ORIGINAL

RETURN To The
DEVILS LAKE BASIN JOINT
WATER RESOURCE BOARD
524 4th Avenue, #27
Devils Lake, ND 58301

# Mississippi Valley Division
# Devils Lake Division/District (Tiger) Team
# Technical Report

Report
To
Division Commander
Mississippi Valley Division

June 1999

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# Executive Summary

As a result of a 4 May 1999, discussion between the North Dakota Congressional delegation, Generals Fuhrman and Anderson, and Assistant Secretary of the Army for Civil works, Dr. Westphal, General Anderson authorized a team to determine if there are decision points and associated action plans at which an emergency outlet and other features of work would be warranted in the Devils Lake Basin. These determinations are to be made part of the technical report being prepared for submission to Congress.

The team investigated conservative scenarios and plans of action to address the potential impacts of those scenarios. As a base to which to compare the proposed actions, the Lake was presumed to fill to its point of natural overflow into the Sheyenne River (elevation 1459). With the uninterrupted continuance of the average of the recent high inflows (years 1993-1998), the Lake will fill to that point by about 2018. With an assumed full lake, the additional scenarios of a standard project flood (SPF), a one per cent, or one hundred year, event, and the further continuation of the average of the recent high inflows were also evaluated. The team addressed several plans for protecting from the consequences of such scenarios. Three structural plans addressed would use a west-end pumped outlet to hold the lake at elevations to prevent a major natural spill from the SPF, the one per cent event, and the actual of the recent high inflows. The assumption for all three plans was that related levees would be raised as required as the lake continued to rise. It became clear that all the plans also require armoring the Tolna Coulee outlet to ensure against erosion and its consequences. Because of those consequences, even a plan of no action should probably include such armoring, if the lake threatens to reach elevations near its overflow level into the Sheyenne. In addition to such plans, the team reviewed the available data as to what other activities should be pursued to protect the City of Devils Lake and smaller communities around the basin.

None of the outlet plans investigated showed benefits exceeding costs. The evaluation did show that the operation of an outlet once the lake reaches a level of 1454 would have substantially lower adverse effects than a natural overflow. Such a plan would protect the population around the basin at a certain elevation, it would have low to moderate downstream impacts, and its impacts in the basin would be mixed, but minimal in the face of an otherwise rising lake. A recommendation is made that this plan be considered for continued NEPA evaluation. The complete evaluation of this plan and other reasonable alternatives as part of the NEPA process would permit the other required congressional criteria to be addressed. If conditions continue to warrant, it would allow plans and specifications to begin if the lake reaches an elevation of 1452 and construction to begin if the lake reaches elevation 1453. At the average of the recent high inflows, these elevations would be reached in approximately 2005 and 2006, respectively.

The report recommends the design standard of six feet of freeboard for advance measures on Devils Lake. This recommendation factors in the standing water against the structures and effects of wind and ice.

The report also recommends raising the levee protecting the City of Devils Lake to the 1460 top of levee (TOL) that is the maximum for its design base. This raise is minimal in cost and maintains the city behind protection from the most current projection of the one hundred-year lake level. Because the raise would require a Project Cooperation Agreement amendment, the report recommends immediately proceeding with the actions necessary to obtain that amendment. It should be borne in mind, that completion of the levee to 1460 TOL does not provide the levee protection envisioned as part of any outlet plan. Any outlet plan to hold the lake at 1454 and contain an SPF event would require levee protection above 1460.

The combined team from the St. Paul District and the Mississippi Valley Division presented an overview of its report to General Anderson on 28 May 1999, and this draft is presented on 3 June 1999.

AUTHORITY

As a result of the 4 May telephone conversation that General Fuhrman and General Anderson had with the North Dakota Congressional Delegation and Dr. Westphal, MVD put together a Division/District team to identify the trigger (decision) point(s) and associated action plans at which an emergency outlet from Devils Lake and other features of work, like emergency spillways, would be warranted. General Anderson agreed that we would try to get this information back to the Delegation in 30 days. This information will become part of the technical report being prepared by MVP.

PURPOSE

Determine if there are decision points and associated action plans at which an emergency outlet and other features of work would be warranted. Make these determinations part of the technical report being prepared. Present these determinations to ASA(CW), DCW, and CG, MVD.

SCOPE

Determine conditions under which an emergency outlet would be warranted, conditions which would warrant further levee raises, and trigger points for each. Determine the hydrologic events and associated risk of occurrence that results in the reasonable worse case human and environmental impacts in Devils Lake and the immediate and downstream regions from flows to the Sheyenne River. For an emergency to exist, the following three elements must be evident:

(1) An event must be identified that results in significant adverse impacts;

(2) Reasonable probability of the occurrence of the event; and

(3) There must be an urgency with respect to time to prevent those impacts from occurring.

## BACKGROUND

The District has studied the ongoing event at Devils Lake thoroughly. The report recently submitted did not take full advantage of that research for its recommended plan, but declared an imminent emergency. The Division does not perceive the imminence of the emergency. This task force will define the conditions for which an emergency would exist and the associated action plans required to respond.

## STUDY OBJECTIVES

1. Assuming Devils Lake is at the point of overflow, determine the worse case human and environmental impacts, and associated risks, in the immediate and downstream regions from natural overflows to the Sheyenne River for the following hydrologic conditions: a. Standard Project Flood; b. 100-Year Flood; and c. inflows equal to that of the last 6 years.

2. Determine the conditions, and their probability of occurrence, required to raise Devils Lake to the level of impending overflow.

3. If the worse case demonstrates the potential for beneficial operation of an emergency outlet, determine conditions that require construction and the trigger points for initiation of construction.

4. Determine the trigger points for initiation of construction on additional levees for continued prevention of loss of life or significant damages to commercial properties in the Devils Lake area.

a. Determine criteria that were the basis of past decisions. Should those criteria continue to be used?

b. What increments of additional protection should be used?

c. How much lead-time is needed for each increment?

d. What is a reasonable freeboard for each increment?

## PAST LEVEE RAISES

In 1986, the Corps, under authority of Section 205 of the 1948 Flood Control Act, constructed a levee to protect the city of Devils Lake against the effects of flooding from Devils Lake. The Section 205 project protected against a lake level of 1440 feet, and, including the 5 feet of freeboard for ice action and wave run-up, was built to top of levee (TOL) 1445 feet.

Abnormal climatological patterns in the Devils Lake drainage area began in 1993, causing the lake to rise to levels not seen in hundreds of years. As a result, in January 1995, after an 8-1/2 foot rise in lake levels, the Governor of North Dakota requested technical assistance and emergency operations from the Corps. The Corps provided technical assistance during State and local planning efforts, conducted technical workshops, provided emergency pumps and sandbags, constructed protective berms along the city of Minnewauken sewage lagoon, and provided emergency protection for the Ramsey County Rural Utility System.

In July 1996, with water levels continuing to rise, the Governor requested the Corps to raise the levee system protecting Devils Lake to TOL 1450. With the projected lake level rising to within 2 feet of the design levee grade and in anticipation of a continued rising trend in lake levels, NCD recommended to HQUSACE approval of the Governor's request. In July 1996, citing the Advanced Measures Program of Public Law 84-99 authority, the Acting Assistant Secretary of the Army (Civil Works) approved a 5-foot raise of the original Section 205 project to TOL 1450. This work began in September 1996 and was completed in October 1997.

Following a 5-foot rise on the lake in 1997, the water level was once again approaching the design levee height. The Director of Civil Works (DCW) approved a 2-foot increment levee raise to TOL 1452 in April 1998. Significant flood flight efforts were also underway throughout the Devils Lake area, including work for the Spirit Lake Nation.

In July 1998, with the lake level at 1444.6, USGS estimates indicated that by the spring of 1999, there would be a 10 percent chance that the lake level would be at 1447. This would put the lake level at the 1447 design level (TOL 1452) currently under construction. Construction on the levee raise from TOL 1450 to TOL 1452 was initiated on 6 July 1998 and scheduled for completion in December 1998. However, the construction contracts for the ongoing levee raise to elevation TOL 1452 contained options that would allow the construction of earthwork to elevation TOL 1457 and the placement of riprap to elevation 1454. Due to the substantial savings ($9.0 million) in construction costs that could be achieved by exercising the two contract options, and the likelihood of additional levee raises in the future, the DCW approved raising the levee to TOL 1457 in August 1998. Work began in September 1998 and is scheduled for completion in September 1999.

Flood flight efforts continued in the Devils Lake area to include the raising of three levees in 1998 for the Spirit Lake Nation. An additional levee raise for the Nation began on 27 May 1999.

## LEVEE RAISE CRITERIA

The following criteria were used to determine if the Corps of Engineers would recommend an emergency levee raise at Devils Lake:

1. Probability of Rise in Lake Level: The USGS developed a probability curve for increase in lake levels. This analysis was used to determine the probability that the lake would rise to threatening levels, ie, the lake would exceed the design elevation. This probability analysis was used to establish that there was an imminent threat of flooding.

2. Construction Time: The time to design and construct the emergency levee raise was estimated at 1 to 2 years.

3. NWS Forecast: The National Weather Service forecast lake elevation for the current year plus the average historic rise due to next spring's snowmelt (1'-2') was used to determine when the lake levels would exceed the design elevation.

4. Constructability: Construction would have to start before the water reached the new levee footprint to prevent construction "in the wet." The levee base would be constructed 'in the dry' to meet recommended engineering design standards

The probability criteria was used to determine the threat, while the remaining criteria were used to determine the trigger elevation.

## MODELING TECHNIQUES

The 3,814-square-mile Devils Lake watershed, located in northeastern North Dakota, is a hydrologic subbasin of the Sheyenne River, which in turn is a subbasin of the Red River of the North basin (Figure 1). The lake level must exceed an elevation of 1,459 feet above mean sea level to spill to the Sheyenne River. Devils Lakes level as of 26 May 1999 was 1446.8 and is forecast to reach 1447.5 to 1448.0 by July 1999. Analyses indicate that the probability of a spill to the Sheyenne River is approximately 1 percent in the next 40 to 50 years. However, the lake level has risen nearly 44 feet since the historic low in the 1940s, with a 22-foot rise in just the last 6 years. Additionally, six of the eight largest inflow events since 1950 have occurred during these last 6 years; and the predicted runoff volume into Devils Lake for 1999 is projected to be in the top three events of record. Since recordkeeping started in 1867, the lake level fell from 1438.4 to its historic low of 1400.9 in 1940 and rebounded to its current historic high of 1446.8 in May 1999 (Figure 2).

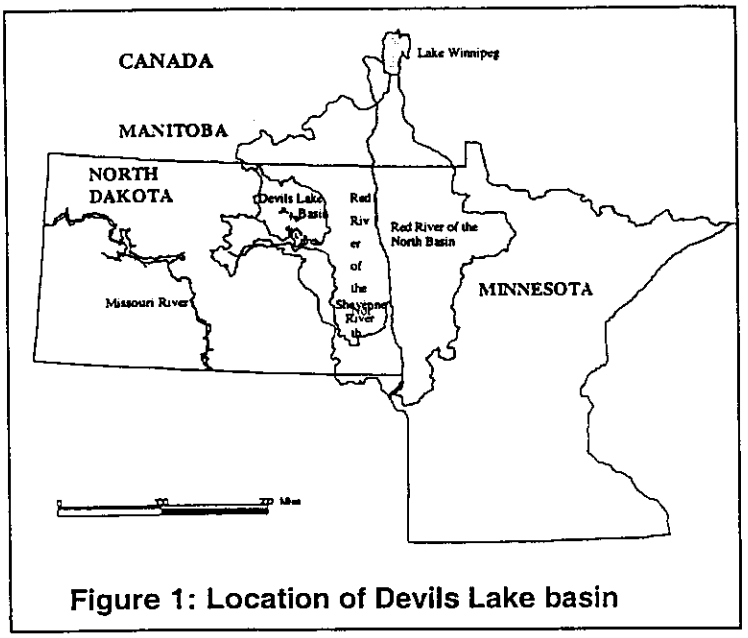


**Figure 1: Location of Devils Lake basin**

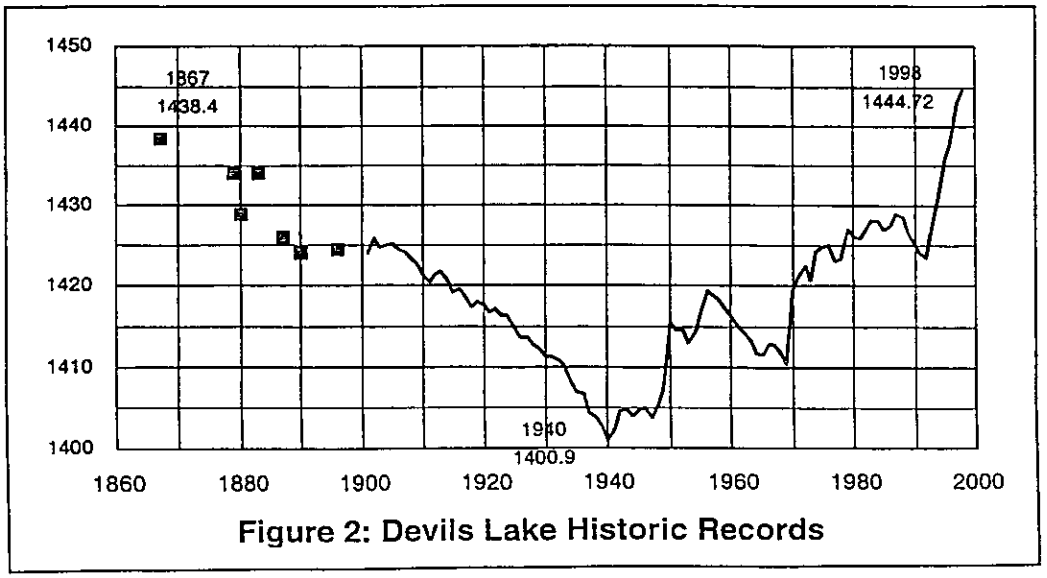


**Figure 2: Devils Lake Historic Records**

The extreme variability in lake levels is a consequence of Devils Lake being a "terminal lake" (i.e., a closed basin), unless exceptional conditions are present. It is believed that the lake has gone from completely dry to overflowing to the Sheyenne River, an elevation range in excess of 70 feet, several times since the lake was formed by the last glacial episode about 10,000 years ago. Figure 3 illustrates the lake level's variability over the past 4,000 years based on geologic evidence analyzed by the North Dakota Geological Survey (NDGS). Based on that evidence, Dr. John Bluemle, State Geologist, says that the lake's natural condition is either rising or falling in response to climatic changes; it should not be expected to remain stable. He also concludes that man's impact on lake levels from agriculture, wetland drainage, and road construction is minor.

