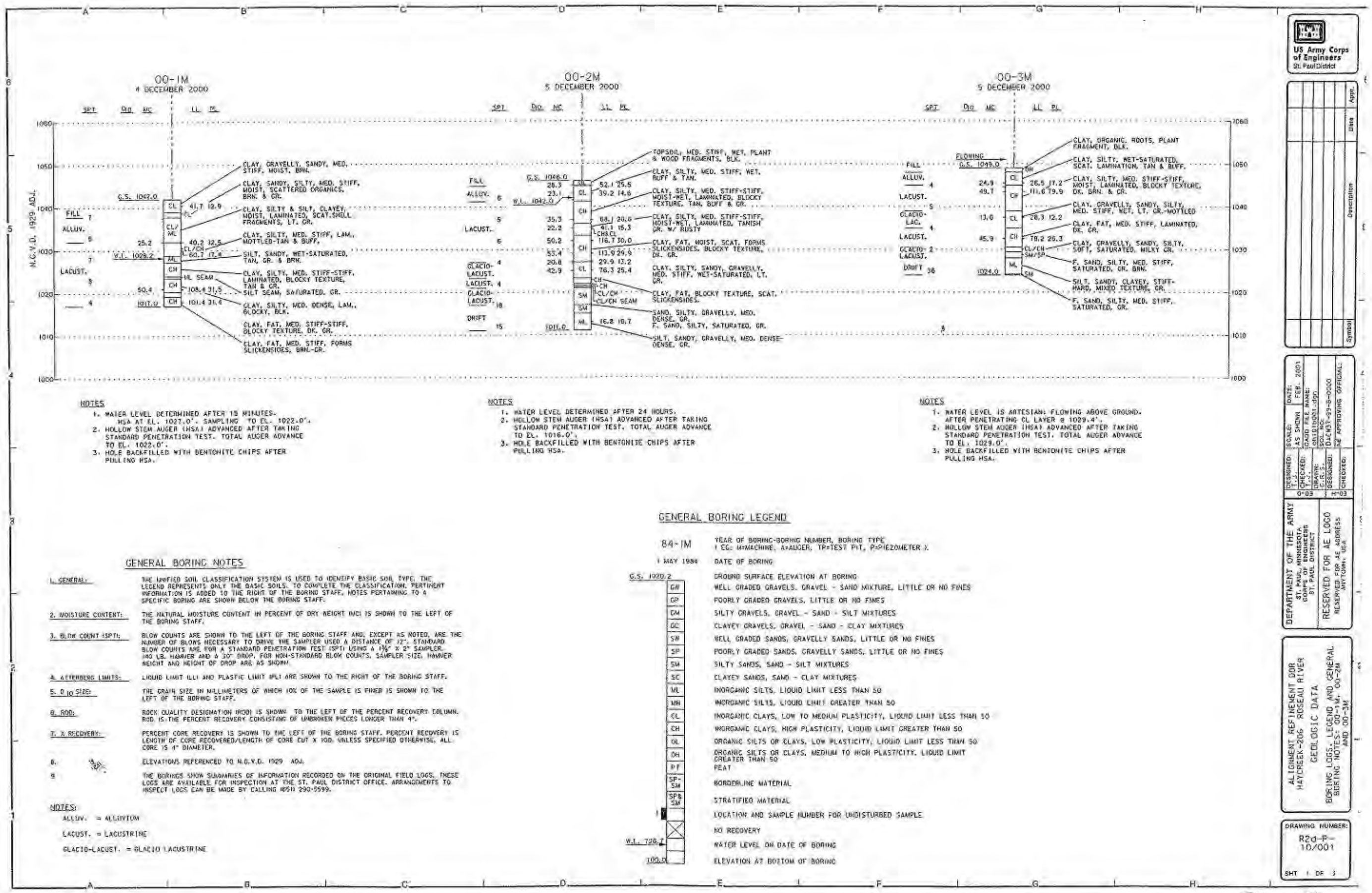

US Army Corps of Engineers
00-1M
4 DECEMBER 2000
00-2M
5 DECEMBER 2000
00-3M
5 DECEMBER 2000
NOTES
GENERAL BORING NOTES
GENERAL BORING LEGEND

Plate 5

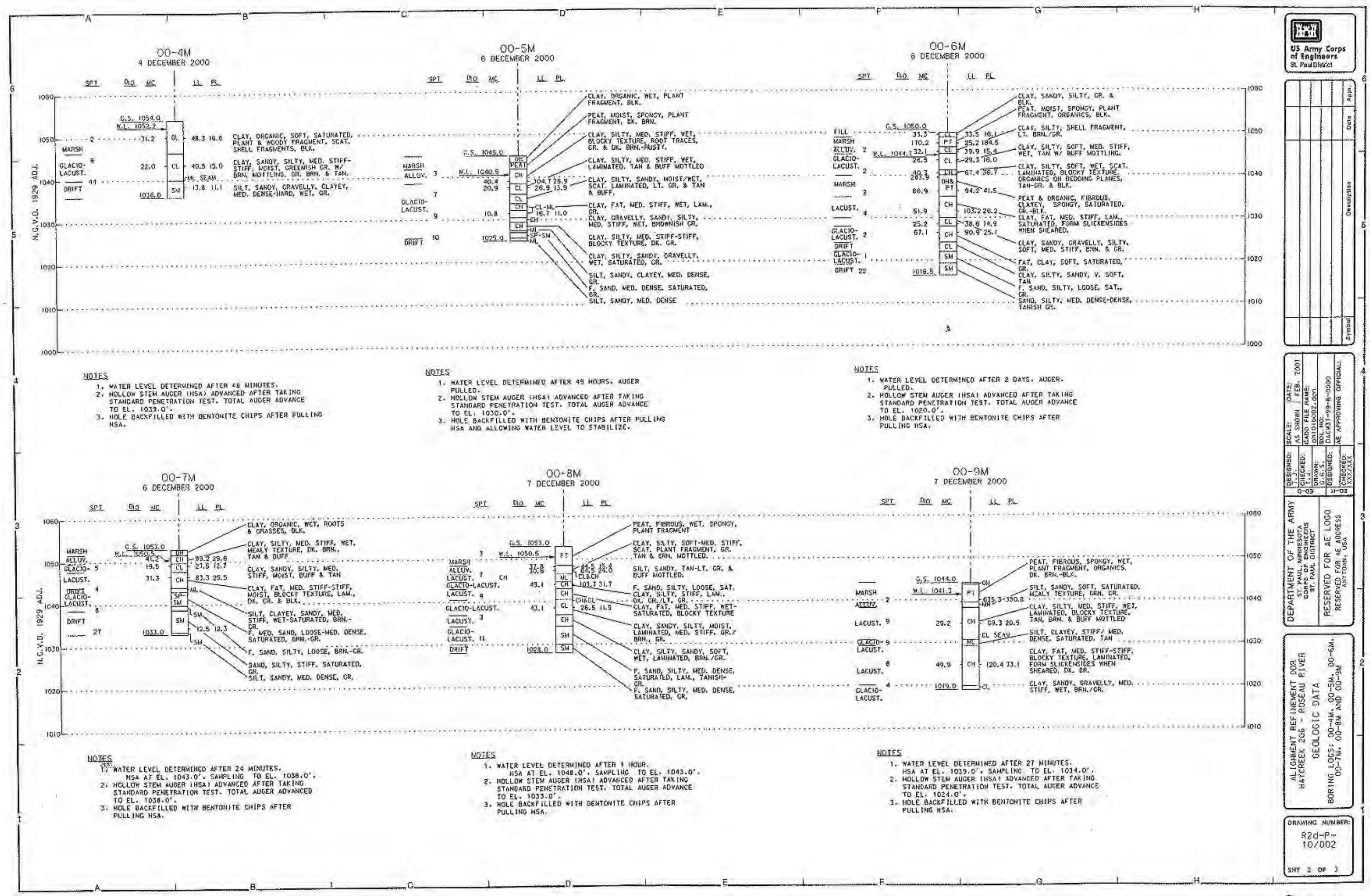
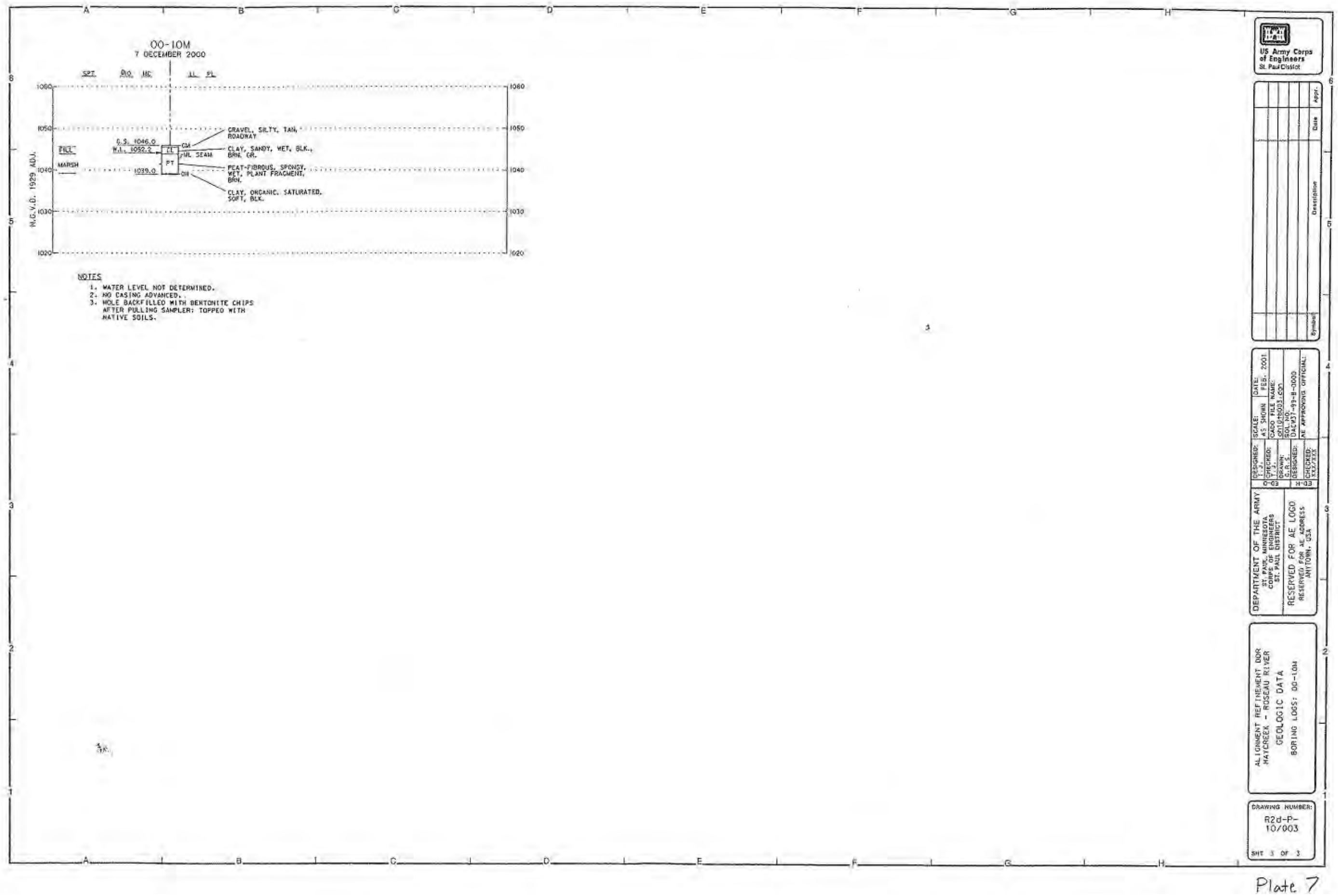
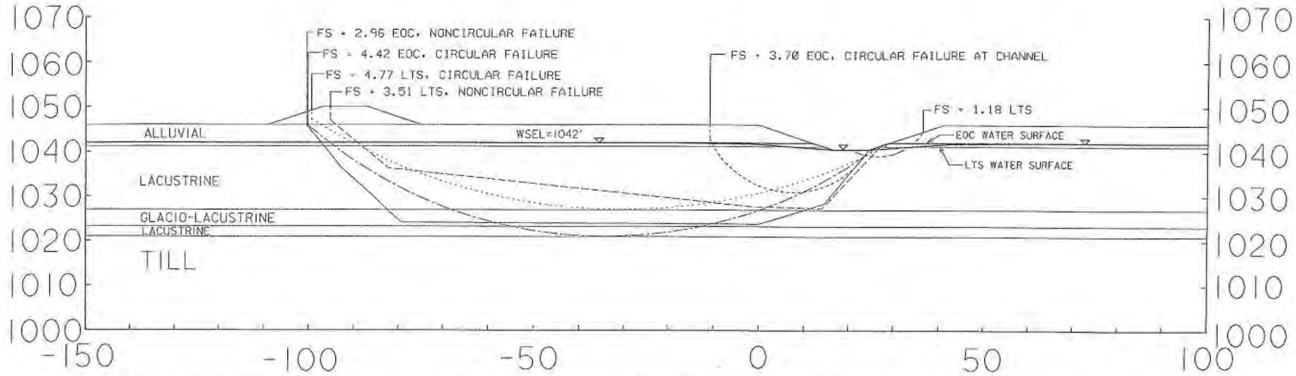

00-4M
4 DECEMBER 2000
00-5M
6 DECEMBER 2000
00-6M
6 DECEMBER 2000
00-7M
6 DECEMBER 2000
00-8M
7 DECEMBER 2000
00-9M
7 DECEMBER 2000
US Army Corps of Engineers
DRAWING NUMBER:
R2d-P-10/D02
SHT 2 OF 3

Plate 6



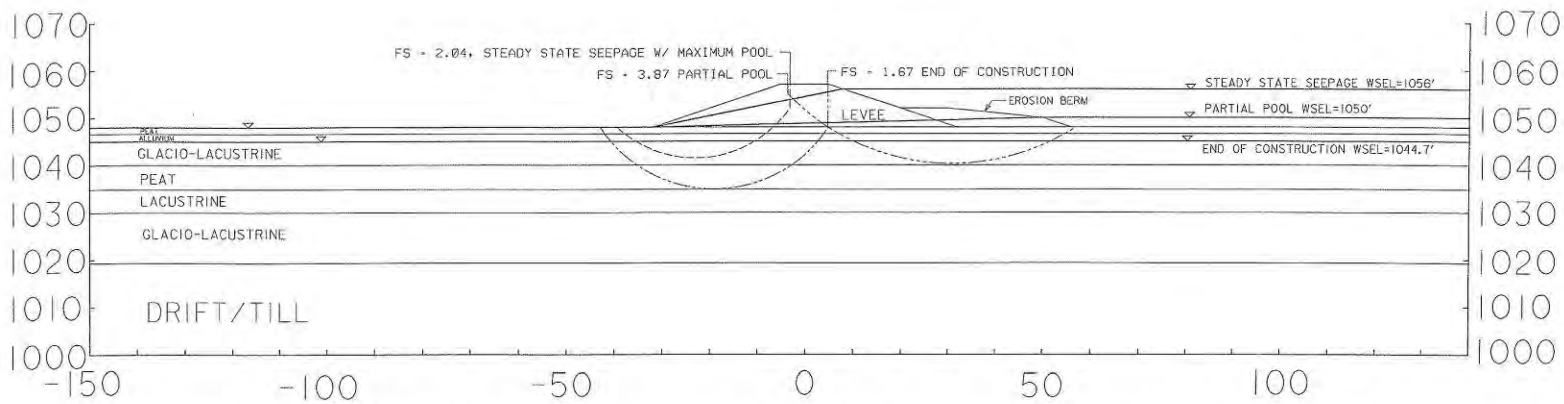
00-10M
7 DECEMBER 2000
SPT
BIO MC
LL PL
N.G.V.D. 1929 ADJ.
FILL
MARSH
G.S. 1046.0
W.L. 1052.2
1039.0
GM
CL
ML SEAM
PT
OH
GRAVEL, SILTY, TAN, ROADWAY
CLAY, SANDY, WET, BLK., BRN, GR.
PEAT-FIBROUS, SPONGY, WET, PLANT FRAGMENT, BRN.
CLAY, ORGANIC, SATURATED, SOFT, BLK.
1060
1050
1040
1030
1020
NOTES
1. WATER LEVEL NOT DETERMINED.
2. NO CASING ADVANCED.
3. HOLE BACKFILLED WITH BENTONITE CHIPS AFTER PULLING SAMPLER; TOPPED WITH NATIVE SOILS.
US Army Corps of Engineers
St. Paul District
Symbol
Description
Date
Appr.
DESIGNED: T.J.
CHECKED: T.J.
DRAWN: G.R.S.
DESIGNED:
CHECKED: XXX/XXX
SCALE: AS SHOWN
DATE: FEB. 2001
CADD FILE NAME: sh10+b003.dgn
SOL. NO: DACW37-99-B-0000
AE APPROVING OFFICIAL:
DEPARTMENT OF THE ARMY
ST. PAUL, MINNESOTA
CORPS OF ENGINEERS
ST. PAUL DISTRICT
RESERVED FOR AE LOGO
RESERVED FOR AE ADDRESS
ANYTOWN, USA
ALIGNMENT REFINEMENT DDR
HAYCREEK - ROSEAU RIVER
GEOLOGIC DATA
BORING LOGS: 00-10M
DRAWING NUMBER:
R2d-P-10/003
SHT 3 OF 3
Plate 7



HAY CREEK STABILITY ANALYSIS: SECTION AT BORING ØØ-2M
LEVEE SETBACK=75', CHANNEL DEPTH=5.5', CHANNEL SIDE SLOPES=1V ON 3H

FILE	CONDITION MODELED	FACTOR OF SAFETY
HC2LTS1.TXT	LONG TERM STABILITY CIRCULAR FAILURE AT CHANNEL	1.18
HC2LTS2.TXT	LONG TERM STABILITY CIRCULAR FAILURE AT LEVEE	4.77
HC2NLT.TXT	LONG TERM STABILITY NONCIRCULAR FAILURE AT LEVEE	3.51
HC2CEC.TXT	END OF CONSTRUCTION CIRCULAR FAILURE AT LEVEE	4.42
HC2NEOC.TXT	END OF CONSTRUCTION NONCIRCULAR FAILURE AT LEVEE	2.96
HC2LOE.TXT	END OF CONSTRUCTION CIRCULAR FAILURE AT CHANNEL	3.7Ø

PLATE 8



NORLAND IMPOUNDMENT STABILITY ANALYSIS: NONROAD LEVEE SECTION
APPROX SECTION LOCATION STATION 118+00 NEAR BORING 00-6M
TOP OF NORLAND EMBANKMENT AT ELEVATION 1057.0 FT

FILE	COND MODELED	F.S.
HC6ECLOW.TXT	END OF CONSTRUCTION	1.67
HC6SSLOW.TXT	STEADY STATE SEEPAGE W/ MAX POOL	2.04
HC6PP50.TXT	PARTIAL POOL	3.87

PLATE 9

Plate 10

A Subsurface Investigation Report

Proposed Improvements
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota

Prepared for the

Roseau River Watershed District

Professional Certification:
I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the
State of Minnesota.

Mark W. Gothard, PE
Principal-Senior Geotechnical Engineer
License Number: 44926
June 6, 2008

MARK W. GOTHARD
LICENSED PROFESSIONAL ENGINEER
44926
STATE OF MINNESOTA

Project HB-08-01075

Braun Intertec Corporation

BRAUN
INTERTEC

Braun Intertec Corporation
3404 15th Avenue East
Suite 9
Hibbing, MN 55746

Phone: 218.263.8869
Fax: 218.263.6700
Web: braunintertec.com

June 6, 2008

Braun Project HB-08-01075

Mr. Rob Sando, Administrator
Roseau River Watershed District
District Office
P.O. Box 26
Roseau, MN 56751

Re: Subsurface Investigation
Proposed Improvements
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota

Dear Mr. Sando:

We have completed the subsurface investigation you authorized on April 2, 2008. The purpose of this investigation was to provide subsurface soil profile and groundwater data to assist HDR, civil engineers for the project, in designing the proposed improvements to the existing Norland Impoundment, northeast of Roseau, Minnesota. The investigation was completed in general accordance with our proposal to Keith Winter, EIT, HDR, dated March 12, 2008.

As requested, we are not providing analysis and recommendations as part of our services, only this summary report containing results and procedures.

Locations and Elevations

The soil borings were completed at the general locations indicated on the Soil Boring Locations-Norland Impoundment drawing provided by HDR and adjacent to stakes placed in the field by HDR. A copy of the drawing is included in the Appendix.

The borings were labeled as indicated on the drawing and are not numbered consecutively.

The as-drilled boring locations and boring ground surface elevations at the borings will be provided by HDR at a future date.

Summary of Results

Logs. Log of Boring sheets indicating the depths and identifications of the various soil strata, penetration resistances, laboratory test data and groundwater observations are attached. The strata changes were inferred from the changes in the penetration test samples and auger cuttings. It should be noted that the depths shown as changes

Providing engineering and environmental solutions since 1957 between the strata are only approximate. The changes are likely transitions and the depths of the changes vary between the borings.

Geologic origins presented for each stratum on the Log of Boring sheets are based on the soil types, penetration resistances, and available common knowledge of the depositional history of the alignment. Because of the complex glacial and post-glacial depositional environments, geologic origins are frequently difficult to ascertain. A detailed investigation of the geologic history of the alignment was not performed.

Soils. Twenty-six standard penetration test borings were completed as part of our investigation. The borings generally encountered 1/2 to 6 feet of peat swamp deposits at the ground surface underlain by native lacustrine sandy silt, silt with sand, silty clay and sandy lean clay. Below the lacustrine silts and clays, Borings B4, B5, B6, B7, B11, B15, B23 and B46 encountered glacially deposited silty sands (at depths ranging from 4 to 19 feet).