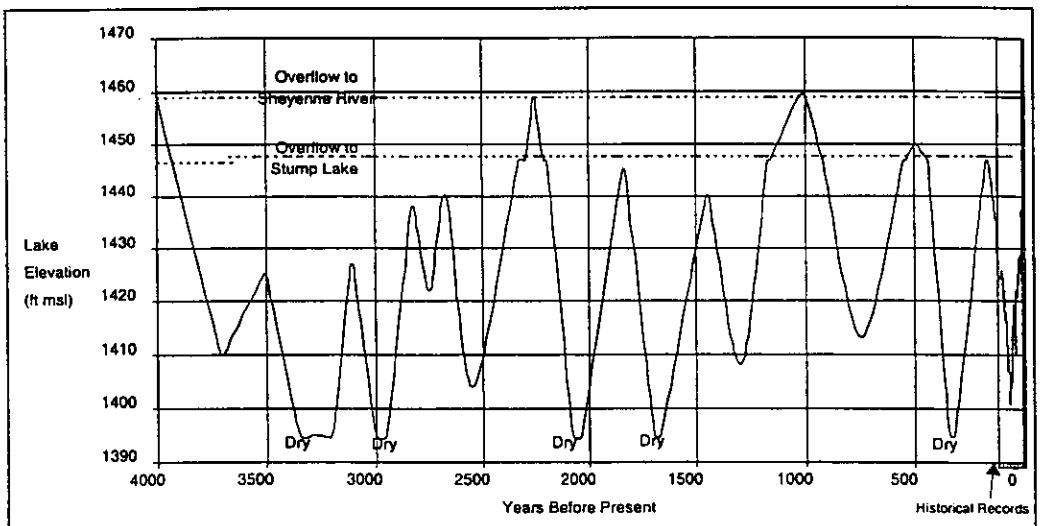


**Figure 3: Devils Lake Fluctuations—4,000 Years**

## Hydrologic Model

To address the objectives of this report a hydrologic model of Devils Lake was developed to evaluate the probability and risk of Devils Lake flooding. A water quality model was developed to evaluate the impacts of with and without emergency project conditions downstream on the Sheyenne and Red River. This model was also used to compare the relative differences in flows and corresponding elevations at key locations downstream.

To determine the existing elevation-frequency, a stochastic model coupled with a statistical water mass-balance model was developed by the U.S. Geological Survey (USGS). Lake elevation-frequency describes the probability of the lake reaching or exceeding a given level, which is useful for planning, management, and project feasibility studies. Standard statistical analysis requires that the peak annual lake levels be independent of previous lake levels (i.e., the data for statistical analysis must be

homogenous, independent, and stationary). For Devils Lake, the annual peak lake levels are not independent. Climate factors supplied by the University of North Dakota Regional Weather Information Center were included in the simulations. These climate factors show generally above-normal expected precipitation for years 1998 through 2002. Estimated model parameters were revised in January of 1999 to include precipitation, evaporation, and inflow data for 1950 through 1998. The longer period of record used to fit the model and the inclusion of climate factors both resulted in an increase in the exceedance levels over those used in the earlier plans. Development, calibration, and verification of this model is described in more detail in, Simulation of Devils Lake Emergency Outlet Using a "5-Box" Water and Sulfate Mass-Balance Model, Independent Technical Review Version (August 17, 1998). Using this model and starting conditions based on the lake level in March 1999 with the forecasted inflows projected by the National Weather Service for the Spring of 1999, the possible future levels of Devils Lake along with the probability of exceeding those levels is presented in Table 1. The lake level that is exceeded with a given probability may change depending on antecedent precipitation, lake levels, and inflows at the beginning of the simulation period. Information in this table should not be used to forecast future lake behavior, because the limited temporal resolution of the model is not sufficient for short-term prediction. It is not used to forecast actual lake levels in the near term. However, assuming stationary climatic conditions, the table can be used by water resource managers to determine the likelihood of future lake levels that may occur. The model was used to generate 10,000 traces of possible future lake levels. With these, the probability that the lake will reach a 1-percent exceedance frequency can be estimated for any given year in the next 50 years. Figure 4 shows these probability relationships graphically.

Event trace was at least 1447.3

**Table 1: Possible Future Levels of Devils Lake**
**(Beginning 01 April 1999 with a starting lake level of 1444.2 ft.)**

**Lake level for which probability of exceedance in given year is**

| Year | 50% | 10% | 5% | 2% | 1% | 0.2% |
|---|---|---|---|---|---|---|
| 2000 | 1447.5 | 1449.4 | 1450.2 | 1451.4 | 1452.2 | 1454.0 |
| 2001 | 1447.2 | 1449.2 | 1450.2 | 1451.7 | 1452.9 | 1457.1 |
| 2002 | 1446.7 | 1449.0 | 1450.4 | 1452.5 | 1454.1 | 1458.4 |
| 2003 | 1446.1 | 1448.8 | 1450.4 | 1452.9 | 1454.7 | 1459.0 |
| 2004 | 1445.5 | 1448.6 | 1450.4 | 1452.9 | 1454.7 | 1459.1 |
| 2005 | 1445.0 | 1448.5 | 1450.2 | 1453.0 | 1454.9 | 1459.0 |
| 2006 | 1444.4 | 1448.3 | 1450.1 | 1453.0 | 1455.0 | 1458.9 |
| 2007 | 1443.8 | 1448.2 | 1450.0 | 1452.7 | 1454.9 | 1458.5 |
| 2008 | 1443.4 | 1448.0 | 1449.9 | 1452.5 | 1454.4 | 1457.8 |
| 2009 | 1442.9 | 1447.8 | 1449.7 | 1452.2 | 1454.4 | 1457.7 |
| 2010 | 1442.5 | 1447.7 | 1449.4 | 1452.1 | 1454.3 | 1457.7 |
| 2015 | 1440.6 | 1446.8 | 1448.6 | 1451.1 | 1452.5 | 1456.5 |
| 2020 | 1439.1 | 1446.3 | 1448.1 | 1450.6 | 1452.2 | 1455.6 |
| 2025 | 1438.1 | 1445.8 | 1447.8 | 1450.3 | 1452.5 | 1455.9 |
| 2030 | 1437.2 | 1445.4 | 1447.6 | 1450.2 | 1452.1 | 1457.2 |
| 2035 | 1436.3 | 1445.2 | 1447.5 | 1450.0 | 1452.1 | 1457.0 |
| 2040 | 1435.7 | 1445.1 | 1447.3 | 1449.7 | 1452.0 | 1455.8 |
| 2045 | 1435.3 | 1444.8 | 1447.0 | 1449.9 | 1452.0 | 1455.5 |

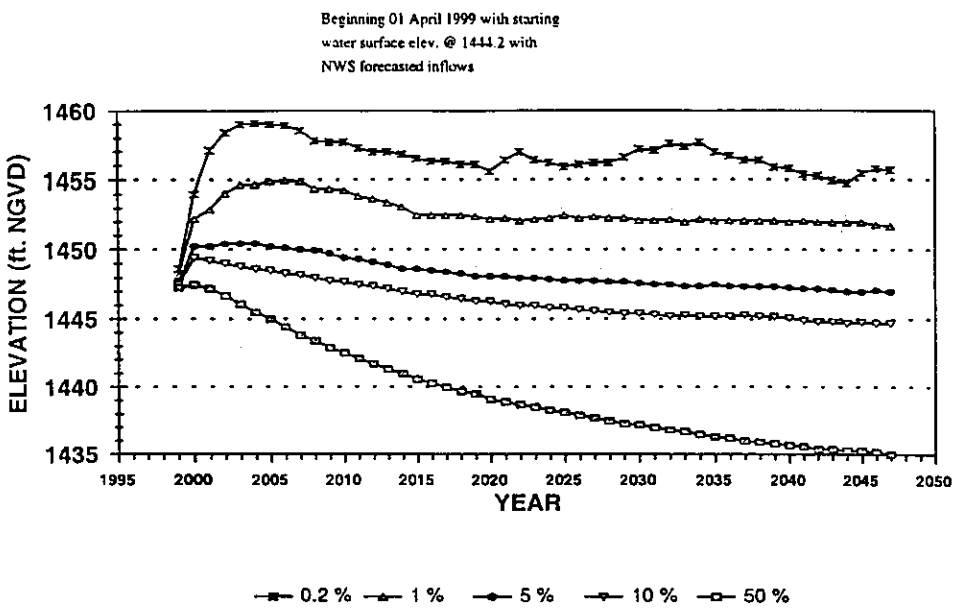
DEVILS LAKE, ND
LAKE LEVEL FREQUENCY; WITHOUT PROJECT
Beginning 01 April 1999 with starting
water surface elev. @ 1444.2 with
NWS forecasted inflows
ELEVATION (ft. NGVD)
1460
1455
1450
1445
1440
1435
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
YEAR
0.2 %
1 %
5 %
10 %
50 %

Figure 4

The USGS model also generates in-lake water quality (sulfate) data and Sheyenne River flows and sulfate data correlated to the lake level "futures." These data are used to (1) regulate emergency outlet releases within water quality and channel capacity constraints, (2) track natural spill rates and water quality, and (3) provide those data to the St. Paul District's HEC-5/5Q water quantity/quality model to route outlet and spill effects down the Sheyenne and Red Rivers.

These data show that the probability of reaching or exceeding 1450 (the design level of protection of the City of Devils Lake levee system) is at about 7 percent in 2000. The probability of reaching or exceeding 1457 (the top of the levee system) peaks at about 0.2 percent in 2004.

The chance of reaching or exceeding a given elevation is much higher over a 20-year period (1999-2018) of analysis, instead of using Table 1's year-to-year probabilities. Table 2 shows that the probability of exceeding the 1450 levee's design level of protection sometime through 2018 is 17.0 percent, and the probability of overtopping the 1457 top of levee in this period is 1.2 percent. The same data show a probability of 0.72 percent of the lake reaching or exceeding the natural spill elevation of 1459.

Table 2 shows the same type of information for a 50-year period. The risk of reaching or exceeding the spill elevation in 50-years is 1.29 percent (i.e., 129 of 10,000 "futures"). These synthesized spill cases have an average duration of 3½ years, an average maximum discharge more than triple the 600-cfs minimum channel capacity in the upper Sheyenne River, and average sulfate concentrations four times the 450-mg/l sulfate standard on the Sheyenne River. Figure 5 shows the lake level probability over longer durations.

450 mg/L
1800 mg/L sulfate.
© over 1800 cfs

**TABLE 2**
**Level Probability of Exceeding Given Level Within**

| | 10 Years | 20 Years | 30 Years | 40 Years | 50 Years |
|---|---|---|---|---|---|
| 1447 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 1448 | 0.5006 | 0.5357 | 0.5564 | 0.5713 | 0.5837 |
| 1449 | 0.2736 | 0.3093 | 0.3320 | 0.3473 | 0.3624 |
| 1450 | 0.1431 | 0.1711 | 0.1907 | 0.2037 | 0.2169 |
| 1451 | 0.0813 | 0.1025 | 0.1186 | 0.1299 | 0.1400 |
| 1452 | 0.0516 | 0.0669 | 0.0795 | 0.0885 | 0.0964 |
| 1453 | 0.0350 | 0.0466 | 0.0571 | 0.0639 | 0.0719 |
| 1454 | 0.0247 | 0.0324 | 0.0401 | 0.0458 | 0.0507 |
| 1455 | 0.0174 | 0.0228 | 0.0291 | 0.0340 | 0.0381 |
| 1456 | 0.0121 | 0.0167 | 0.0207 | 0.0245 | 0.0274 |
| 1457 | 0.0087 | 0.0121 | 0.0145 | 0.0175 | 0.0196 |
| 1458 | 0.0061 | 0.0082 | 0.0104 | 0.0124 | 0.0139 |
| 1459 | 0.0049 | 0.0072 | 0.0092 | 0.0114 | 0.0129 |

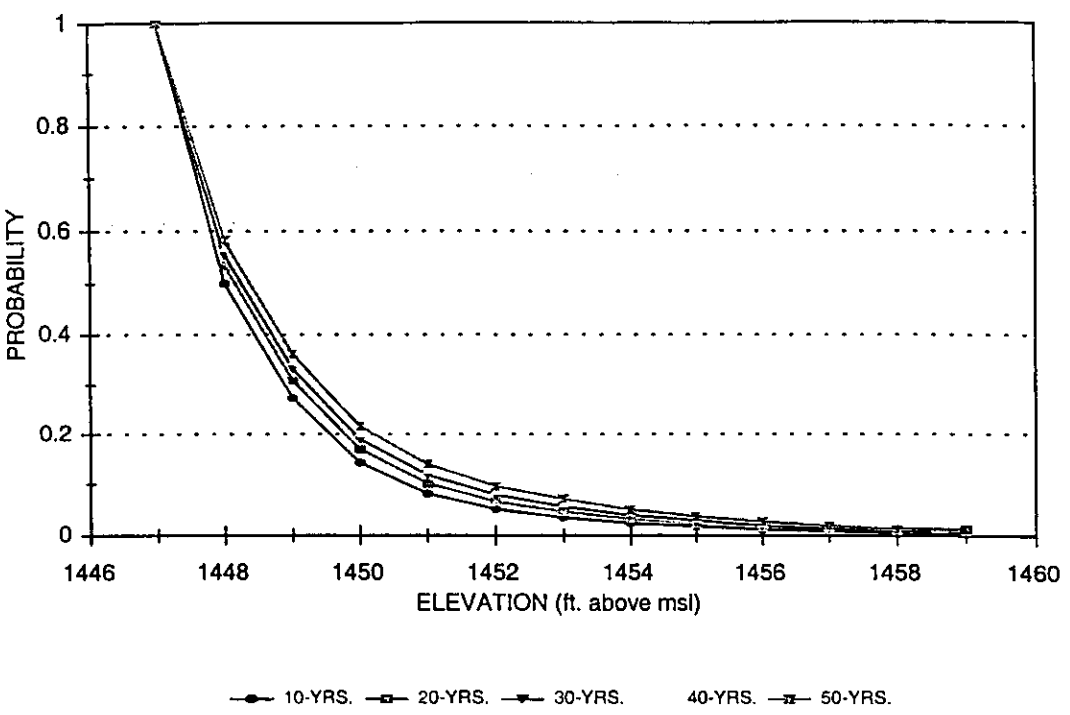
DEVILS LAKE, LEVEL PROBABILITY
OF EXCEEDING GIVEN LEVEL WITHIN:
PROBABILITY
1
0.8
0.6
0.4
0.2
0
1446
1448
1450
1452
1454
1456
1458
1460
ELEVATION (ft. above msl)
10-YRS.
20-YRS.
30-YRS.
40-YRS.
50-YRS.

**Figure 5**

The USGS model is updated periodically to incorporate the most recent inflow, precipitation, and evaporation data. Nonetheless, when the model's results are compared year by year with actual conditions, there have been concerns that the model does not adequately simulate the lake's recent, unprecedented succession of unusually high inflow events, (see table below). Therefore, the model's validity and its use as a basis for economic, feasibility, and hydrological effectiveness analyses has been questioned.

There has been some fine-tuning of the model to address this concern. Climate factors to show the likelihood of a wetter climate through 2002 were incorporated into the model. The climate study concluded that it was not possible to develop reliable climate factors further into the future. Changing its base of historic data from 1950 through 1998 to 1993 through 1998 to better assess the lake's near-term flood potential was considered, but the 1993 through 1998 time period was found to be too short to give reliable statistics. That adjustment would have significantly increased the probability of near term higher lake levels, and perhaps natural spills to the Sheyenne River. As an alternative, year by year future lake elevations were determined assuming an annual inflow equal to the average of 1993 through 1998, and the results used to evaluate the time it could take for the lake to reach the various trigger elevations. Other related suggestions include: updating the model's regression equations to reflect the proposed period of record change, effects on inflows due to a saturated basin, and increased contributing area.

**Table 3: Comparison of Lake Level Probability Estimates Made in 1994, 1995, 1998 and 1999 with the Actual Peak Lake Levels Reached from 1994 through 1999, Devils Lake, North Dakota**

| | | Indicated Probability of Reaching or Exceeding the Actual Lake Level | | | |
|---|---|---|---|---|---|
| Year | Elevation | Estimates made in Spring 1994 | Estimates made in Spring 1995 | Estimates made in Spring 1998 | Estimates made in Spring 1999 |
| 1994 | 1430.7 | 36% | | | |
| 1995 | 1435.9 | 3% | 12% | | |
| 1996 | 1437.8 | 3% | 12% | | |
| 1997 | 1443.0 | less than 1% | 2% | | |
| 1998 | 1444.7 | less than 1% | 2% | 42% | |
| 1999 | 1447.5 (1) | less than 1% | less than 1% | 6% | 5% |
| 1% Chance Level | | 1443.4 | 1446.6 | 1453.0 | 1453.4 |
| 0.2% Chance Level | | | | | 1457.3 |

(1) Based on forecast made in April 1999.

Outside experts reviewed the stochastic model used to determine future lake elevation probabilities and concluded the model is the best available and follows the current state-of-the-art. However, future lake levels depend ultimately on future precipitation and evaporation, which cannot be predicted several months into the future, much less several years. If the recent wet climate continues, the lake will continue to "beat the odds" of the stochastic model.

**Water Quality Standards**

The effect of outlet operation on the water quality of the Sheyenne River and Red River of the North is an issue to a wide variety of interests—natural resource agencies and groups concerned with possible effects on biota and wildlife habitat, farmers who plant in the floodplain or irrigate with river water, industries that use river water, communities that tap the rivers as a source of potable water, commercial fishermen on Lake Winnipeg, etc. Legal constraints on water quality impacts fall into two categories – the qualitative language of the Boundary Waters Treaty and North Dakota's antidegradation policy and the specific concentration limits established by North Dakota and Minnesota under the authority of the Federal Clean Water Act and the Treaty Between the United States and Great Britain Related to Boundary Waters, and Questions Arising Between the United States and Canada), signed January 11, 1909. The Treaty states: "It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other." In May 1969, the United States and Canada adopted specific water quality objectives recommended by the International Joint Commission (IJC), which was established by Article VII and given jurisdiction by Article VIII over matters dealing with Article IV. Those objectives are:

- TDS 500 mg/l
- Sulfate 250 mg/l
- Chloride 100 mg/l
- Dissolved Oxygen (DO) 5.0 mg/l
- Fecal coliform 200 per 100 ml

The Devils Lake water quality studies focused on the TDS, sulfate, and chloride objectives because the outlet is not expected to have a measurable impact on DO or fecal coliform. The outlet's potential water quality effects must also be compared to water quality standards applicable to the Sheyenne River and Red River of the North. The State of North Dakota designates the Sheyenne River a Class IA stream. The Red River of the North, which defines the border between North Dakota and Minnesota in the study area, is classified as a Class I stream by North Dakota and Class IC, 2B, 3B stream by the State of Minnesota. The two States have minor differences in some Red River of the North standards; however, the standards of primary interest in this study are identical and match the objectives at the International boundary. The State of North Dakota also has an antidegradation policy for surface and ground waters in the State and rivers, streams, and lakes along its borders. This policy does not include specific quantitative requirements but, instead, promulgates a broad public policy of maintaining or improving water quality

for the purposes of public health and enjoyment, biota protection, and social, economic, and industrial development. In general, this is interpreted such that a proposed discharge, e.g., the emergency outlet, should not degrade the receiving waters such that existing users are adversely affected. The Corps of Engineers has addressed this policy by developing a downstream water quality model to assess water quality effects, using that model to test alternative outlet operating plans to limit those effects, and identifying downstream water users and unavoidable effects that would have to be mitigated.

**Water Quality Model**

In Lake Water Quality

Devils Lake in-lake, outlet, and over flow water quality for the seven scenarios studied was estimated using an EXCEL spreadsheet 5-box model (COE-5 Box) of the lake. The 5 "boxes" or bays in the model represent West Bay, Main Bay, East Bay, East Devils Lake, and the Stump Lakes. The COE-5 Box model is a conservative mass routing model and is essentially a simplified version of the USGS 5-box Model of Devils Lake.

The COE 5-Box model simulates future volumes and sulfate concentrations of each of the bays based on estimated future conditions for inflow, evaporation, and outflow (due to pumping or overflow. The model computes the mass of sulfate residing in each of the bays based on a simple mass balance equation. TDS, chloride, hardness, and non-carbonate hardness are simultaneously computed for each bay based on historical relationships with sulfate. All inflows to the lake are assumed to enter West Bay through Big Coulee and no flow is assumed to enter through Channel A. Inter bay flows are computed to maintain a constant water surface elevation between the bays. Each Bay is assumed to be well mixed within itself (no wq gradient within a bay). The model is conservative so no interaction occurs between the sediment and water column (no-sulfate fluxes to or from the sediment).

Outflow occurs from West Bay if pumping is simulated or from Stump Lake if the water surface elevation of the lakes exceeds 1459.0 feet Mean Sea Level. When simulated, pumping occurs at 350 cfs in the months May through November. Outflow due to overflow of Stump Lakes is computed using a rating curve developed by the COE using HECRAS modeling techniques. Pumped outflow and overflow sulfate concentrations are assumed equal to the bay they originate from.

The 5-box model computes water and mass-transport (of dissolved solids) from segment to segment based only on the direction and volume of inflow. In other words, as the lake rises due to inflow predominantly from the western end, the water only flows eastward. The model only allows westward flow if outlet pumping exceeds inflow. The model does not account for periods of westward flow that is periodically caused by wind. The spatial segregation of Devils Lake waters observed recently (historically) was clearly determined by the interaction of hydrology, weather, and geomorphic forms attendant in the past. In a recent field study(Summer 1998)large reversing flows have been observed

between the lake segments. It is conceivable that at the recent higher lake levels a process leading toward spatial homogeneity could be at work.

The COE 5-box model does not simulate ice formation and does not account for exclusion of sulfate and other dissolved water quality constituents into the liquid fraction during the winter. The fact that as much as 95 percent of dissolved solids are excluded during ice formation is well established and recently confirmed by a survey conducted by the USGS in Devils Lake in February 1999. In the scenarios studied, outlet operation is restricted to the open water period May through November so downstream considerations due to pumping increased winter dissolved solids are not critical for downstream impacts.

HEC-5Q Water Quality Simulation Module

The HEC-5Q water quality simulation module was originally developed so that temperature and various conservative and non-conservative water quality constituents could be quantitatively evaluated in reservoir system planning and management. Conservative constituents are those that can be assumed to remain in solution and travel with the flow (i.e., salt). Non-conservative constituents are those that are expected to change phase (i.e., solid/liquid/gas) or enter into different chemical and biological cycles. The HEC-5Q loads the selected water quality constituents into the flow routing information generated by the HEC-5 flow simulation module to predict water quality conditions over time throughout the system's reservoir and stream reaches. HEC-5Q can write output to a graphical user interface (GUI) that allows a graphical representation of model results. The interface displays a schematic map of the model from which the user selects specific points or river reaches for which to generate longitudinal and time series plots of different constituents including flow, water surface elevation, and water quality variables.

In the Devils Lake study, the HEC5Q water quality simulation module tracked the following water quality constituents (all modeled as conservative constituents):

- TDS
- Sulfate
- Chloride
- Total hardness
- Non-carbonate hardness
- Temperature
- Devils Lake tracer

Sulfate was modeled because it is the Sheyenne River's most restrictive water quality standard and, along with TDS and chloride, is a potential limiting constituent for meeting water quality standards on the Red River of the North and IJC objectives at the International Border. Total and non-carbonate hardness and temperature may be used to evaluate the effect on downstream municipal water supply treatment costs. The tracer is a virtual (not real) substance with a fixed concentration of 1000 mg/l in Devils Lake. It is used to study and help interpret mass routing phenomenon observed in the downstream

reaches. It can also be used to determine what percentage of the water occurring at a given time and place downstream originated in Devils Lake. Daily flow from Devils Lake (pumping or spill) and the Sheyenne River and their associated sulfate, TDS, chloride, and total and non-carbonate hardness concentrations were used as inputs in the HEC-5Q model. Daily flow and constituent concentrations used in the model were described in the description of the COE 5-Box model. Incremental local flows for the Sheyenne and Red Rivers were constructed using historical records from the actual years modeled for the HS6 scenario, 1996 flows for the 6 year average simulation years, and 1979 flows for the SPF and 100-year events. Daily sulfate concentrations for the Sheyenne River headwaters were computed using a relationship developed by the North Dakota USGS. The equation relates sulfate concentration to flow and is described in the USGS ITR report "Simulation of Devils Lake Emergency Outlet Using a "5 Box" Water and Sulfate Mass-Balance Model". The equation was slightly modified for use by the Corps. The standard error term was eliminated, and the equation result was increased by 20 percent to match the historical mean concentrations. Mean monthly tributary concentrations were applied to the remaining downstream local flows (input as tributaries) to determine loadings for the HEC-5Q model. The tributary loadings used in the 5Q model were developed and utilized in an earlier application of the model for evaluating effects of an emergency outlet on Devils Lake. Calibration runs were accomplished using flows from the historic period 1971 through 1996. The calibrated model produced a simulated data set with a similar mean value for each constituent studied. The range of data values also fell within the range of historic values. A "smoothing" effect of the simulated data range (lower standard deviation for simulated data versus historic data) was evident the further downstream a simulation was made. This effect was due to the assumption of mean tributary concentrations which tended to smooth out the maximum and minimum events produced in the simulated data. The model however is very good for evaluating relative down stream water quality differences which may be experienced from the operation of a Devils Lake outlet on the Sheyenne and Red Rivers. A complete HEC-5Q modeling run involves; reading the COE 5-Box model's output data for the specified scenario at the insertion point including outlet pumping rate and chemical constituent concentrations; generating corresponding downstream tributary flows and concentrations using incremental flows described above, and running the HEC-5 and –5Q models to compute daily flow, stage and chemical constituent concentrations in all computational cells defining reaches of the Sheyenne River, Lake Ashtabula, and the Red River of the North from the insertion point to the International border. Two runs are made for each scenario, a spill (no-pumping or baseline run) and a pumping (emergency outlet operational run). The spill and pumping runs are compared to identify impacts of operation of an emergency outlet for the specific scenario. During the study the Corps used the COE 5-Box and 5/5Q models to examine a number of hypothetical future traces based on a West Bay outlet configuration and the following operational parameters:

- 350 cfs pumping capacity
- 600 cfs receiving stream channel capacity
- No water quality limit in the receiving stream
- Pumping operations limited to the period, May through December

- Devils Lake starting elevation 1454.2
- Devils Lake starting sulfate concentrations (Listed in Table 5)
- 5-Box model Scenario futures based on average of historic record 1993 through 1998 for simulated years 2008 – 2016, application of one of the 3 events (SPF, 100-year, HS6), and resumption of the average historic 6 year record following the completion of the respective event.

Six scenarios were selected to examine outlet performance and downstream effects for a range of hypothetical futures. Each scenario assumed the lake would reach elevation 1459.0 in the year 2018 if an emergency outlet was not operational. In April 2018 one of the three events (SPF, 100-year, or HS6) was applied to the lake. The same events were also simulated assuming an emergency outlet was in place and began operation in May 2008. The emergency outlet was designed to hold the lake near elevation 1454.2 assuming inflow to Devils Lake was the average of the historic period 1993 through 1998.

## ASSUMED FUTURE LAKE CASE

Three hypothetical flood events were selected to address the objectives of this study. They include the Standard Project Flood (SPF), the 1 percent event (analogous to the 100-year event for riverine studies) and the events that occurred the last 6 years (i.e., 1993, 1994, 1995, 1996, 1997, and 1998 in the same chronological order).

### SPF

The SPF represents the most severe combination of meteorological and hydrologic conditions that are considered reasonably characteristic of the geographic region. To estimate the SPF for Devils Lake, the SPF was developed as 40 percent of the Probable Maximum Flood (PMF). The PMF is defined as that flood which would result from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region. PMFs were developed for locations at adjacent drainage areas that straddle the Devils Lake Basin and have similar size drainage area. These locations are: the Pembina River at Walhalla, North Dakota, (drainage area = 3,310 square miles) and the Sheyenne River at Baldhill Dam (drainage area = 3,350 square miles.) The PMF volume at these locations is 2,879,000 acre-feet. at Walhalla and 2,875,000 ac.-ft. at Baldhill Dam. The drainage area of the Devils Lake Basin is 3,810 sq. mi. and therefore; the PMF volume was estimated to be 2,880,000 acre feet. The SPF volume was estimated to be 40 percent and results in a volume of 1,152,000 acre-feet. This volume was estimated to be a 0.2 percent event for Devils Lake.

The most critical storm was the 15 March storm. Other storms that were studied include the 01 April, 15 April, and the all-season storms. The SPF was adopted as a 15 March event. Historic inflows into Devils Lake have occurred primarily in April, May, and June. Because of the severity of this event, the inflow duration was assumed to

occur over a 4-month period (i.e., April, May, June, and July) with the first inflow beginning on 1 April.

The hydrograph volume distribution was assumed to be 1/6, 1/3, 1/3, and 1/6 for each of the four months. This inflow hydrograph was then routed through Devils Lake at a full pool elevation of 1459.0. This is the elevation at which Devils Lake would begin to overflow to the Sheyenne River via Tolna Coulee. Because of the fairly restrictive nature of this outlet relative to the total volume of Devils Lake at this elevation, the shape and peak of the outflow hydrograph are not very sensitive to the assumption made for shape of the inflow hydrograph. A graph of the inflows and outflows is shown in a later section. The peak of the outflow hydrograph occurs in July with a peak outflow discharge of 1750 cfs. The corresponding peak elevation of Devils Lake is 1462.2 (Figure 8).