Penetration Resistances. Penetration resistances in the unfrozen peat swamp deposits ranged from 1 to 2 blows per foot (BPF), indicating the peat was very loose. Penetration resistances in the unfrozen silts ranged from 1 to 10 BPF. These values indicated the silts were very loose to loose. Penetration resistances in the unfrozen silty clays and clays ranged from 2 to 10 BPF. These values indicate the silty clays and clays were soft to medium. Penetration resistances in the at-depth silty sands ranged from 1 to 52 BPF, indicating the silty sands were very loose to very dense.

Groundwater. Groundwater was not observed in the borings while drilling and sampling. After the hollow-stem auger had reached the bottoms of the holes, groundwater was not observed to depths of 9 1/2 to 19 1/2 feet. After the auger had been withdrawn from the holes, groundwater was not observed above cave-in depths ranging from 2 to 11 1/2 feet. In silty and clayey soils, however, it may take several hours or days for groundwater to rise to its hydrostatic level.

Seasonal and annual fluctuations of both perched and hydrostatic groundwater levels should be anticipated. In particular, elevated levels should be expected following spring thaw and heavy rains. Also, in silty and clayey soils, perched levels are common following spring thaw and heavy rains.

Laboratory Testing. Several laboratory tests were performed on samples of the native soils encountered. The tests on the samples from the borings consisted of moisture-density, sieve-hydrometer analysis, Atterberg limits and pocket penetrometer tests. The results are summarized in the Summary of Laboratory Tests sheet that follows the logs. The results of the moisture-dry density, Atterberg limits and pocket penetrometer tests are also shown on the attached Log of Boring sheets. The results of the sieve-hydrometer analyses are also plotted on the Grain Size Accumulation Curves that follow the summary sheet.

Moisture Content Tests. Six moisture content tests were performed on samples from the borings. The results indicated the soils had moisture contents ranging from about 11 to 37 percent.

Dry Density Tests. The unit weights of six samples were determined. The dry unit weights ranged from 75 to 125 pounds per cubic foot.

Atterberg Limits. Atterberg limits tests were performed on seven samples. The liquid limits of the samples tested ranged from 26 and 41 percent; the plastic limits ranged from 15 to 35 percent, and the plastic indexes ranged from 2 to 19 percent. These values indicated the soil classifications of the samples tested were silty sand (SM), sandy silt and silt with sand (both ML), silty clay (CL-ML) and lean clay with sand (CL).

Sieve-Hydrometer Analyses. Six sieve-hydrometer analyses tests were completed to evaluate the grain-size distributions of the soils. The samples had 13 to 64 percent sand-sized particles, 29 to 72 percent silt-sized particles, and 7 to 41 percent clay-sized particles. Based upon the test results, the materials were then classified in accordance with the American Society for Testing and Materials (ASTM) classification system. The samples tested were classified as silty sand (SM), sandy silt and silt with sand and lean clay with sand (CL).

Unconfined Compressive Strength Tests. Some of the samples were tested with a pocket penetrometer. The results are presented in tons per square foot (tsf). Pocket penetrometers strengths ranged from 1/2 to 1 3/4 tsf in the samples tested.

Procedures

Drilling and Sampling. The penetration test borings were performed between April 22 and 24, 2008, with a core and auger drill mounted on an all terrain-carrier. The drill was equipped with 3 1/4-inch inside diameter hollow-stem auger. Sampling for the borings was conducted in general accordance with ASTM D 1586, "Penetration Test and Split-Barrel Sampling of Soils." Using this method, we advanced the borehole with the hollow-stem auger to the desired test depth. A 140-pound hammer falling 30 inches was then used to drive the standard 2-inch split-barrel sampler a total penetration of 1 1/2 feet below the tip of the hollow-stem auger. The blows for the last foot of penetration were recorded and are an index of soil strength characteristics. Samples were taken at 2 1/2-foot vertical intervals to the 15-foot depth and then at 5-foot intervals to the termination depths of the borings. A representative portion of each sample was sealed in a glass jar.

Soil Classification. Our drill crew chief visually and manually classified the soils encountered in the borings in accordance with ASTM D 2488, "Description and Identification of Soils (Visual-Manual Procedures)." A summary of the ASTM classification system is attached. All samples were then returned to our laboratory for review of the field classifications by a soils engineer. Representative samples will remain in our Hibbing office for a period of 60 days to be available for your examination.

Groundwater Observations. The hollow-stem auger was checked for the presence of groundwater while drilling. Immediately after taking the final samples in the bottoms of the borings, the holes were probed through the hollow-stem auger to check for the presence of groundwater. Immediately after withdrawal of the auger, the holes were again probed and the depths to water or cave-ins were noted. These borings were then immediately backfilled.

General

Please refer to the attached report for a more detailed summary of our results. If we can provide additional assistance, please call Mark Gothard at 800.828.7313 or 218.263.8869.

Sincerely,
BRAUN INTERTEC CORPORATION

Mark W. Gothard

Mark W. Gothard, PE
Principal-Senior Geotechnical Engineer

c: Brian Hauth, EIT
HDR-Thief River Falls, MN

Attachments:
Soil Boring Location Drawing
Descriptive Terminology
Log of Boring sheets B-2 to B-5, B7, B8, B11, B12, B15 to B23, B25, B29, B33, B34, B37, B40, B44, B46 and B47
Summary of Laboratory Tests Sheet
Grain Size Distributions (6)

BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B2** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/24/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			The ground surface elevations at the borehole locations will be determined by HDR at a future date.
3.0	ML	SILT with Sand, brownish gray, moist to wet, very loose. (Lacustrine)	2		
			3		
			4		
11.0			4		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 2 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/9/08 11:31

HB-08-01075 Braun Intertec Corporation B2 page 1 of 1

BRAUN
INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota		BORING: B3 LOCATION: See sketch.	
DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/24/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
9.0	ML	SILTY with Sand, brownish gray, moist to wet, very loose. (Lacustrine)	2 3 4		
11.0	CL	SANDY LEAN CLAY, gray, moist, soft. (Lacustrine)	3		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 4 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

HB-08-01075 Braun Intertec Corporation B3 page 1 of 1

BRAUN
INTERTEC

LOG OF BORING

Braun Project HB-08-01075 **Subsurface Investigation** **Norland Impoundment** **Roseau River Watershed District** **Northeast of Roseau, Minnesota**	BORING: **B5** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/24/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
3.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
	CL-ML	SILTY CLAY, gray to brownish gray, moist to wet, soft to rather soft. (Lacustrine)	2		
			3*		*LL=26 PL=20 PI=6
			4		
			4		
			6		
18.0			7		
21.0	SM	SILTY SAND, fine- to medium-grained, a trace to a little Gravel and a few Cobbles, brownish gray, moist, loose to medium dense. (Glacial Till)	20		
		END OF BORING Water not observed while drilling. Water not observed with 19 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 7 1/2 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/9/08 11:31

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BRAUN INTERTEC — **LOG OF BORING**

Braun Project HB-08-01075 **Subsurface Investigation** **Norland Impoundment** **Roseau River Watershed District** **Northeast of Roseau, Minnesota**	BORING: **B7** LOCATION: See sketch.
DRILLER: L. Raatsi — METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08 — SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
0.5	PT	PEAT, fibrous, black, frozen. (Swamp Deposit)			
	ML	SILT with Sand, brownish gray, moist to wet, loose. (Lacustrine)	6		
			8		
7.0	SM	SILTY SAND, fine- to medium-grained, brown, wet, loose to medium dense. (Glacial Till)	10		
11.0			11		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN INTERTEC — LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B8** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08	SCALE: 1" = 4'

Depth feet	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
0.0–0.5	PT	PEAT, fibrous, black, frozen. (Swamp Deposit)			
0.5–4.0	ML	SILT with Sand, trace of Gravel, brown, moist, loose. (Lacustrine)	8		
4.0–11.0	CL-ML	SILTY CLAY, brownish gray, moist to wet, rather stiff to medium. (Lacustrine)	10 8 7		
11.0		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 1/2 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN™ INTERTEC — **LOG OF BORING**

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B11** LOCATION: See sketch.
DRILLER: L. Raatsi — METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08 — SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
	ML	SILT with Sand, brownish gray, moist to wet, very loose to loose. (Lacustrine)	2		
			4*		*MC=20% DD=94 pcf LL=34 PL=29 PI=5 % Sand=16 % Silt=72 % Clay=12
			6		
12.0			6		
	SM	SILTY SAND, fine- to medium-grained, brown to gray, moist to wet, very loose to very dense. (Glacial Till)	3		
			1*		*MC=31% DD=78 pcf LL=20 PL=18 PI=2 %Sand=64 %Silt=29 %Clay=7
21.0			70		
		END OF BORING Water not observed while drilling. Water not observed with 19 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 4 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 5/6/08 11:31

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BRAUN℠
INTERTEC

LOG OF BORING

Braun Project HB-08-01075 **Subsurface Investigation** **Norland Impoundment** **Roseau River Watershed District** **Northeast of Roseau, Minnesota**	BORING: **B12** LOCATION: See sketch.
DRILLER: L. Raatsi — METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08 — SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
11.0	ML	SILT with Sand, brownish gray, moist to wet, very loose to loose. (Lacustrine)	3 4 5 4		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 8/6/08 11:31

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BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota		BORING: B-15 LOCATION: See sketch.	
DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08	SCALE: 1" = 4'

Depth feet	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
0.0 – 1.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
1.0 – 6.0	ML	SILT with Sand, brownish gray, moist to wet, loose. (Lacustrine)	8 19		
6.0 – 11.0	SM	SILTY SAND, fine- to medium-grained, a little Gravel and a few Cobbles, brown, moist, medium dense to very dense. (Glacial Till)	42 52		
11.0		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 2 1/2 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 8/6/08 11:31

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BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B16** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
8.0	ML	SILT with Sand, brownish gray, moist to wet, very loose. (Lacustrine)	2		
			4		
			5		qp=1 1/4 tsf
11.0	CL	SANDY LEAN CLAY, gray, wet, rather soft. (Lacustrine)	4		qp=1 tsf
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN℠ INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B17** LOCATION: See sketch.
DRILLER: L. Raatsi — METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08 — SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
11.0	ML	SILT with Sand, brownish gray, moist, very loose to loose. (Lacustrine)	4 4 6 8		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

HB-08-01075 Braun Intertec Corporation B17 page 1 of 1

BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B18** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen. (Swamp Deposit)			
11.0	ML	SILT with Sand, brownish gray, moist to wet, very loose. (Lacustrine)	2 4 4 3		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 4 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B19** LOCATION: See sketch.
DRILLER: L. Raatsi / METHOD: 3 1/4" HSA, Autohammer	DATE: 4/22/08 / SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
11.0	ML	SILT with Sand, brownish gray, moist to wet, very loose to loose. (Lacustrine)	4 4 5 6		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 8/6/08 11:31

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BRAUN INTERTEC — **LOG OF BORING**

Braun Project HB-08-01075
Subsurface Investigation
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota

BORING: B20
LOCATION: See sketch.

DRILLER: L. Raatsi | METHOD: 3 1/4" HSA, Autohammer | DATE: 4/24/08 | SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
11.0	ML	SILT with Sand, brownish gray, moist to wet, very loose to loose. (Lacustrine)	4 4 5 4		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN™ INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B21** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/24/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
11.0	ML	SILT with Sand, brownish gray, moist to wet, very loose. (Lacustrine)	2 4 4 3		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 1/2 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

HB-08-01075 Braun Intertec Corporation B21 page 1 of 1

BRAUN INTERTEC — LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B22** LOCATION: See sketch.
DRILLER: L. Raatsi — METHOD: 3 1/4" HSA, Autohammer	DATE: 4/24/08 — SCALE: 1" = 4'

Depth feet	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
0.0–1.0	PT	PEAT, fibrous, black, frozen. (Swamp Deposit)			
1.0–12.0	ML	SILT with Sand, grayish brown, frozen to moist to wet, very loose to loose. (Lacustrine)	4 3* 5 5		*MC=25% DD=82 pcf LL=40 PL=35 PI=5 %Sand=28 %Silt=58 %Clay=14
12.0–21.0	ML	SANDY SILT, gray, moist to wet, soft to rather soft. (Lacustrine)	3 4* 4		*MC=28% DD=87 pcf LL=38 PL=34 PI=4 %Sand=32 %Silt=52 %Clay=16
21.0		END OF BORING Water not observed while drilling. Water not observed with 19 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 6 1/2 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075
Subsurface Investigation
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota

BORING: **B23**
LOCATION: See sketch.

DRILLER: L. Raatsi | METHOD: 3 1/4" HSA, Autohammer | DATE: 4/23/08 | SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen. (Swamp Deposit)			
8.0	ML	SILT with Sand, brownish gray, frozen to moist to wet, very loose. (Lacustrine)	2 3 4		
11.0	SM	SILTY SAND, fine- to medium-grained, gray, wet, very loose. (Glacial Till)	4		

END OF BORING

Water not observed while drilling.

Water not observed with 9 1/2 feet of hollow-stem auger in the ground.

Water not observed to cave-in depth of 3 1/2 feet immediately after withdrawal of auger.

Boring immediately backfilled.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN INTERTEC — LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B25** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/22/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
11.0	ML	SILT with Sand, brownish gray, moist to wet, very loose. (Lacustrine)	3 4 4 4		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN℠
INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota		BORING: B29 LOCATION: See sketch.	
DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
1.5	PT	PEAT, fibrous, black, frozen. (Swamp Deposit)			
11.0	ML	SILT with Sand, brownish gray, frozen to moist to wet, very loose to loose. (Lacustrine)	4 7 4 4		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: B33 LOCATION: See sketch.
DRILLER: L. Raatsi METHOD: 3 1/4" HSA, Autohammer	DATE: 4/22/08 SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
3.5	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)	2		
11.0	ML	SILT with Sand, brownish gray, moist to wet, very loose to loose. (Lacustrine)	1 5 4		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 4 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/6/08 11:31

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BRAUN℠
INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B34** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/24/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
	PT	PEAT, fibrous, black, frozen to wet, very loose. (Swamp Deposit)	2		
6.0			1		
	ML	SILT with Sand, gray to brownish gray, moist to wet, very loose to loose. (Lacustrine)	4		
11.0			5		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/9/08 11:31

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BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota		BORING: B37 LOCATION: See sketch.	
DRILLER: L Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/23/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
1.5	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
11.0	ML	SILT with Sand, brownish gray, moist to wet, very loose. (Lacustrine)	3 4 4 4		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 4 1/2 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 8/6/08 11:31

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BRAUN[SM]
INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: B4 LOCATION: See sketch.
DRILLER: L. Raatsi — METHOD: 3 1/4" HSA, Autohammer	DATE: 4/24/08 — SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
7.0	CL-ML	SILTY CLAY, brownish gray, moist to wet, soft. (Lacustrine)	3 2		
11.0	SM	SILTY SAND, fine- to medium-grained, brown, moist to wet, loose to very loose. (Glacial Till)	9 4		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 4 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 6/5/08 11:31

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BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: B40 LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/22/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
7.0	ML	SANDY SILT, brownish gray, moist to wet, loose. (Lacustrine)	10 10		
21.0	ML	SILT with Sand, brownish gray to gray, moist to wet, loose to very loose. (Lacustrine)	5 5 1 4 2		
		END OF BORING Water not observed while drilling. Water not observed with 19 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 11 1/2 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 5/5/08 11:31

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BRAUN INTERTEC — **LOG OF BORING**

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B44** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/22/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
1.5	PT	PEAT, fibrous, black, frozen to wet. (Swamp Deposit)			
7.0	CL	LEAN CLAY with Sand, brownish gray, moist to wet, rather soft. (Lacustrine)	4		qp=1 3/4 tsf
			4		qp=1 1/4 tsf
11.0	ML	SILT with Sand, grayish brown, moist to wet, very dense. (Lacustrine)	4		
			4		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 2 1/2 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 8/6/08 11:31

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BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: **B46** LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/22/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
1.5	PT	PEAT, fibrous, black, frozen. (Swamp Deposit)			
7.0	CL	LEAN CLAY with Sand, grayish brown, moist, medium. (Lacustrine)	8		qp=2 tsf
			6*		*MC=37% DD=75 pcf LL=34 PI=15 %Sand=21 %Silt=38 %Clay=41 qp=1 1/2 tsf
19.0	ML	SILT with Sand, grayish brown, moist to wet, loose to very loose. (Lacustrine)	6		
			4		
			4		
			3*		*MC=11% DD=125 pcf LL=41 PL=34 PI=7 %Sand=14 %Silt=69 %Clay=17
21.0	SM	SILTY SAND, fine- to medium-grained, trace of Gravel and a few Cobbles, brown, wet, dense. (Glacial Till)	38		
		END OF BORING Water not observed while drilling. Water not observed with 19 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 11 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 5/6/08 11:31

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BRAUN INTERTEC

LOG OF BORING

Braun Project HB-08-01075 Subsurface Investigation Norland Impoundment Roseau River Watershed District Northeast of Roseau, Minnesota	BORING: B47 LOCATION: See sketch.

DRILLER: L. Raatsi	METHOD: 3 1/4" HSA, Autohammer	DATE: 4/24/08	SCALE: 1" = 4'

Depth feet 0.0	ASTM Symbol	Description of Materials (ASTM D2488 or D2487)	BPF	WL	Tests or Notes
2.0	PT	PEAT, fibrous, black, frozen. (Swamp Deposit)			
4.0	CL	LEAN CLAY with Sand, brownish gray, moist to wet, soft. (Lacustrine)	2		qp=1/2 tsf
11.0	ML	SILT with Sand, grayish brown, moist to wet, very loose to loose. (Lacustrine)	4 7 6		
		END OF BORING Water not observed while drilling. Water not observed with 9 1/2 feet of hollow-stem auger in the ground. Water not observed to cave-in depth of 3 feet immediately after withdrawal of auger. Boring immediately backfilled.			

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING 01075.GPJ BRAUN.GDT 8/6/08 11:31