## 1-Percent Event

The event duration that would cause the highest elevation for Devils Lake (i.e., critical duration) for the 1-percent event was assumed to be approximately 1-year. One-percent events with durations that are shorter or longer were assumed to be not as critical; therefore; this event was adopted for analysis. The 1-percent duration was estimated by using the USGS probability model. Based on an assumed starting water surface elevation and then performing a statistical analysis on the next years inflow volume resulted in a 1-percent volume of 606,000 acre-feet.

This 1-percent event was routed through Devils Lake assuming an inflow time distribution based on three months (April, May, and June). The peak outflow discharge of 530 cfs occurred in May (Figure 9) with a peak lake elevation of 1461.0 (Figure 10).

## Last 6 Years Historic Events

The last 6 years, historic events were selected for evaluation. These events are 1993, 1994, 1995, 1996, 1997, and 1998. These events were based on the inflow, precipitation, and evaporation that occurred during these years. The annual inflow volume was distributed in the same 3 months as the 1-percent event. Table 3 shows pertinent data for the last 6 years and the averages for specified period of record.

**Table 4: Ranking of Recent Inflows, Precipitation, and Evaporation**

| Year | Inflow, Acre-feet | Precipitation, inches | Evaporation, inches | Inflow ranking 1950-1998 | Precipitation ranking, 1950-1998 | Evaporation ranking, 1950-1998 |
|---|---|---|---|---|---|---|
| 1993 | 265,500 | 24.48 | 26.42 | 6 | 5 | 48 |
| 1994 | 205,600 | 26.66 | 31.15 | 8 | 3 | 41 |
| 1995 | 402,000 | 18.24 | 37.96 | 2 | 19 | 3 |
| 1996 | 279,700 | 20.07 | 31.16 | 4 | 12 | 40 |
| 1997 | 521,900 | 21.67 | 32.24 | 1 | 10 | 31 |
| 1998 | 272,400 | 17.80 | 31.89 | 5 | 24 | 34 |
| 1950-1998 average | 92,700 | 18.02 | 33.39 | | | |
| 1950-1992 average | 60,400 | 17.53 | 33.61 | | | |
| 1993-1998 average | 324,500 | 21.49 | 31.80 | | | |

net evap

15.4

16.1

10.3

The highest peak outflow discharge occurred in 1997 as expected with an outflow discharge of 245 cfs (Figure 11) and a peak Devils Lake elevation of 1460.4 (Figure 12). The probability of this 6-year historic inflow was estimated to be 2 percent.

$\frac{10.3}{16.1} = 64\%$ of norm

## Required Pump Sizes

Pump sizes were determined to hold the lake at different elevations assuming inflows, precipitation, and evaporation equal to their averages in the recent wet period from 1993 through 1998. These yearly values are: inflow 324,500 acre-feet, precipitation 21.49 inches and evaporation 31.8 inches. As the lake rises and the surface area increases, the total volume of both direct precipitation and evaporation also increase. Since evaporation is greater than direct precipitation, the required pump size to maintain an elevation decreases as the lake rises. As a lake gets deeper, it tends to stay cooler in the summer and evaporation can decrease. However, as Devils Lake rises the surface area expands very fast and the average depth stays fairly constant. At elevation 1445 the average depth is 20 feet and at 1459 it's 19 ft. Assuming a constant evaporation rate with rising lake stage is reasonable since the average depth does not increase with rising lake level. The following graph shows the pump sizes needed to maintain different lake elevations.

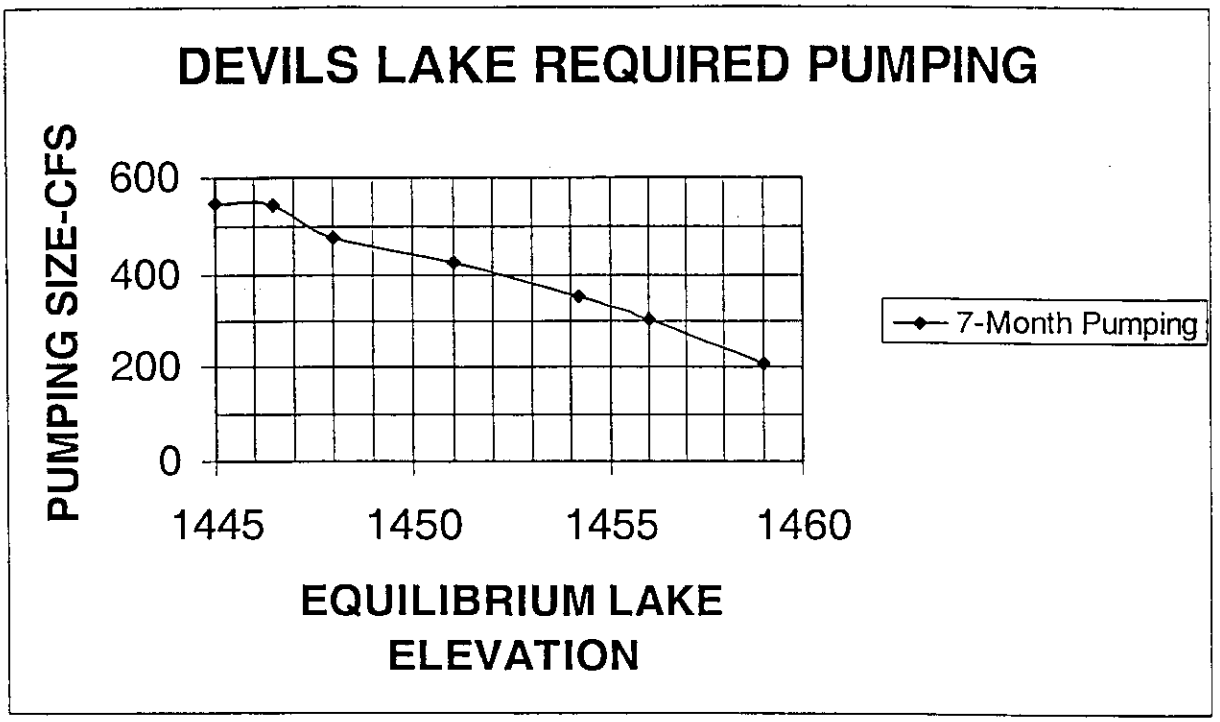


**Figure 6**

Pump sizes required to maintain the lake at three different elevations were determined: 1454.2, 1456.6 and 1457.6. These are the elevations required to assure the lake would not overflow for a standard project flood, a 100-year flood, and a flood with an inflow equal to the average of 1993 through 1998, respectively.

| Design Flood | Inflow (ac-ft) | Storage at Drawdown (ac-ft) | Drawdown Elev | Pump Size (cfs) |
|---|---|---|---|---|
| SPF | 1,152,000 | 4,150,295 | 1454.4 | 350 |
| 100-year | 606,000 | 4,696,295 | 1456.6 | 290 |
| 1993-1998 | 324,500 | 4,977,795 | 1457.6 | 250 |

Storage at the overflow elevation of 1459 is 5,302,295 acre-feet. Storage at drawdown elevation is storage at 1459 minus the inflow.

Devils Lake Outflows

Outflows for the existing Tolna Coulee outlet were computed for the SPF, the 100-year flood and for 6 years with inflows, precipitation and evaporation equal to 1993 through 1998. The starting lake elevation is 1459. No erosion of the Tolna Coulee was assumed. The attached data is for only the outflow at Tolna Coulee - it does not include the routing down the Sheyenne and Red Rivers or the coincident flows on those streams.

How can you assume this when it will happen without armoring the outlet

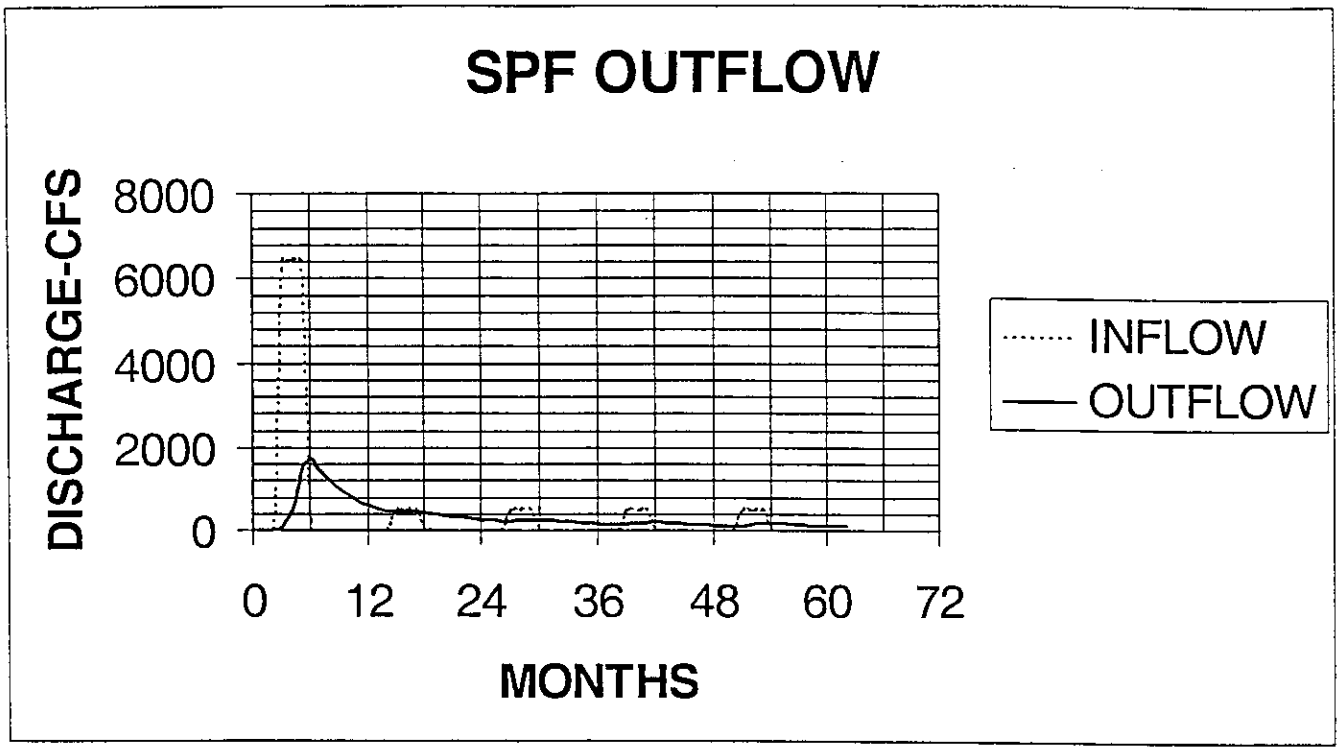
SPF OUTFLOW
DISCHARGE-CFS
8000
6000
4000
2000
0
0
12
24
36
48
60
72
MONTHS
INFLOW
OUTFLOW

**Figure 7**

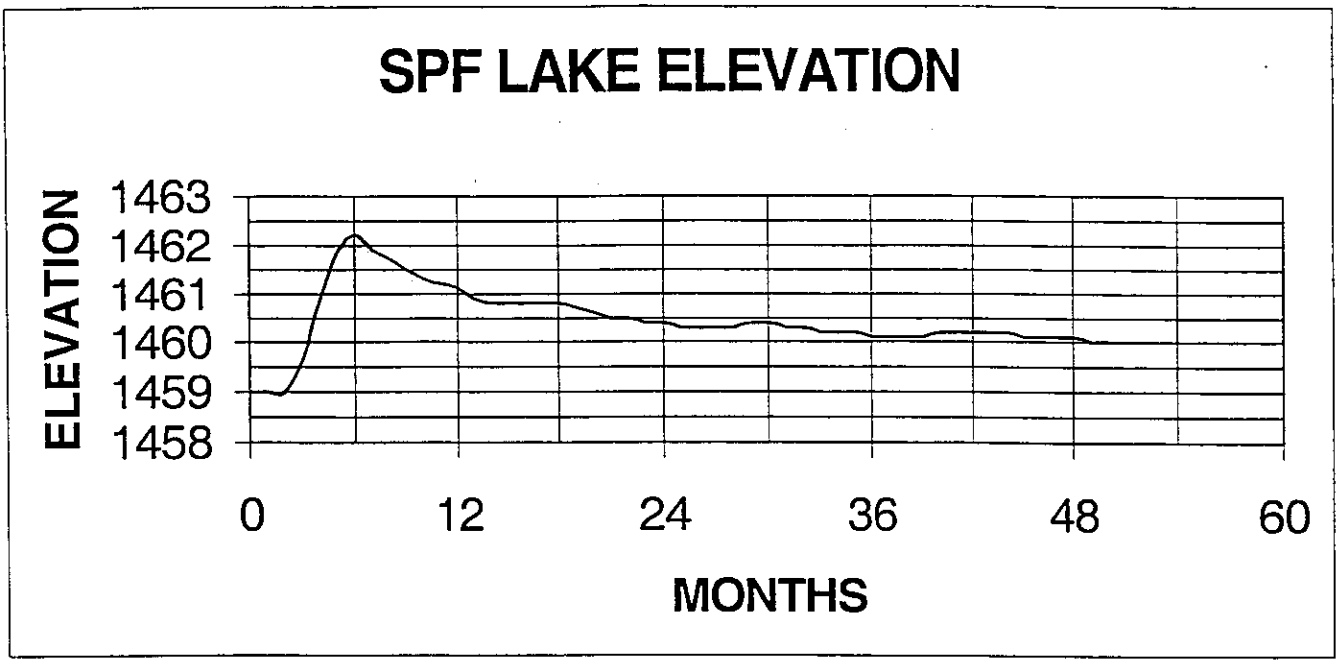
SPF LAKE ELEVATION
ELEVATION
1463
1462
1461
1460
1459
1458
0
12
24
36
48
60
MONTHS