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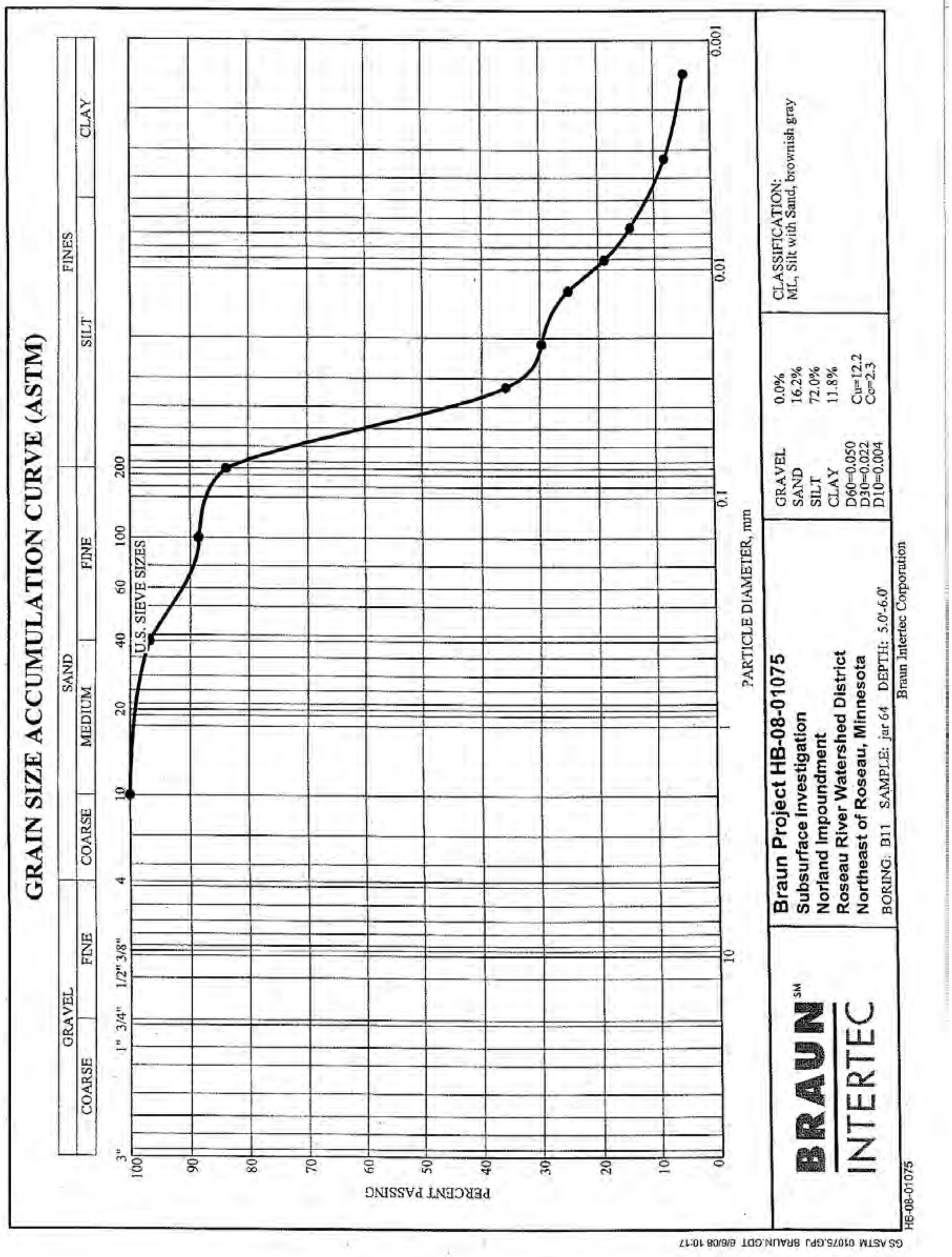
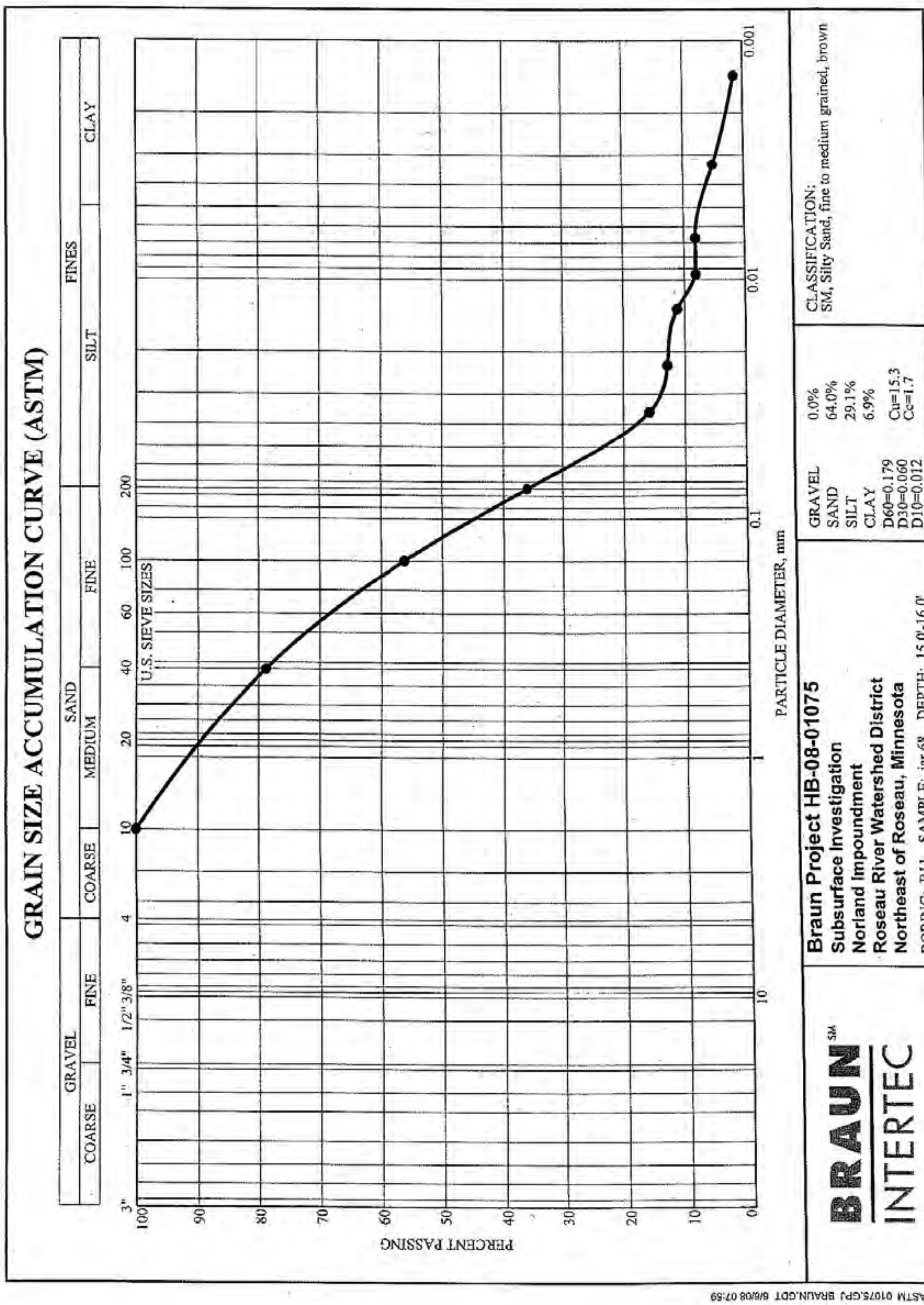
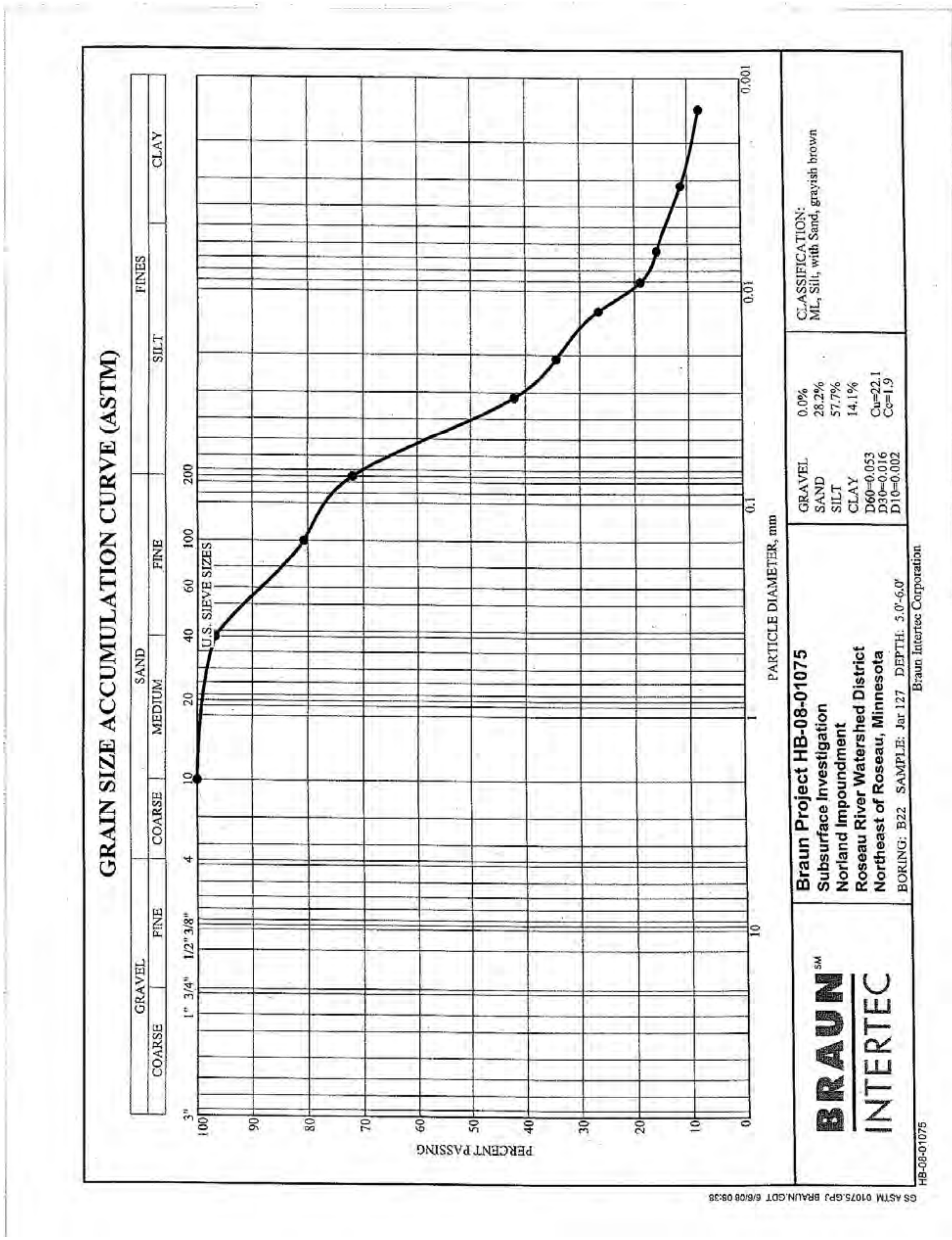
SUMMARY OF LABORATORY TESTS

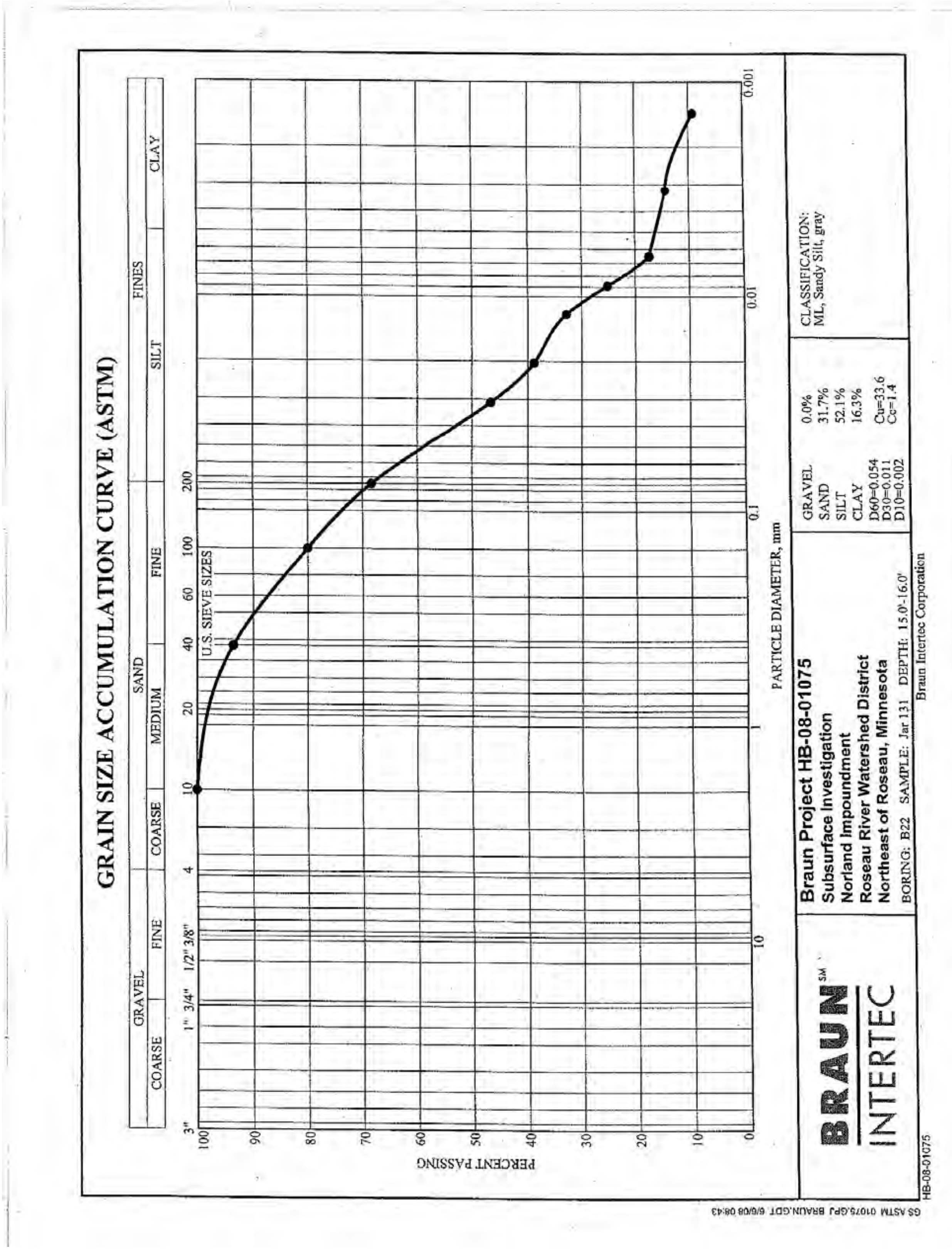
BRAUN PROJECT HB-08-01075
SUBSURFACE INVESTIGATION
PROPOSED IMPROVEMENTS
NORLAND IMPOUNDMENT
ROSEAU RIVER WATERSHED DISTRICT
NORTHEAST OF ROSEAU, MINNESOTA