Figure 8

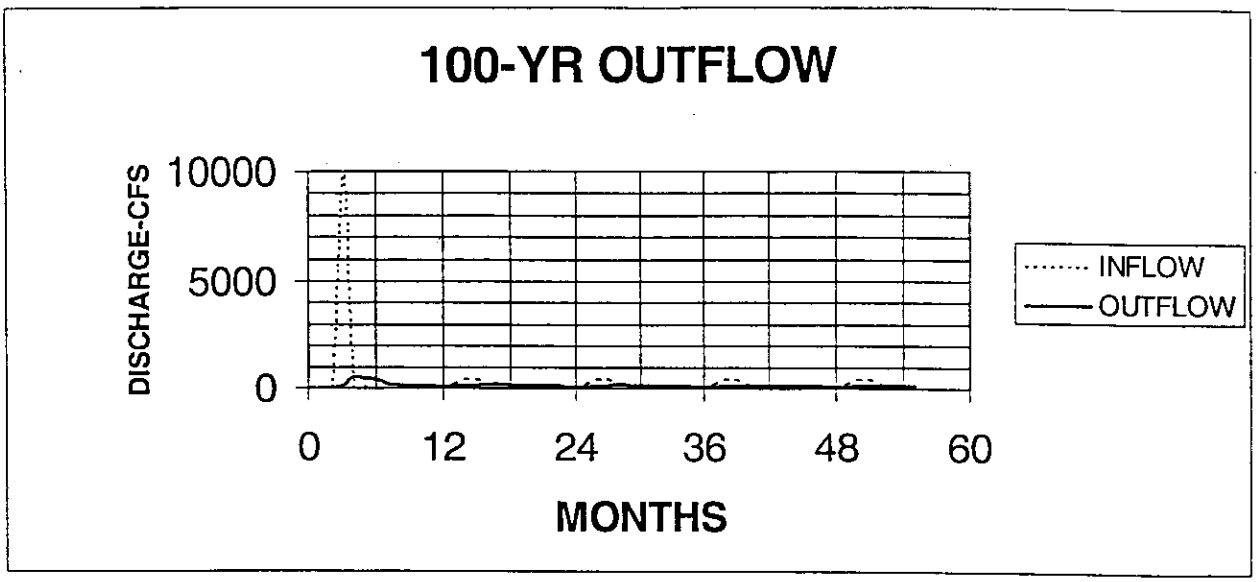
100-YR OUTFLOW
DISCHARGE-CFS
10000
5000
0
0
12
24
36
48
60
MONTHS
INFLOW
OUTFLOW

Figure 9

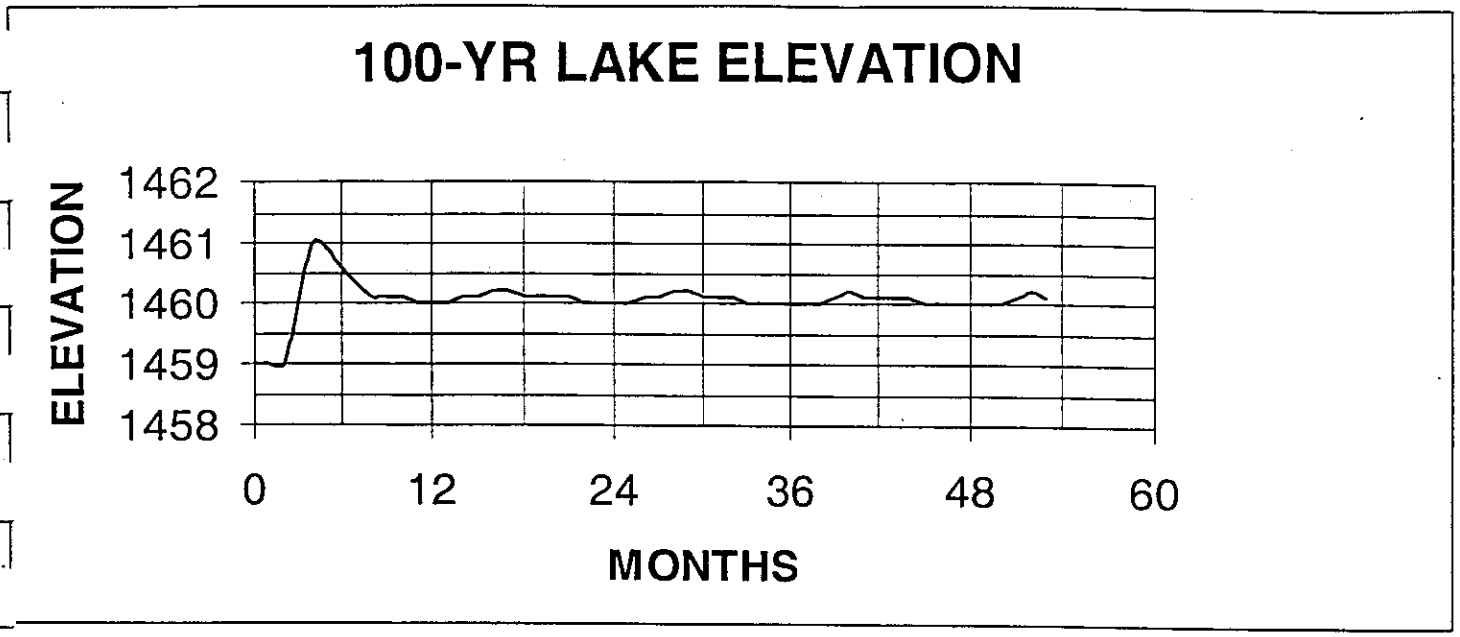
100-YR LAKE ELEVATION
ELEVATION
1462
1461
1460
1459
1458
0
12
24
36
48
60
MONTHS

Figure 10

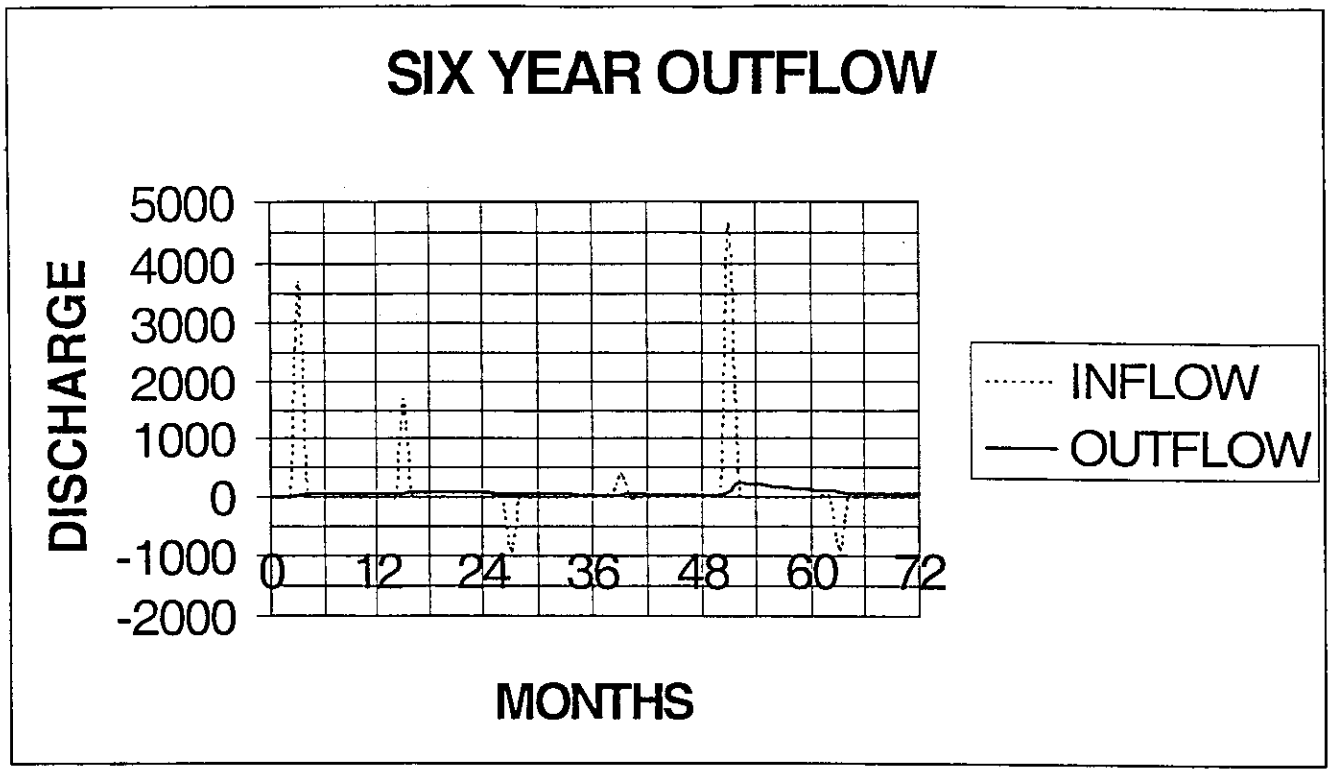
SIX YEAR OUTFLOW
DISCHARGE
5000
4000
3000
2000
1000
0
-1000
-2000
0
12
24
36
48
60
72
MONTHS
INFLOW
OUTFLOW

Figure 11

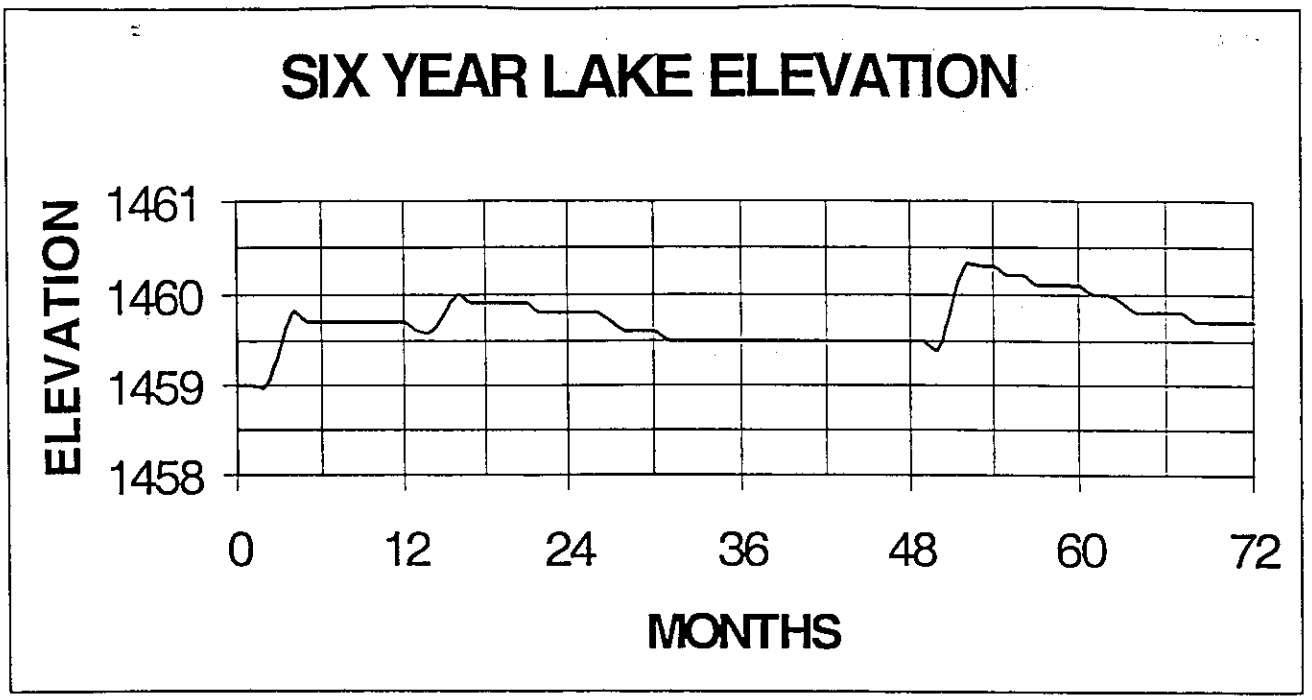
SIX YEAR LAKE ELEVATION
ELEVATION
1461
1460
1459
1458
0
12
24
36
48
60
72
MONTHS

Figure 12

| Flood | Peak Outflow (cfs) | Flow 1 year After peak (cfs) | Peak Lake Elev | Lake elev 1-year After peak |
|---|---|---|---|---|
| SPF | 1740 | 1440 | 1462.2 | 1460.8 |
| 100-year | 530 | 168 | 1461.0 | 1460.2 |
| 1993-1998 | 245 | 73 | 1460.3 | 1459.8 |

Outflows were determined using monthly routings. Several simplifying assumptions were made. The SPF inflow of 1,152,000 acre-feet was assumed to occur over four months. For the SPF year direct precipitation on the lake and evaporation were assumed to be much smaller than the inflow and were ignored. The inflow for each year after the SPF and 100-year inflows was assumed to be the average the net inflow (inflow plus direct precipitation minus evaporation) from 1993 through 1998. The 100-year inflow of 606,000 ac-ft was assumed to be spread evenly over 2 months. For the 100-year event the negative inflow of evaporation minus direct precipitation was assumed to occur over three months starting after the inflow was finished. For the 1993 through 1998 event, the net inflow was assumed to occur over 2 months. Sensitivity analysis indicated these assumptions could have some impact on the peak outflows, but the outflow volumes should be fairly good. For example, for the 100-year when inflow, direct precipitation and evaporation were lumped together and entered in 2 months as net inflow (as was done for the 1993-1998 event), the peak outflow discharge decreased from 530 cfs to 275 cfs. Changes of this magnitude could be expected for the 1993 through 1998 peak outflow if the inflow, precipitation, and evaporation were modeled more accurately.

The outflow discharge-elevation rating curve for Tolna Coulee was determined from previous studies using HEC-RAS. The SPF inflow was determined in previous studies as 40% of the PMF volume. The PMF volume was obtained from PMF studies done for the Sheyenne and Pembina Rivers. The 100-year inflow of 606,000 acre-feet, precipitation of 22.5 inches and evaporation of 30.4 inches was determined by the USGS. These are the long-term 1 percent averages. They determined the near-term 1 percent inflow was about equal to the SPF inflow. The near-term is higher due to hydrologic persistence and the present extremely wet conditions of the basin.

Tolna Coulee Erosion

If Tolna Coulee was not protected it would likely erode during a standard project flood overtopping. Soil data indicates the high point in the coulee is made of erodible material probably deposited since the last overtopping event. A rough analysis of the possible extent of the erosion and the impacts on outflows and lake elevations was performed. The Colby method was used to estimate the sediment transport capacity of the overflow. As the coulee eroded the hydraulics of the overflow was recomputed and the revised outflow hydrograph determined. This was done in several steps until the high point in the coulee had eroded to elevation 1450. At this point the high point was

completely eroded. The computations indicated the outflow had peaked at this time - erosion below 1450 would increase the duration of the outflow but not the peak. It was found that the hump in the Tolna Coulee outlet was eroded from elevation 1459 to 1450 in 168 days. The peak lake stage for the SPF was only lowered 0.2 feet, from 1462.2 to 1460 (Figure 13). The duration of flooding in the lake, especially above elevation 1450, would be decreased significantly, probably by years, if erosion were allowed to occur. The outflow peak for the SPF increased from 1740 cfs to 12,500 cfs. The computed change in lake elevations is shown below. The line labeled outlet elevation shows the controlling elevation on the coulee as it erodes.

Outflows are shown below in Figure 14. The computed peak outflow increased from 1740 cfs to 12,500 cfs if natural erosion was allowed.