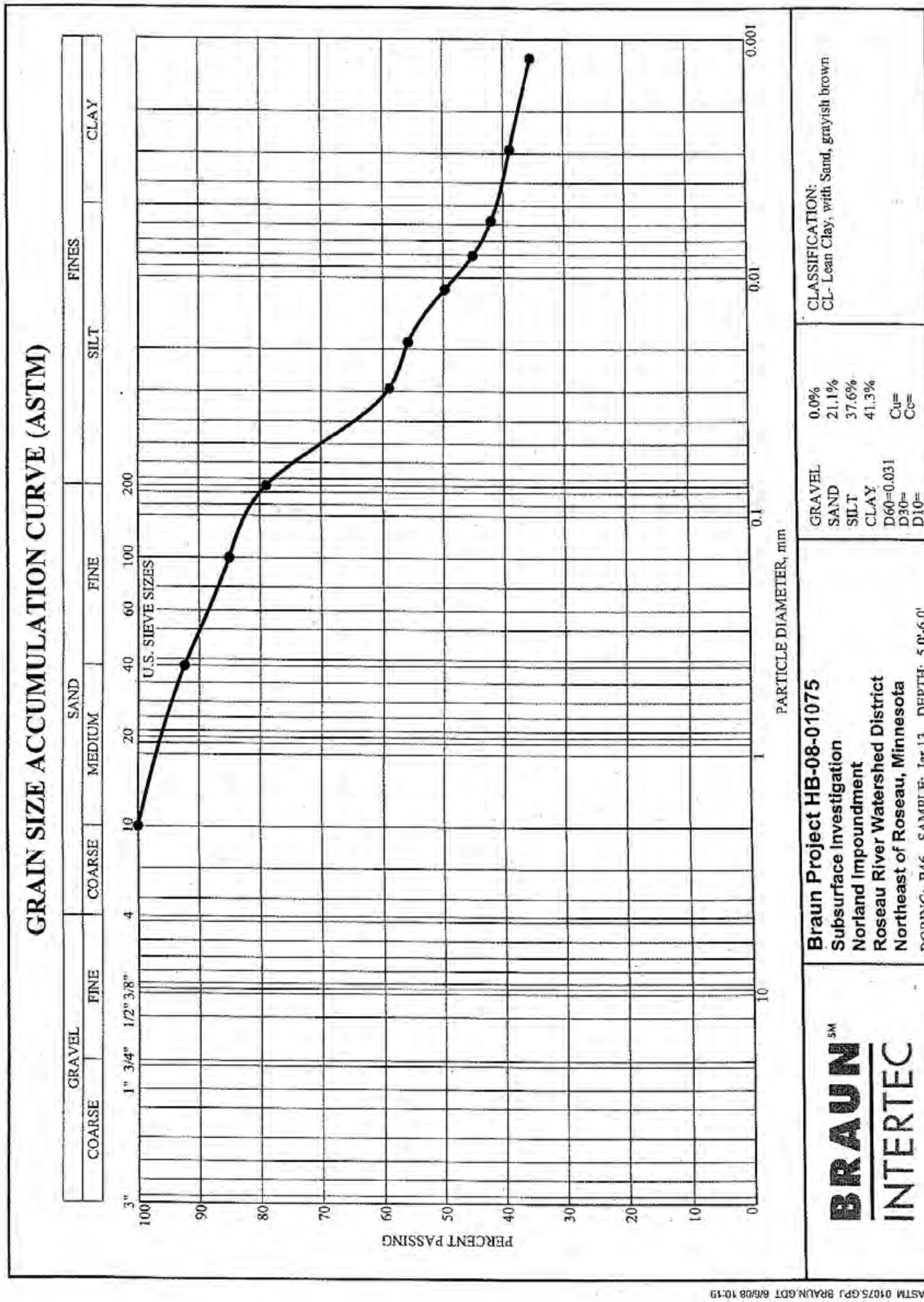
Boring	Sample Depth	Water Content (%)	Dry Density (pcf)	Atterberg Limits			Hydrometer Analysis			Unified Soil Classification	Unconfined Compression, Qp (tsf)
				LL	PL	PI	%Sand	%Silt	%Clay		
B5	5-6'			26	20	6				CL-ML Silty Clay	1 1/2
B11	5-6'	20	94	34	29	5	16	72	12	ML Silt with Sand	
B11	15-16'	31	78	20	18	2	64	29	7	SM Silty Sand	
B22	5-6'	25	82	40	35	5	28	58	14	ML Silt with Sand	
B22	15-16'	28	87	38	34	4	32	52	16	ML Sandy Silt	
B46	5-6'	37	75	34	15	19	21	38	41	CL Lean Clay with Sand	1 1/2
B46	15-16'	11	125	41	34	7	13	69	18	ML Silt with Sand	


GRAIN SIZE ACCUMULATION CURVE (ASTM)
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
FINES
SILT
CLAY
3"
1"
3/4"
1/2"
3/8"
4
10
20
40
60
100
200
U.S. SIEVE SIZES
PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
10
1
0.1
0.01
0.001
PARTICLE DIAMETER, mm
Braun Project HB-08-01075
Subsurface Investigation
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota
BORING: B11 SAMPLE: jar 64 DEPTH: 5.0'-6.0'
Braun Intertec Corporation
GRAVEL 0.0%
SAND 16.2%
SILT 72.0%
CLAY 11.8%
D60=0.050
D30=0.022
D10=0.004
Cu=12.2
Cc=2.3
CLASSIFICATION:
ML, Silt with Sand, brownish gray
BRAUN INTERTEC
HB-08-01075
GS ASTM 01075.GPJ BRAUN.GDT 6/6/08 10:17


GRAIN SIZE ACCUMULATION CURVE (ASTM)
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
FINES
SILT
CLAY
3" 1" 3/4" 1/2" 3/8" 4 10 20 40 60 100 200
U.S. SIEVE SIZES
PERCENT PASSING
100 90 80 70 60 50 40 30 20 10 0
10 1 0.1 0.01 0.001
PARTICLE DIAMETER, mm
GRAVEL 0.0%
SAND 64.0%
SILT 29.1%
CLAY 6.9%
D60=0.179 Cu=15.3
D30=0.060 Cc=1.7
D10=0.012
CLASSIFICATION:
SM, Silty Sand, fine to medium grained, brown
BRAUN INTERTEC
Braun Project HB-08-01075
Subsurface Investigation
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota
BORING: B11 SAMPLE: jar 68 DEPTH: 15.0'-16.0'
Braun Intertec Corporation
HB-08-01075
GS ASTM 01075.GPJ BRAUN.GDT 6/6/08 07:59


GRAIN SIZE ACCUMULATION CURVE (ASTM)
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
FINES
SILT
CLAY
3"
1"
3/4"
1/2" 3/8"
4
10
20
40
60
100
200
U.S. SIEVE SIZES
PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
10
1
0.1
0.01
0.001
PARTICLE DIAMETER, mm
GRAVEL 0.0%
SAND 28.2%
SILT 57.7%
CLAY 14.1%
D60=0.053 Cu=22.1
D30=0.016 Cc=1.9
D10=0.002
CLASSIFICATION:
ML, Silt, with Sand, grayish brown
BRAUN INTERTEC
Braun Project HB-08-01075
Subsurface Investigation
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota
BORING: B22 SAMPLE: Jar 127 DEPTH: 5.0'-6.0'
Braun Intertec Corporation
HB-08-01075
GS ASTM 01075.GPJ BRAUN.GDT 6/6/08 08:38


GRAIN SIZE ACCUMULATION CURVE (ASTM)
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
FINES
SILT
CLAY
3" 1" 3/4" 1/2" 3/8" 4 10 20 40 60 100 200
U.S. SIEVE SIZES
PERCENT PASSING
100 90 80 70 60 50 40 30 20 10 0
10 1 0.1 0.01 0.001
PARTICLE DIAMETER, mm
BRAUN INTERTEC
Braun Project HB-08-01075
Subsurface Investigation
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota
BORING: B22 SAMPLE: Jar 131 DEPTH: 15.0'-16.0'
Braun Intertec Corporation
GRAVEL 0.0%
SAND 31.7%
SILT 52.1%
CLAY 16.3%
D60=0.054 Cu=33.6
D30=0.011 Cc=1.4
D10=0.002
CLASSIFICATION:
ML, Sandy Silt, gray
HB-08-01075
GS ASTM 01075.GPJ BRAUN.GDT 6/6/08 08:43


GRAIN SIZE ACCUMULATION CURVE (ASTM)
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
FINES
SILT
CLAY
3" 1" 3/4" 1/2" 3/8" 4 10 20 40 60 100 200
U.S. SIEVE SIZES
PERCENT PASSING
PARTICLE DIAMETER, mm
10
1
0.1
0.01
0.001
GRAVEL 0.0%
SAND 21.1%
SILT 37.6%
CLAY 41.3%
D60=0.031
D30=
D10=
Cu=
Cc=
CLASSIFICATION:
CL- Lean Clay, with Sand, grayish brown
BRAUN INTERTEC
Braun Project HB-08-01075
Subsurface Investigation
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota
BORING: B46 SAMPLE: Jar 13 DEPTH: 5.0'-6.0'
Braun Intertec Corporation
HB-08-01075
GS ASTM 01075.GPJ BRAUN.GDT 6/6/08 10:19