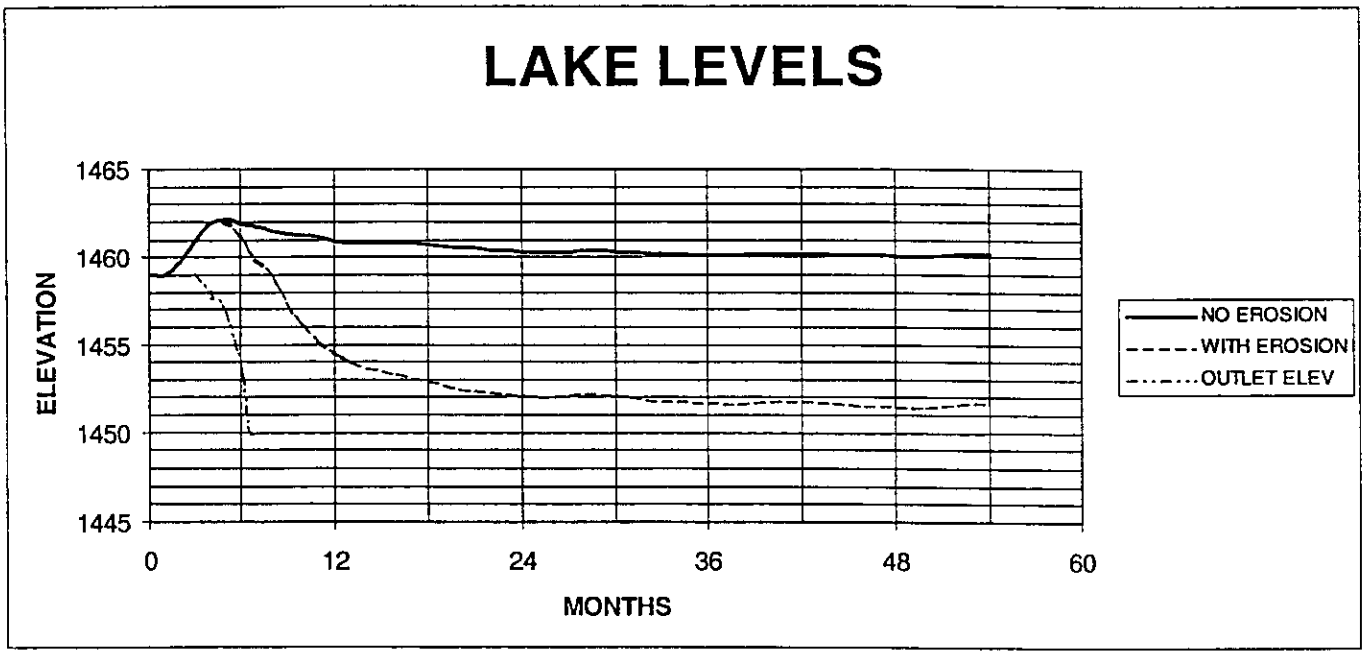


**Figure 13**

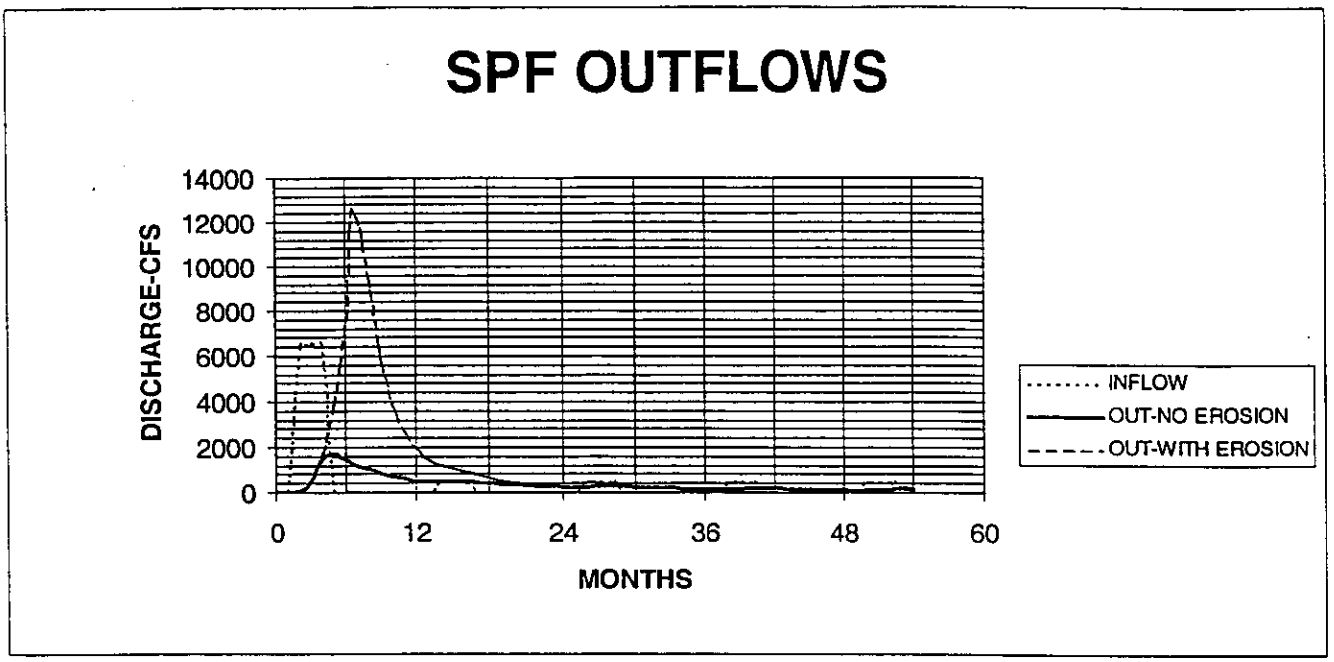
SPF OUTFLOWS
DISCHARGE-CFS
14000
12000
10000
8000
6000
4000
2000
0
0
12
24
36
48
60
MONTHS
INFLOW
OUT-NO EROSION
OUT-WITH EROSION

**Figure 14**

## Simulation Methodology

The simulation methodology was designed to provide information regarding two necessary objectives. One is to establish a decision time line for taking emergency action. The second is to establish a time sequence to evaluate the environmental, water quality, and economic effects of no emergency action and an emergency project. For the first objective it was necessary to conservatively assume that the lake would experience the same climatic conditions as the last 6 years in terms of inflow, precipitation, and evaporation. Figure 15 shows the historic lake elevations up to year 1999 and projected elevations to year 2020. As the lake elevation rises the surface area increases and therefore, the volume per foot of rise increases. Additionally, evaporation will increase resulting in a damping effect on lake elevation rise. Based on the last 6 years of record inflows projected forward in time, the lake will reach the spill elevation of 1459.0 in the year 2018.

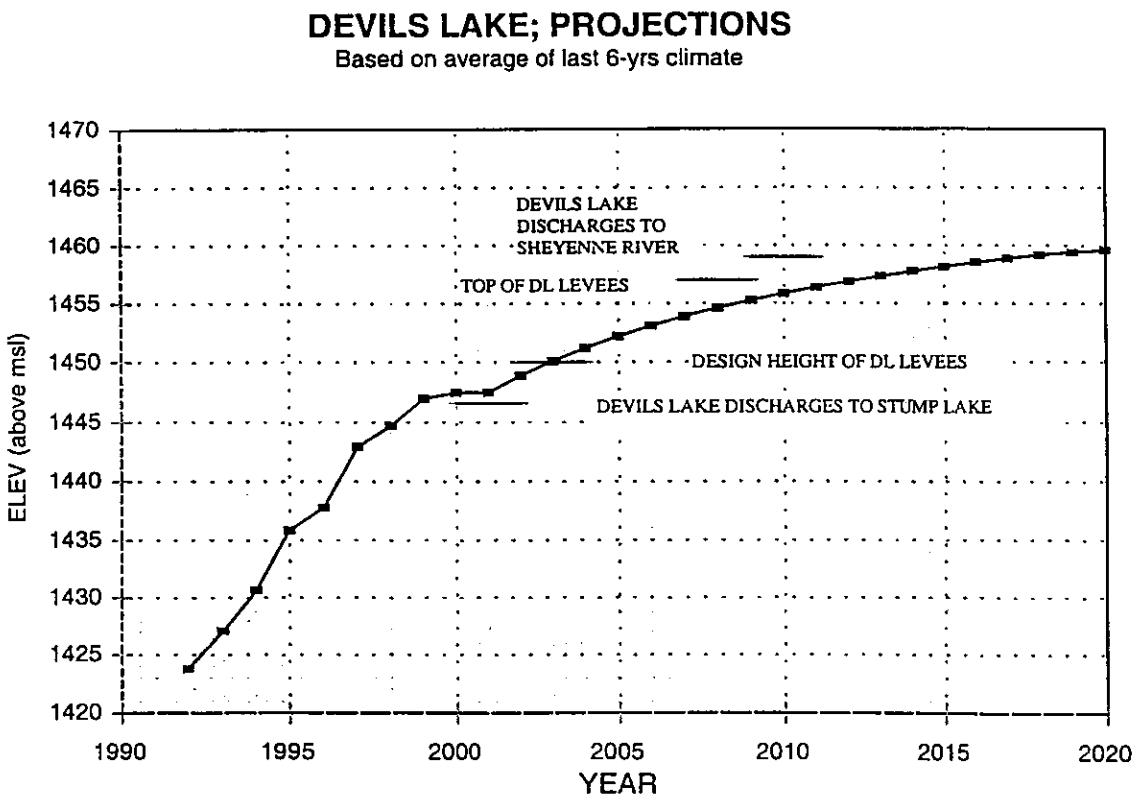


**Figure 15**

The SPF was selected as a design event of significance that could potentially cause major downstream economic and environmental damage. To prevent a major natural spill, the lake would have to be at elevation 1454.2. At this elevation the lake provides storage below the spill elevation equal to the SPF inflow volume. The lake projection graph in Figure 15 shows that this elevation would be reached in the year 2008. This assumes the last 6 years of climatic conditions necessary to define an

emergency time frame to take emergency action. Various pump sizes were evaluated to hold the lake steady at this elevation and prevent it from rising, and thereby consuming flood storage reserved for the SPF. Assuming the last 6 years of climatic conditions, a pump size of 350 cfs would hold the lake at elevation 1454.2. This assumes that the pump operates for a 7-month period from 1 May to 1 December. → what about 1450 mg/L sulfate?

To evaluate the environmental, water quality, and economic effects of the adopted hypothetical events, simulations were made for with and without emergency project conditions. These simulations were done with the HEC-5Q model, which routed flows and water quality downstream on the Sheyenne River and then on the Red River to the Canadian border. Plots of discharge, elevations, and water quality were made in time and space with each condition in the same time frame for relative comparisons and differences. Assumptions were made regarding the with and without emergency project condition.

The without emergency condition assumes that the lake is at full pool or the spill elevation of 1459.0. Therefore no outflow occurs until then. A simulation was made for each design event (i.e., the SPF, 1-percent, and the 6-years historic) for a 1-year period. Because the duration of the SPF event can last beyond 1-year, and because there are six historic events a post flood period of 5 years was selected. The post flood events for the SPF and 1-percent were assumed to be a continuation of the average of the last 6 years climatic conditions which is the same as the conditions leading up to the design year 2018. For the last 6-years of historic events, the remaining five years were simulated.

The with emergency project condition assumes that a 350 cfs pump is operated at a lake level of 1454.2. Therefore, to be consistent in the impact evaluation, the pump would have to be assumed to be operating at 350 cfs beginning in year 2008, the year that the lake is projected to reach 1454.2. Average conditions based on the last 6 years are assumed to occur for the next ten years to the design year of 2018. This is consistent with the without-emergency condition for this time period. Once year 2018 is reached, the three selected design events are simulated. The next 6 years assume the same conditions as the without project simulation. The pump would be pumping 350 cfs in the design year 2018 and the following 5 years.

In summary, there is a 16-year-simulation period (i.e., 1 January 2008 to 1 January 2024). A 10-year pre-flood period from 2008 to 2018, a design year at 2018, and a post flood period from 01 Jan 2019 to 01 Jan 2024. This simulation interval is for with and without emergency project conditions. One can then evaluate the effects of pumping before and after the design year with the effects of spilling in the design year and thereafter.

## Downstream Incremental Local Flow

In evaluating the effects of the three adopted flood events, assumptions were required about the coincidental flooding that would coincide with these three events. For example when the SPF event occurs for Devils Lake, it would not be reasonable to assume that the SPF would occur at each control point on the Sheyenne River and the Red River. A major event would occur however, therefore; based on available data, it was assumed that the 1979 flood event would coincide with the SPF and the 1-percent event. The 1979 event is deemed to be representative of a major event with timing that is typical for this basin. For the six historic events the actual historic events downstream were used except for 1997 and 1998 which were not available. For these years 1995, and 1993 were used respectively.

For the 10-year pre-flood simulation interval and the 5-year post flood interval, the 1996 event was selected as representative of average conditions that occurred over the last 6 years. This is consistent with the assumptions used for Devils Lake pre- and posts flood periods.

## Modeling Techniques

### Initial Conditions

The initial COE 5-Box conditions are descibed in Table 5.

**TABLE 5**
**COE 5-Box Model Initial Assumptions**

| Bay | Elevation (ft MSL) | Volume (acre-ft) | Sulfate (mg/l) |
|---|---|---|---|
| West Bay | 1454.2 | 1,341,807 | 291 |
| Main Bay | 1454.2 | 1,012,322 | 429 |
| East Bay | 1454.2 | 899,634 | 727 |
| East Devils Lake | 1454.2 | 282,541 | 1697 |
| Stump Lakes | 1454.2 | 612,452 | 2855 |

Initial starting conditions were assumed to be equal to the concentrations from USGS trace 2415 at elevation 1454.2 that were computed for an earlier study on Devils Lake. The initial starting elevation was determined to be the elevation that would contain the SPF event to the Devils Lake Basin without overflowing into the Sheyenne River. The model was assumed to start on 1 January 2008. The date was determined as the time when the lake would reach elevation 1454.2 if the average inflow and evaporation for the historic period 1993 through 1998 was repeated annually from projected 1999 conditions.

Devils Lake Inflow Water Quality

Inflow to Devils Lake was assumed to have a median sulfate concentration of 214 mg/l. The sulfate inflow quality was derived during calibration of an early version of the 5-box model to historic conditions from 1992 through 1996. This 1992 through 1996 data represents a period of rising lake levels and decreasing sulfate concentrations.