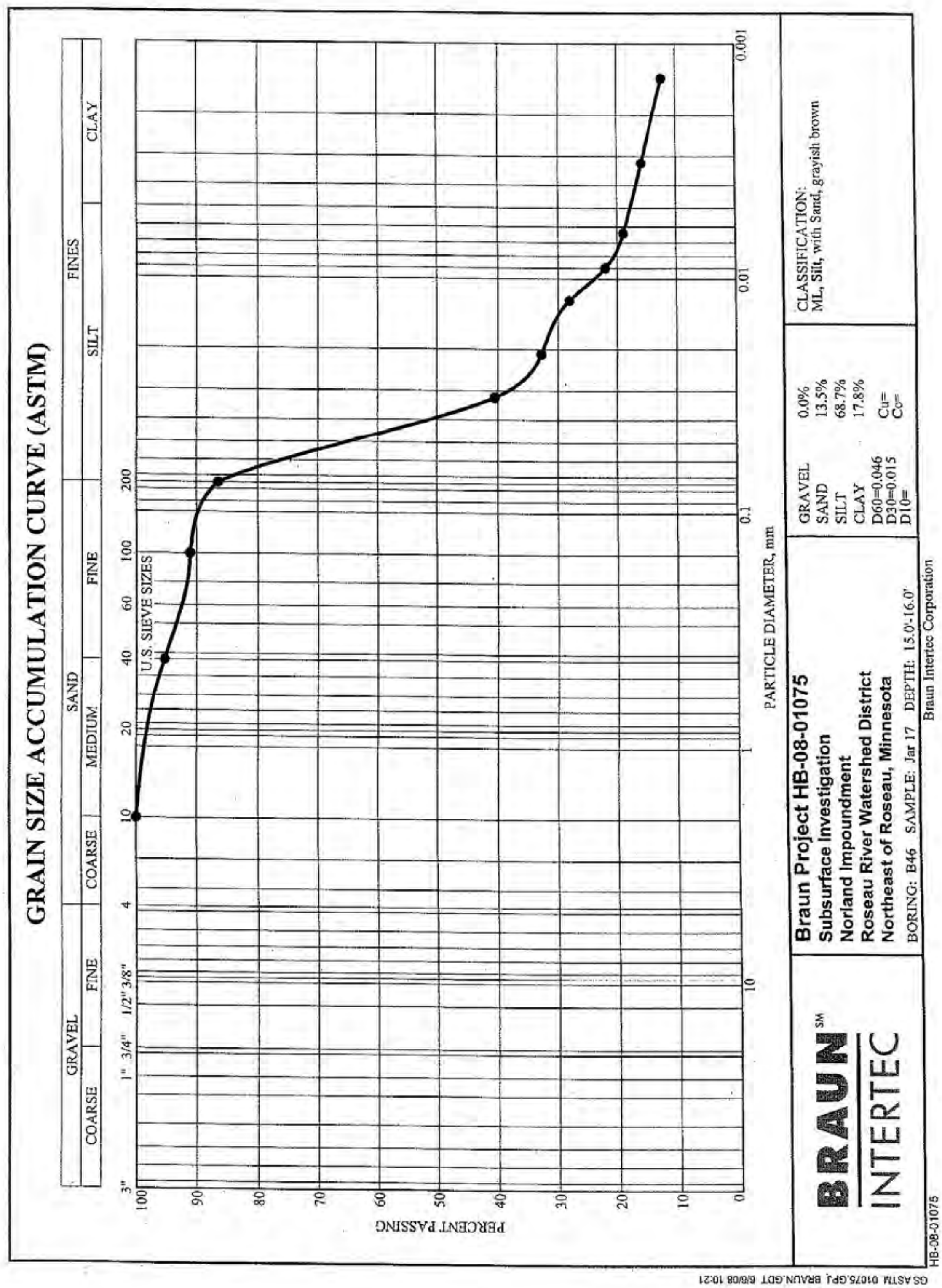

GRAIN SIZE ACCUMULATION CURVE (ASTM)
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
FINES
SILT
CLAY
3" 1" 3/4" 1/2" 3/8" 4 10 20 40 60 100 200
U.S. SIEVE SIZES
PERCENT PASSING
PARTICLE DIAMETER, mm
Braun Project HB-08-01075
Subsurface Investigation
Norland Impoundment
Roseau River Watershed District
Northeast of Roseau, Minnesota
BORING: B46 SAMPLE: Jar 17 DEPTH: 15.0'-16.0'
Braun Intertec Corporation
GRAVEL 0.0%
SAND 13.5%
SILT 68.7%
CLAY 17.8%
D60=0.046
D30=0.015
D10=
Cu=
Cc=
CLASSIFICATION:
ML, Silt, with Sand, grayish brown
BRAUN INTERTEC
HB-08-01075

Plate 11

HDR | ONE COMPANY *Many Solutions*®

Technical Memo

To:	Nathan P. Dalager, P.E., HDR		
From:	Douglas M. Voegele, P.E., HDR	Project:	Norland Impoundment Roseau, Minnesota
CC:	File		
Date:	August 18, 2008	Job No:	54803

RE: Geotechnical Evaluation of the Proposed Norland Impoundment

I. Introduction

This technical memorandum presents the results of the geotechnical analyses and engineering evaluation of the proposed Norland Impoundment near Roseau, Minnesota. The purpose of this work is to provide geotechnical design recommendations for the proposed earthen dam, as well as construction recommendations based on the encountered subsurface conditions at the project site.

This memorandum presents findings, conclusions and recommendations regarding:

- Subsurface soil and groundwater conditions;
- Evaluation of the engineering characteristics of the embankment and foundation soils
- Evaluation of the slope stability of the embankment and foundation soils;
- Estimation of settlements of the embankment crest;
- Evaluation of foundation underseepage and embankment seepage; and
- Recommendations for construction.

II. Project Description

The Norland Impoundment is part of larger flood control project proposed for the Hay Creek and Norland watersheds in Roseau County, Minnesota. The project site is located approximately 3 miles northeast of the City of Roseau, upon the relatively flat, ancestral bed of glacial Lake Agassiz. The purpose of this project is to provide flood damage reduction with respect to stream flow from the Hay Creek and Norland drainage areas in order to help reduce the frequency and severity of flooding on the nearby Roseau River. The Norland Impoundment will enclose approximately 3200 acres within an earthen embankment stretching approximately 10 miles in length, creating in turn controlled storage for nearly 10,300 acre-feet of floodwater.

Figure 1 illustrates the proposed embankment cross section for the impoundment based upon HDR's Preliminary Engineer's Report, dated November 8, 2007. From the description provided in the report, the top of the proposed embankment will be at elevation 1057 feet with embankment slopes of 4:1 on the dry side and 5:1 on the wet side. A proposed drainage channel having an 8-foot wide bottom with 3:1 side slopes will be located along the exterior of the impoundment. The 12-foot offset located next to the drainage channel is reserved for construction of a maintenance road to allow access to the channel or exterior embankment slope. A second maintenance road will be constructed on the crest of the embankment.

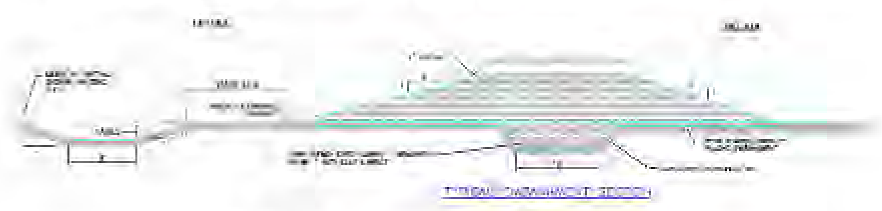


Figure 1 – Typical Embankment Section

HDR Engineering, Inc. | 9987 Carver Road, Suite 200, Cincinnati, Ohio 45242 | Phone (513) 984-7500, Fax (513) 984-7580, www.hdrinc.com | Page 1 of 7

III. Subsurface Exploration

An initial subsurface exploration at the project site was conducted by the U.S. Army Corps of Engineers; St. Paul District (USACE) in December 2000 as part of the Hay Creek Environmental Rehabilitation Project. This initial exploration program consisted of ten borings, designated as 00-1M through 00-10M, that were performed to determine the thickness and distribution of organic deposits and the foundation conditions at the site. The borings ranged in depth from 7 to 35 feet below the existing ground surface, with the target depth being the underlying glacial drift at the site. A copy of the graphical borings logs are presented in the *Hay Creek Section 206 Study, Appendix G – Geotechnical Analysis* as prepared by the USACE.

As shown on the attached boring location plan, the USACE test borings were located in the western portion of the site, with only three borings (00-6M, 00-7M, 00-8M) located within the proposed footprint of the impoundment. As such, an additional 26 test borings were performed by Braun Intertec, Inc., of Hibbing, Minnesota as authorized by the Roseau River Watershed District to supplement the existing subsurface information at the site. The depth of these supplemental borings ranged from 11 to 21 feet below the ground surface, with copies of the test boring logs provided in the *Subsurface Investigation Report* prepared by Braun Intertec for the Roseau River Watershed District (report dated June 6, 2008).

IV. Laboratory Testing

Soil index testing was performed by both the USACE and Braun Intertec on select soil samples collected during their respective subsurface exploration programs to substantiate the visual soil classifications made in the field. The results of these tests are presented in their individual reports previously listed in this document.

V. Site Conditions

From our review of the test borings logs, the foundation soils present at the project site primarily consist of glacio-lacustrine deposits overlying glacial till to the maximum depths explored at the site. In addition, peat deposits were encountered at or just below ground surface across the entire the site. This overlying layer of highly compressible peat ranges from approximately 1 to 6 feet in thickness, and was noted to have poor engineering properties in the USACE report.

Below the peat, a 5 to 22-foot thick layer of lean to highly plastic clays and silts was encountered. These soils consist primarily of shallow lake bottom sediments, most of which are believed to have been derived from the underlying glacial till. As such, changes between the various strata at the site are considered approximate and likely vary between the borings as a result of fluctuating glacial lake levels. Glacial till consisting of loose to very dense silty sand was encountered below the lacustrine deposits.

A summary of the soil index properties for the foundation soils encountered at the project site is provided in Table 1.

Table 1 - Pertinent Properties of Embankment Fill and Foundation Soils

Property	Peat	Lacustrine (CL, ML)	Lacustrine (CH, OH)	Glacial Till (SM)
Moisture Content (%)	170 to 284	11 to 43	31 to 67	31
Dry Density (pcf)	-	75 to 125	-	78
Liquid Limit (LL)	25 to 94	26 to 44	67 to 103	12 to 20
Plasticity Index (PI)	41	4 to 29	30 to 77	0.2 to 2.0
SPT Blowcount (bpf)	2 to 3	2 to 10	2 to 4	4 to 70

Groundwater was not observed during drilling and sampling in the 2008 test borings performed at the site. However, water levels ranging from 2.5 to 5.3 feet below the ground surface (El 1044.7 to El 1050.5) were observed during drilling of the test borings at the site by the USACE in 2000.

VI. Engineering Evaluations

A. Slope Stability Analyses

Slope stability analyses were performed at two critical embankment sections based on the estimated height of embankment and the encountered subsurface conditions at the site. From review of the test borings at the site as well as the existing topography, these critical locations were determined to be at the northwest corner of the impoundment, near boring 00-8M, and at the southwest corner of the impoundment, near boring 00-6M.

Based on the existing topography and a crest elevation of 1057 feet, the embankment height was estimated at 7 feet. The embankment geometry was based on that provided in the 2007 Preliminary Engineer's Report. (See Figure 1.)

The adopted design strengths for the various soil materials at the site are presented in Table 2. These parameters were developed for the slope stability analyses based on the laboratory testing performed by the USACE (2000) and Braun Intertec (2008), from past USACE project is the Red River basin, published correlations with SPT data and plasticity indices (NAVFAC, 1982), (EM 1110-1-1904, 1990), (EM 1110-2-1913, 2000), and our engineering experience and judgment. Please note that it was assumed that the embankment fill will consist of the native soils encountered at the project site, exclusive of any highly organic material (peat) that overlies the site.

Table 2 - Adopted Shear Strengths

Material	Unit Weight γ_{total}	UU Strengths		CD Strengths	
		c	Φ	c'	Φ'
	(pcf)	(psf)	(degrees)	(psf)	(degrees)
Random Fill	115	1000	0	200	28
OH/PT (Lacustrine)	98	250	0	0	20
ML/CL/CH (Lacustrine)	102	400	0	0	23
SM (Till)	120	0	32	0	32

where: c, c' = total and effective cohesion or undrained shear strength, and
Φ, Φ' = total and effective angle of internal friction

The slope stability analyses were performed using the software package GSTABL7 with STEDwin. This program is a Windows version of the computer program STABL as developed by Purdue University through the support of the Indiana State Highway Commission. The program's capacity to analyze circular failure surfaces using the Modified Bishop's Method of Slices was used in these analyses. The minimum target factors of safety used in the analyses were based on USACE requirements for Stability of Earth and Rockfill Dams (EM 1110-2-1902) as provided in Table 3 below.