Model Run Assumptions

Model simulations were made from 1 January 2008 to 31 December 2023. Seven different scenarios, four spill and three pump scenarios, were simulated by the COE-5 Box model. The four spill scenarios included applying the SPF, 100-year event, the 1993 through 1998 historic record (HS6), and the SPF with erosion to the lake when the elevation reached 1459.0. The three pump scenarios assumed a 350 cfs West Bay pump operating 7 months a year when the lake elevation reaches 1454.2. The SPF, 100-year, and HS6 events were then superimposed upon the pumping record at the same time as the respective spill scenario. Table 6 shows the model timing and assumptions.

2008-2018

Yearly inflow and net evaporation are assumed equal to the 1993 through 1998 yearly average inflow and net evaporation of 324,500 acre-feet and 10.31 inches, respectively. Evaporation loss was based on the surface area of the lake. Monthly evaporation and inflow were distributed evenly throughout the year so the lake elevation would be equal to 1459.0 for the spill scenarios on 1 April 2018.

(2) Real Estate Implications

No real estate acquisition will be required for downstream.

## ERODE STUMP LAKE OUTLET

Tolna Coulee Erosion. If Tolna Coulee was not armored and was allowed to erode naturally, a peak flow of 12,500 cfs would enter the Sheyenne River in July of the first year. This compares with a natural flow of 1,740 cfs if the coulee was armored. This flow was not routed down river to determine discharges at downstream points but some attenuation would be expected, especially through Lake Ashtabula. Judgments were made though in an effort to estimate the magnitude of downstream impacts from this event. Increasing the flow at Valley City for instance from 1,000 cfs to 10,000 cfs causes $25 - $30 million in damage. Increasing the flow at Lisbon from 1,000 cfs to 9,500 cfs causes approximately $4 million in damages. Increased area flooded from Reach 1 through Reach 4 may amount to about 40,000 acres. Increased area flooded in Reach 5 for this event might range from 50 – 100,000 acres. No damages would be expected along the Red River since it appears that at each index station the additional flow would be contained within the channel.

a. Basin Effects – Water Quality Impacts

This scenario assumes that the natural outlet channel erodes 9 feet from 1459 feet to 1450, allowing a peak discharge of 12,500 cfs. The event results in significant improvement of water quality in the entire lake chain with relatively fresh West Bay water flushing the entire system. The TDS throughout the system would be spacially uniform at about 800 mg/l.

That would be a significant benefit

b. Downstream Effects

(1) Water Quality Impacts

The downstream impacts from the eroded spill scenario would causes exceedances of TDS, sulfate, and chloride standards within all downstream reaches for differing periods of time. Peak TDS concentrations of up to 4000 to 5000 mg/l could occur at all locations along the Red River as well as the Sheyenne River. Considering that the erosional event would be complete in 1 year, adverse downstream effects would not recur in subsequent years as in the other spill scenarios.

this would be a severe consequence.

The community water supplies would still be able to meet their finish water objectives for hardness removal but would probably have to resort to an ion exchange process or an alternate raw water source to meet drinking water objectives for sulfate and TDS. Some agricultural users would probably find the water unusable for irrigation and stock watering.

no probably about it.

(2) Environmental Impacts

Downstream effects resulting from the erosion of the natural outlet to elevation 1450 would be significant. There would be increased sedimentation in the Sheyenne River and Lake Ashtabula. Erosion would also increase in the Sheyenne River. There would be substantial effects to the downstream aquatic resource on the Sheyenne and Red Rivers. Higher flows, changed water quality, sedimentation, erosion, increased groundwater levels, and overbank flooding would result in the loss of aquatic and riparian habitats. Increased erosion and sedimentation would impact cultural resources along the rivers.

## COORDINATION

Several State and Federal agencies were contacted and requested to identify their perspective on the potential effects of a natural spill. Responses were received from the U.S. Fish and Wildlife Service, Minnesota Pollution Control Agency and the Minnesota Department of Natural Resources. The North Dakota Department of Health and the North Dakota Game and Fish Department declined to provide any comment at this time. All the agencies that responded identified that the effects of a natural spill would likely have significant adverse effects on the Sheyenne and Red Rivers and that the operation of an emergency outlet would likely have less effects than a natural spill. The Minnesota agencies reiterated their position that the NEPA process should be completed prior to initiating construction of an outlet.

## TRIGGER ELEVATIONS FOR POSSIBLE ACTIONS

a. Ongoing Activities

(1) Devil's Lake Levee raise to 1460

We estimate that this action will take 6 months to design and 1 year to construct.

(a) Devils Lake City Levee Freeboard

The freeboard required to prevent wave overtopping does not increase for levee elevations greater than 1457.0. The design worst case is for the portion of the levee at the end of Creel Bay. The design wave height of 3.8 ft was based on deep water conditions and thus would not increase as the lake gets higher and the lake deeper. This wave would runup 5.0 ft on the levee. The design wave is based on an annual wind (50% chance of exceedence in any year). While this wind has a large probability of being exceeded during the project life somewhere along the project, it is far less likely that it will occur in the critical direction required to create the design wave for Creel Bay. The bay is fairly long and skinny and wind would have to be blowing from the southeast. The wind rose for historic winds indicates this is a rare occurrence. 5-ft of freeboard is adequate to prevent wave overtopping for ice-free conditions. An extra 2 feet of freeboard was included in the current design to account for the possible impact of ice ride-up and pile-up. Table 10 of the Oct 1997 "Ice Influence Zone Analysis, Devils Lake, North Dakota" shows a maximum of 0.8 ft should be adequate for ice pile-up. Thus 6 feet of freeboard is considered adequate for the combination of wave overtopping and ice pile-up.

The standard project flood inflow volume of 1,152,000 acre-feet would cause the lake to rise to about elevation 1460.0 if the lake was at 1455.5 (4.5 ft rise) and would raise the lake to 1454.5 if the lake was at 1448.0 (6.5 ft rise). This indicates it might be possible to decrease the freeboard as the lake and levees rise. However, as the lake and the levees get higher the impact of overtopping increases and the probability of getting large runoff volumes such as the SPF may increase. This increase in probability can be due to hydrologic persistence (when it's wet it tends to stay wet) and also because as Devils Lake gets higher so do the lakes and ponds that drain to Devils Lake and the soil moisture is likely higher. The wet conditions in the basin required to raise the lake increase the amount of runoff from a given storm. Because of the increased impact of overtopping and the possible increased chance of getting major inflows, the freeboard should not be reduced as the lake rises. To contain an SPF 6.0 ft of freeboard is recommended.

(b) Devils Lake Design Elevation

The present levee top elevation is 1457 and the design lake elevation is 1450. One of the determining factors in setting the levee height at 1450 was to provide certifiable protection for the expected FEMA 100-year flood elevation of 1450. FEMA has indicated they intend to still use a regulatory 100-year elevation of 1450 even though the lake has gone up significantly since the FEMA study was completed. In this report we are recommending the levees at Devils Lake should be designed to provide safe protection for the peak 1% exceedence elevation estimated by the USGS model for any year in the next 50 years. From Table 1, this is currently 1455.0 in the year 2006. By the above criteria, the top of levee would be set 6 feet above this or 1461.0. However, the levee can be fairly economically raised to 1460 and this provides about 5 feet of freeboard over the short-term 1 percent peak, and about 7 feet of freeboard over the long-term 1 percent peak annual elevation. This is considered adequate to certify that the levee provides protection for a 1 percent flood.

(2) Devil's Lake Levee raise above 1460

We estimate that this action will take 1 year to acquire ROW and design and 1 year to construct.

(3). Assumptions

Since these actions are being undertaken pursuant to PL 84-99, environmental studies have already been completed. In addition, the current levee (presently under construction to 1457) was originally designed to be raised in increments to 1460. It is possible that minimal additional ROW may be needed for the tieback levee at Highway 19 near the Devils Lake Airport which would cost about $5,000. Very little additional design is required to go to 1460.

(4) Outlet Scenarios

Too long!

1. Prevent SPF from overtopping 1459 – This scenario requires holding the lake level to 1454.2 with a 350 cfs pump and outlet works. We estimate that environmental studies, design, and construction will take 6 years. In order to meet these objectives, the trigger point is 2002.

2. Prevent 100-year event from overtopping 1459 – This scenario requires holding the lake level to 1456.6 with a 300 cfs pump and outlet works. We estimate that environmental studies, design, and construction will take 6 years. In order to meet these objectives, the trigger point is 2005.

3. Prevent recent 6-year average flows from overtopping 1459 – This scenario requires holding the lake level to 1457.8 using a 250 cfs pump and outlet works. We estimate that environmental studies, design, and construction will take 6 years. In order to meet these objectives, the trigger point is 2008.

4. Assumptions – We assumed that environmental studies will take 3 years, design will take 1 year, and construction will take 2 years for each of the above scenarios. Of these, the environmental studies contain the greatest risks for schedule slippage. In the short time the team had to evaluate the Devils Lake flooding problem, we identified a number of affected interests with sometimes conflicting positions on the solution(s) to the problem. These include the city of Devils Lake (as well as other, smaller communities in the area), the Spirit Lake Tribe, the U.S. Fish and Wildlife Service, various state agencies from both North Dakota and Minnesota, lake users and landowners (both public and private), downstream users and landowners (both public and private), and the Canadian government. It is unlikely that any solution proposed so far will mutually satisfy all these interests. The NEPA process is likely to be contentious, and if any of the affected parties feel their interests are not being properly evaluated, litigation is likely to result. In this case, the time line becomes problematic; we have all heard horror stories of litigation dragging on for years. In addition, the State Department has taken the position that it prefers to wait until the NEPA process is complete until making a determination that the outlet alternative selected complies with the 1909 Boundary Waters Treaty with Canada. This can only add time to the overall process. The 6-year environmental/design/construct estimate is a "best-case" scenario. It is quite likely that this process could take substantially longer.

So why wait? continue studies now.

**Armor Stump Lake Outlet**

We estimate that this feature will require 5 years lead time: 3 years for environmental studies, 1 year for design, and 1 year for construction. Although this feature is one of the least costly ones studied, its purpose is likely to be controversial (prevention of massive scouring of the Stump Lake outlet, with resultant outflows), and the same caveats discussed in conjunction with the outlet works above apply here.

OTHER COMMUNITIES IN THE BASIN

Churchs Ferry

This plan (Feature 1 in Table 3 of the Summary) includes raising the Churchs Ferry levee, from its present elevation of 1453 (3 feet freeboard above 1450) to elevation 1455 feet. The cost of this plan is about $200,000, and action would be initiated by 2003 at a trigger elevation of 1450 feet. Because we lack economic justification for additional levee raises, advance measures would not be appropriate. Levee raises would be based on an emergency situation. These actions are based on the assumption that the railroad will be raised. If it is not raised, the residents would be relocated.

Minnewauken

This plan (Feature 4 in Table 3 of the Summary) includes the construction of and emergency levee, temporary in nature and designed for limited (3-5 feet) head differential, to elevation 1451, and relocation of residents in Minnewauken, at least by the time this elevation is exceeded. This emergency levee would provide additional time to relocate residents and the cost is estimated at $100,000. This work would begin, at about elevation 1448, when necessary to ensure the levee raise stays ahead of the rising lake level. The cost of relocations is estimated at $6.7 million and must be initiated by 2004 at a trigger elevation of 1451. Relocation of residents is considered as the only option above 1451 due to lack of economic justification for additional levee raises.

# SUMMARY

## FULL LAKE SCENARIOS STUDIED

Based on a conservatively high estimate of inflows, (average flows of 1993 through 1998), Devils Lake will fill to the point of natural outflow (El. 1459) into the Sheyenne River by about 2018 (see Figure 1). The effects in the Devils Lake Basin include $42.2 million in flood damages and $525 million in expenditures for local protection works. The water quality actually freshens, especially in East Devils Lake and Stump Lake. Environmental impacts include 155,000 acres inundated, mixed (some beneficial; some adverse) aquatic impacts, and highly adverse cultural impacts, with 23 known sites affected. No real estate acquisitions would be required. There would be no downstream impacts. The probability of the Lake filling to elevation 1459 and then experiencing a SPF is about 1 chance in 70,000. Impacts were based on the assumption that the natural outlet from Stump Lake to the Sheyenne River was armored. If the natural outlet was not armored, the peak discharge from the SPF would increase from 1,740 cfs to 12,500 cfs and about a half-million cubic yards of material would be eroded from the outlet and delivered to the Sheyenne River. The flows in the Sheyenne River would be equal to or greater than the peak outflow with armoring of 1,740 cfs for about 9 months, and equal to or greater than 3,000 cfs for about 6 months. This would result in flooding of 6,000 acres for 9 months and 35,000 acres for 6 months. The impacts on operation of Lake Ashtabula could be handled. The gates on Baldhill Dam should be able to handle 12,500 cfs; however, it is likely the full storage potential of the dam would be utilized to try and reduce the downstream peak. The pool might be allowed to reach the new emergency spillway. While the gates and spillway should be able to handle the outflow, it would far exceed historic records of around 5000 cfs and some maintenance would likely be required. Armoring of the outlet would adversely impact flooding in the lake area. During the SPF the lake would rise an additional 0.2 feet flooding an additional 4,200 acres. However, the most significant impact is on the increase in duration of flooding in the lake to lands between elevation 1450 and 1462. It is probable that we would be required to purchase real estate interests in the 170,000 acres of lands between those elevations.

### Full Lake and SPF

The effects in the Devils Lake Basin include $67.4 million in flood damages. The water quality is substantially improved due to displacement and dilution of saltier water in East Devils Lake and Stump Lake. Environmental Impacts include 192,000 acres inundated, mixed aquatic impacts, and highly adverse cultural impacts. No real estate acquisitions would be required.

The downstream impacts include $2.0 million in flood damages above those that such an event in the region would already cause along the downstream area. Water quality standards and international standards are exceeded on the Sheyenne and Red Rivers. Some municipal water utilities may find the water untreatable to meet sulfate and TDS objectives without an extended treatment process or using an alternate source of raw water. Some agricultural users may find the water unsuitable for some purposes, including irrigation and stock watering. Environmental effects would be high and adverse on terrestrial, aquatic, and cultural resources. No real estate acquisitions would be required.