Table 3 – Minimum Required Factors of Safety

Case	Loading Case	Minimum FS
I	End of Construction	1.3
II	Rapid Drawdown	1.5
III	Steady Seepage	1.3
IV	Steady Seepage (a=0.045g)[1] w/Seismic	1.1

(1.) Source: USGS Seismic Hazard http://earthquake.usgs.gov/research/hazmaps/

For the seismic case, a horizontal earthquake acceleration of 0.45g was selected in accordance with USGS Seismic Hazard mapping, which represents the maximum design earthquake (MDE) that corresponds to the value of ground acceleration with a 90% probability of not being exceeded in 50 years. The vertical acceleration at the site was assumed to be 0g.

The minimum factors of safety calculated for each section under the various loading conditions are presented in Table 4. The analyses indicate that the proposed embankment section exceeds the minimum requirements for each loading case. However, it should be noted that these analyses assumed that the overlying peat has been removed from beneath the embankment (with the undercut extending a minimum of 5 feet outside the proposed footprint of the embankment) and replaced with suitable fill material. Stability analyses performed for the proposed embankment with an intact underlying peat layer did not meet the required minimum target factors of safety.

Table 4 - Calculated Minimum Factors of Safety

	Boring No.	Case	Minimum FS
Northwest Corner of Impoundment	00-6M	I	2.79
		II	1.58
		III	1.58
		IV	1.26
Southwest Corner of Impoundment	00-8M	I	2.03
		II	1.56
		III	1.56
		IV	1.25

B. Settlement Analyses

Settlement analyses were performed to estimate the magnitude of settlement of the levee crest due to compression of the foundation soils under the weight of the new embankment fill. A summary of the consolidation properties of the foundation soils as determined from published correlations as well as our engineering experience and judgment are presented in Table 5.

Table 5 - Consolidation Properties

Material	C_c	C_v (ft²/day)	OCR
Lacustrine	0.22	0.20	1.5
Glacial Till	0.09	0.65	2.0 - 4.0

Settlement analyses were performed using the subsurface information collected from borings 00-6M, 00-8M, B-5 and B-46 as these borings were noted to have relatively thick layers of compressible, lacustrine soils. As shown in Table 6, the lacustrine soils were noted to range from 15 to 24 feet at these locations. The underlying glacial till was assumed to be incompressible, and overlying peat was assumed to be completely removed prior to fill placement. The settlement analyses were performed using variable embankment heights and width as the size of the embankment will vary depending upon the elevation of the existing ground.

The predicted settlements as a result of primary consolidation over the range of selected embankment heights are summarized in Table 6. It should be noted that the highly compressible peat underlying the embankment was assumed to be completely undercut for these analyses as described in Section 6.A of this report.

Table 6 - Predicted Consolidation Settlement

Location	Boring No.	Lacustrine Thickness (feet)	Embankment Height (feet)	Predicted Settlement (inches)
Northwest	00-8M	16	3	4.0
			5	6.3
			7	8.3
Southwest	00-6M	24	3	3.7
			5	7.0
			7	10.9
Northeast	B – 5	15	3	2.3
			5	5.4
			7	7.8
Southeast	B - 46	19	3	3.6
			5	7.6
			7	11.4

The time-rate of settlement of the foundation soils under the embankment loading at the site was estimated based on correlations obtained from EM 1110-2-1913 and past experience with these materials. Due to the fine-grained nature of the foundation soils, the time required for consolidation to occur will be fairly long, on the order of 2 years or more. Therefore, the majority of the settlement of the crest of the levee will occur after the fill is placed.

D. Seepage Through the Embankment and Foundation

As the lacustrine deposits at the site vary in thickness, underseepage analyses were performed using a critical section along the west embankment near Boring 00-7M where the lacustrine soils were a minimum of five feet in thickness. The analyses modeled a semi-impervious layer of lacustrine material, primarily composed of silts and clays (ML, CH), overlying a more pervious, very thick section of glacial till composed of silty sand (SM). Permeability values (k) of $1.15x10^{-5}$ and $2.0x10^{-4}$ ft/day were used for the lacustrine and glacial till stratum, respectively, as determined by USACE "Investigation of Underseepage and its Control Lower Mississippi River Levees (No. 3-424)". The water level within the impoundment was assumed to be at El 1055 (2 feet below the top of the embankment) for the analyses.

The underseepage analyses were completed using the finite element computer program UKSEEP. This program was developed at the University of Kentucky (2008) and calculates equipotential lines and head drops for the flow of water through a layered porous material. Based on this data, estimates of the gradient, i, can be calculated at any point within the subsurface profile.

Exit gradients in excess of certain values can indicate a potential for excessive foundation underseepage and uplift pressures acting on the lacustrine soils that serve as a natural blanket providing underseepage resistance at the site. The impact of excessive underseepage and uplift can result in the development of sand boils and even piping failure of the embankment.

The results of the underseepage analyses revealed a critical upward seepage gradient of less than 0.2 at the landside toe of the embankment. As a maximum upward seepage gradient of 0.5 at the landside toe is specified by the USACE in EM-1110-2-1913, the embankment is considered stable in regards to underseepage.

As the embankment soils are expected to be composed primarily of CL and CH material with a Plasticity Index (PI) > 15, and CL and ML soils with a PI < 15 to a lesser extent, the embankment is expected to have intermediate to high resistance to piping and cracking based on guidance provided by the Naval Facilities Engineering Command (NAVFAC, 1986). Therefore, the potential for the development of seepage through the levee and exiting on the landward face is considered negligible.

VII. Findings and Recommendations

A. Summary of Findings

Based on our understanding of the proposed project and our geotechnical engineering evaluations, a stable embankment utilizing select on-site soils can be constructed for the Norland Impoundment provided that the overlying peat at the site has been completely removed from beneath the footprint of the embankment. The peat encountered at the project site is described as fibrous and consisting of slightly decomposed plant fragments and roots. In addition, the peat deposits are relatively weak with little shear strength ($c = 250$ psf, $\varphi = 0^{\circ}$) and are considered to be highly compressible. Slope stability analyses performed with an intact peat layer underlying the embankment resulted in calculated factors of safety less than the required target safety factors. As such, the peat should be completely undercut and replaced with suitable fill material. The results of the stability, settlement and underseepage analyses with the recommended undercut and replacement indicate that the proposed embankment geometry as shown in Figure 1 meets or exceeds the target USACE requirements for several worst case or critical locations based on the existing topography and/or subsurface information at the site.

B. Recommendations for Construction

1. Foundation Preparation

The project site is overlain with highly compressible peat varying from approximately 12 inches to 6 feet in depth. Experience has shown that settlement for embankments bearing upon organic soils is a long term phenomenon and that this subsidence is inherently uneven. In addition, the overlying peat deposits are relatively weak with little shear strength. As such, it is recommended that the peat be completely undercut and replaced with suitable fill material. The limits of the overexcavation should extend a minimum of 5 feet past the toe of the embankment with the side slopes of the overexcavation inclined at 2:1 or flatter.

2. Earthwork and Compaction Requirements

Prior to general fill placement, all topsoil and peat should be removed from areas to receive fill. The stripped areas should extend a minimum of five feet beyond the construction areas, and any stripped material removed from the fill areas. The existing topsoil and peat should not be used as embankment fill as these materials are difficult to compact, exhibit low relative strength, are prone to shrinkage and cracking upon drying, and can be highly permeable. However, these materials can be stockpiled for future use on the final embankment surface to promote vegetative growth.

The exposed surface shall be scarified and mixed with the first lift of fill. All fill will be placed in 6 to 9-inch loose lifts and compacted to at least 98% of the maximum dry density as determined by ASTM D 698-91 (Standard Proctor test) within a corresponding 0 to +4% of the optimum water content as determined by the referenced test. Frequent in-place density tests should be performed to ensure adequate compaction is achieved.

The silts (ML), lean clay (CL) and possibly fat clay (CH) soils encountered at the site appear to be suitable for use as embankment fill, provided these materials are relatively free of topsoil, organics, vegetation and any other deleterious materials. Any materials that potentially be used as embankment fill should be tested in a laboratory prior to their use in order to verify their suitability for use as fill material and to determine their compaction characteristics. It is recommended that the borrow material meet the following requirements:

- CL or CH soils - Liquid Limit (LL) less than 50
- Plasticity Index (PI) greater than 15
- Percent clay greater than 25

It is recommended that any CH soils not be placed in the outer 3 feet of the embankment fill. Also, when using cohesive soils, proper moisture control should be exercised to achieve proper compaction and a soil structure resistant to excess moisture loss and cracking.

3. Embankment Overbuild

In order to maintain adequate freeboard for the crest of the earthen dam, the embankment should be overbuilt a total of 12 inches above the required profile grades to account for any long-term settlement of the foundation soils. The actual amount of overbuild will vary depending on the height of the embankment section (see Table 5).

VIII. Limitations

This memorandum presents the findings, conclusions and recommendations for the geotechnical aspects of the engineering evaluations of the proposed modifications of the Norland Impoundment, located just northeast of Roseau, Minnesota. It has been prepared in accordance with generally accepted engineering practice and in a manner consistent with the level of care and skill for this type of project within this geographical area. No warranty, expressed or implied, is made.

The conclusions and recommendations presented herein are based on research and available literature, the results of the field exploration and laboratory materials testing performed by others, and the results of engineering analyses.

Geotechnical engineering and the geologic sciences are characterized by uncertainty. Professional judgments presented herein are based partly on our understanding of the proposed construction, partly on our general experience and the state-of-the-practice at the time of this writing.

IX. References

Braun Intertec, Inc., "Subsurface Investigation Proposed Improvements, Norland Impoundment, Roseau River Watershed District, Northeast of Roseau, Minnesota", dated June 6, 2008.

HDR Engineering, Inc., "Hay Creek Setback Levees and Norland Impoundment Preliminary Engineer's Report (Draft)", dated November 8, 2007.

Naval Facilities Engineering Command (NAVFAC), Foundations & Earth Structures, Design Manual 7.02, Revalidated by Change 1, September 1986.

U.S. Army Corps of Engineers, Design and Construction of Levees, EM 1110-2-1913, Department of the Army, Corps of Engineers, April 30, 2000.

U.S. Army Corps of Engineers, Investigation of Underseepage and its Control Lower Mississippi River Levees (No. 3-424), October 1956.

U.S. Army Corps of Engineers, Slope Stability, EM 1110-2-1902, Department of the Army, Corps of Engineers, October 31, 2003.

U.S. Army Corps of Engineers – St. Paul District, Hay Creek Environmental Rehabilitation Project, Roseau County, Minnesota, Ecosystem Restoration Report/Environmental Assessment, March 2002.

U.S. Army Corps of Engineers – St. Paul District, "Hay Creek Section 206 Study, Appendix G – Geotechnical Analysis", undated