**Full Lake and 100-Year Event/Average of Recent High Inflows**

The impacts, assuming the outlet is armored to prevent erosion, for the occurrence of the 1 percent or 100-year event and average flows for recent years with the lake full are as follows:

a. Full Lake and 100-Year Event. The effects in the Devils Lake Basin include $53.5 million in flood damages. The water quality shows minor improvement in East Devils Lake and Stump Lake. Environmental impacts include 179,000 acres inundated, mixed aquatic impacts, and highly adverse cultural impacts. No real estate acquisitions would be required. The downstream impacts include minimal flood damages above those that such an event in the region would already cause along the downstream area. Water quality standards are exceeded on the Sheyenne and Red Rivers. Some municipal water utilities may find the water untreatable to meet sulfate and TDS objectives without an extended treatment process or using an alternate source of raw water. Some agricultural users may find the water unusable for some purposes. Environmental effects would be moderate and adverse on terrestrial resources, and high and adverse on aquatic and cultural resources. No real estate acquisitions would be required. The probability of the lake filling and experiencing a 100-year event is about 1 chance in 14,000.

b. Full Lake and Average of Recent High Inflows. The effects in the Devils Lake Basin include $46.2 million in flood damages. The water quality shows some improvement in TDS. Environmental impacts include 179,000 acres inundated, mixed aquatic impacts, and highly adverse cultural impacts. No real estate acquisitions would be required. The downstream impacts include minimal flood damages above those that such an event in the region would already cause along the downstream area. Water quality standards are exceeded on the Sheyenne and Red Rivers. Some municipal water utilities may find the water untreatable to meet sulfate and TDS objectives without an extended treatment process or using an alternate source of raw water. Some agricultural users may find the water unsuitable for some purposes at times. Environmental effects would be moderate and adverse on terrestrial resources, and high and adverse on aquatic resources. There would be low cultural resources effects. No real estate acquisitions would be required. The probability of the lake filling and experiencing average flows of recent years is about 1 chance in 7,000.

## EMERGENCY PLANS INVESTIGATED

a. Prevent Overtopping from SPF

This plan (Plan 1 in Table 2) includes a 350 cfs pumping station to maintain an average lake level of about 1454.2 feet. The lake storage between this elevation and the overflow elevation of 1459 would provide sufficient storage to contain the SPF volume without outflow from the lake at Stump Lake. The plan also provides for raising the Devils Lake levee to elevation 1463 to provide 100-year protection. The total first cost of the Plan is about $103 million with an annual O&M cost of $2 million. Based on the current high rates of inflow, and a lead-time of 6 years to satisfy environmental issues, design, and construction, the action would require initiation by 2002. This would be at a trigger elevation of 1450 feet. However, for such a complex project, five and a half years (6/1999 through 2004), rather than three years is considered a more realistic time frame to complete the NEPA process. Therefore, if the NEPA process were to continue and be completed by the time the lake reaches elevation 1452 (about 2005), P&S could be initiated at that time to allow for construction to begin at lake elevation 1453, in about 2006.

The effects in the Devils Lake Basin include $42.2 million in flood damages and $238 million for local protection works (including the levee for the city of Devils Lake). Costs for local protection works would be $287 million less than for the full lake scenarios since trigger points above 1454.2 would not be reached. The water quality effect would be a slight freshening of water in the lake chain. Most municipal water utilities would still be able to meet finish water objectives using their existing treatment facilities, with the possible exception of Valley City, which might need to resort to an alternate source of raw water. Environmental impacts would be mixed; possibly beneficial terrestrial and cultural impacts, and possibly adverse aquatic impacts. Real estate acquisitions of $785,000 would be required.

The downstream impacts include minimal flood damages above those that such an event in the region would already cause along the downstream area. Water quality standards for TDS are exceeded on the Upper Red River, but that exceedance is within the system's ambient ranges. Environmental effects would be low on terrestrial resources, and moderate and adverse on aquatic and cultural resources. Real estate acquisition costs are unknown, but would exceed $4,000,000. The probability of outflow from the lake for this plan is about 1 chance in 16,000.

b. Prevent Overtopping from 100-Year Flood

This plan (Plan 2 in Table 2) includes a 300 cfs pumping station to maintain an average lake level of about 1456.6 feet. This provides storage for the 100-year flood without exceeding the outflow elevation of 1459. This plan also provides 100-year protection for Devils Lake by raising the levee to elevation 1456. The total first cost of this plan is about $112 million with an annual O&M cost of about $2 million. Total costs for local protection works would be $352.6 million (including the levee for the city

of Devils Lake). These costs are $172.8 million less than the costs for the full lake scenarios. Based on the current high rates of inflow, and lead-time of 6 years, action would require initiation by 2005. This would be at a trigger elevation of 1452 feet.

Basin impacts from this plan would be essentially the same but slightly Moderated from those of the SPF. Lake levels would be higher, and thus, still fresher. Economic damages would be higher and would present the potential for higher real estate requirements. Environmental impacts would be mixed, with more acres inundated, and more cultural sites affected, but with fresher water benefiting some species.

Downstream impacts would be almost identical to those of the SPF plan. With a minimally smaller pump, the flood damages would be slightly smaller, the water quality impacts even more with ambient range, the environmental impacts more moderate, and the real estate requirements slightly smaller, but still over $4.3 million. The probability of outflow from the lake for this plan is about 1 chance in 7,000.

c. Prevention of Overtopping from Average of Recent High Flows

This plan (Plan 3 in Table 2) includes a 250 cfs pumping station to maintain an average lake level just below 1459. This prevents overflow for inflows equal to those from 1993 through 1998. This plan also provides 100-year protection to Devils Lake by raising the levee to elevation 1466. The total first cost of this plan is about $112 million with an annual O&M cost of about $2 million. Based on the current high rates of inflow, and a lead-time of 6 years, action would require initiation by 2008. This would begin at a trigger elevation of 1454.5 feet.

The basin impacts of this plan would be essentially identical to the lake full scenario. The effects in the Devils Lake Basin include $42.2 million in flood damages. The water quality actually freshens, especially in East Devils Lake and Stump Lake. Environmental impacts include 155,000 acres inundated, mixed (some beneficial; some adverse) aquatic impacts, and highly adverse cultural impacts, with 23 known sites affected. No real estate acquisitions would be required. The probability of outflow from the lake for this plan is about 1 chance in 5,000.

The downstream impacts would be moderated even further from those of the SPF and 100-year plans because of the smaller pumping requirement. The most important impact is the $4.3 million in real estate requirements. The probability of outflow from the lake for this plan is about 1 chance in 5,000.

d. Raise Devils Lake Levee to 1460

This plan (Plan 4 in Table 2) consists of raising the Devils Lake levee to elevation 1460 to provide 100-year level of protection. The cost of this plan is about $7 to $9 million. About 2 years lead time is required to complete the plan. FEMA has adopted elevation 1450 feet as the 100-year lake level for the purpose of certifying the Devils Lake area for the Flood Insurance Program. The current USGS estimate of the

peak 1% lake level is 1455. Based on a design freeboard of 6 feet and the levee currently at elevation 1457, there is about a 3 percent chance that the lake will rise to the "effective" levee design water level of 1451 next year. The decision made last year (August 1998) to initiate the current levee raise to 1457 was based on a 10 percent chance of exceeding the levee design water level in the next year (1999). Based upon the 3 percent chance that the lake will rise to the "effective" design water level of 1451 by next year, the District should immediately proceed with necessary reports and PCA amendments to raise Devils Lake Levee to TOL 1460. Preparation of P&S to raise the levee should begin as soon as possible to allow for advertisement for bids by February 2000 and completion of construction by the end of 2000.

e. Armor Stump Lake Outlet

This plan (Plan 5 in Table 2) consists of constructing a sheetpile and riprap structure in the outlet from Stump Lake to the Sheyenne River to prevent erosion of the outlet. This plan was assumed to be in place for the full lake scenarios studied. The cost of this plan is estimated at about $1 million. Based on the current high rates of inflow, and a 5-year lead-time, action would require initiation by 2013. This would begin at a trigger elevation of 1457.5 feet.

(1) Armor Stump Lake (assume lake full). The effects in the Devils Lake Basin are the same as with a full lake and include $42.2 million in flood damages. The water quality actually freshens, especially in East Devils Lake and Stump Lake. Environmental impacts include 155,000 acres inundated, mixed aquatic impacts, and highly adverse cultural impacts, with 23 known sites affected. Further analysis is required to determine if armoring the Stump Lake Outlet (Tolna Coulee) results in a taking of real property. Several Supreme Court decisions during the past century indicate that no real estate taking would result from efforts to prevent the natural outlet from eroding. Ultimately, this issue may be decided by the court. If armoring Stump Lake Outlet were considered to be a taking, the estimated real estate costs would be $43 million. If not, the real estate costs for armoring would only be $10,000.

The downstream impacts include flood damages prevented of $35.0 million, and the protection of 100,000 to 150,000 acres of agricultural lands. Water quality impacts would be directly proportional to any volumes released. Positive environmental impacts derive from avoiding flows and sedimentation. There would be no downstream real estate requirements.

(2) Do not Armor Stump Lake (assume lake fills, overflows, and erodes outlet). The effects in the Devils Lake Basin are the same as with a full lake and include $42.2 million in flood damages, except that $37.2 million in land is recovered as the lake recedes to expected new outlet level. The water quality exceeds standards at all downstream stations and the water is unusable for municipal and industrial needs. Environmental effects would be high and adverse on terrestrial, aquatic, and cultural resources. No real estate acquisitions would be required.

## EMERGENCY PLANS INVESTIGATED FOR OTHER COMMUNITIES IN THE BASIN

The town of Minnewaukan will be provided levee protection up to 1451. Both Churchs Ferry and Minnewaukan are recommended for relocation at higher lake levels. Other actions are shown in Table 3 by feature. Combined costs for actions at all trigger points are shown in Table 4 by elevation.

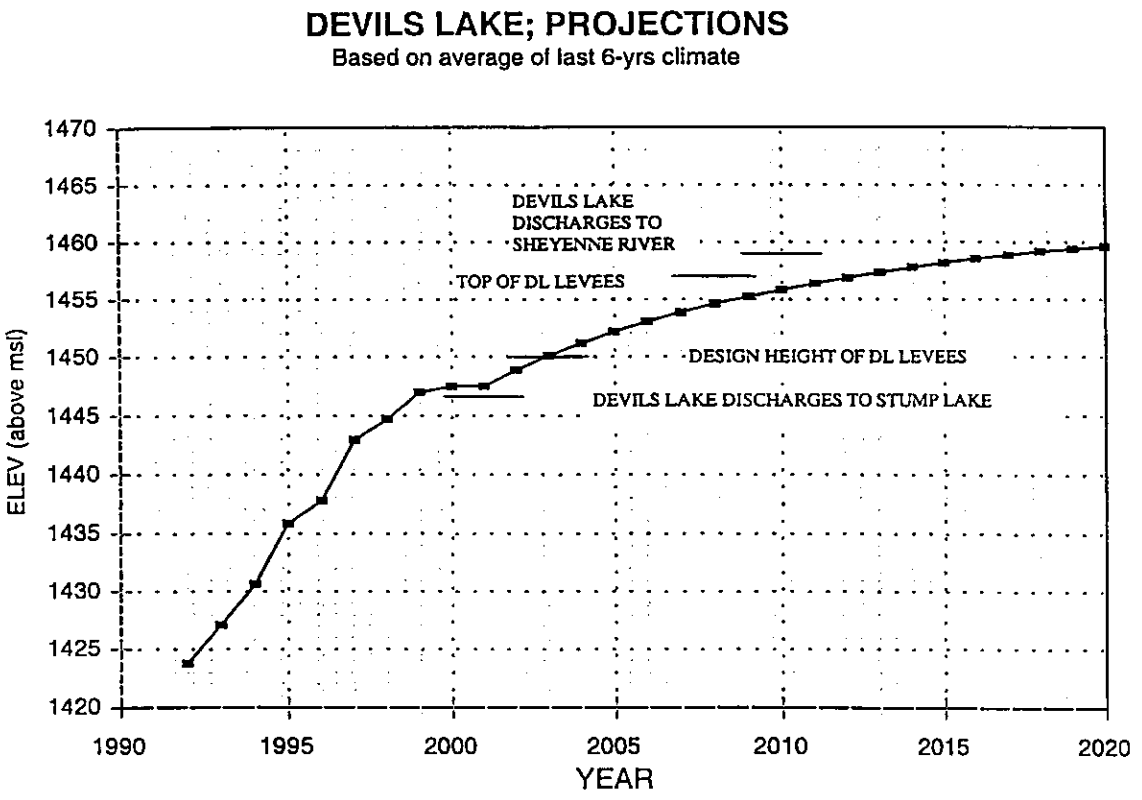


**Figure 1**

# TABLE 1
## Devils Lake Summary Tables
## Scenarios

| # | Conditions | Devils Lake Impacts | Downstream Impacts | Probability Over 20 Years |
|---|---|---|---|---|
| 1. | Full Lake (& No Overtop) | • Flood Damages - $42.2 million.<br>• Local Protection Cost- $525 million<br>• WQ Impacts – Lake chain freshens, especially East Devils Lake and Stump Lake.<br>• Environmental Impacts<br>  • Terrestrial – 155,000 acres inundated.<br>  • Aquatic – Beneficial and adverse impacts.<br>  • Cultural – High adverse, 23 known sites affected.<br>• RE Requirements – None required. | None | 1 in 140 |
| 2. | Full Lake and SPF* | • Flood Damages - $67.4 million.<br>• Local Protection Cost- $525 million<br>• WQ Impacts– Substantially improved due to displacement and dilution of saltier water in East Devils Lake and Stump Lake.<br>• Environmental Impacts<br>  • Terrestrial – 192,000 acres inundated.<br>  • Aquatic – Same as lake full.<br>  • Cultural – High; adverse.<br>• RE Requirements – None required. | • Flood Damages - $2 million<br>• WQ Impacts – Exceeds WQ standards and international objectives on Red River and Sheyenne. Some agricultural users may find the water unsuitable for some purposes, including irrigation and stock watering. - municipal treatment plant?<br>• Environmental Impacts<br>  • Terrestrial – High; adverse.<br>  • Aquatic – High;adverse.<br>  • Cultural – High;adverse.<br>• RE Requirements – None | 1 in 70,000 |

## TABLE 1 (Continued)
## Devils Lake Summary Tables
## senarios

| # | Conditions | Devils Lake Impacts | Downstream Impacts | Probability Over 20 Years |
|---|---|---|---|---|
| 3. | Full Lake and 100-Year* | • Flood Damages - $53.5 million.<br>• Local Protection Cost- $525 million<br>• WQ Impacts – Minor improvement in East Devils Lake and Stump Lake.<br>• Environmental Impacts<br>  • Terrestrial – 179,000 acres Flooded.<br>  • Aquatic – Same as lake full.<br>  • Cultural – High; adverse.<br>• RE Requirements – None required. | • Flood Damages - minimal<br>• WQ Impacts – Exceeds WQ standards on Sheyenne River and Red River. Some agricultural users will find water unsuitable for some purposes.<br>• Environmental Impacts<br>  • Terrestrial – Moderate; adverse.<br>  • Aquatic – High; adverse.<br>  • Cultural – High; adverse.<br>• RE Requirements – None. | 1 in 14,000 |
| 4. | Full Lake and average of recent high inflows* | • Flood Damages - $46.2 million.<br>• Local Protection Cost- $525 million<br>• WQ Impacts – Some improvement in TDS.<br>• Environmental Impacts<br>  • Terrestrial – Same as 100-year.<br>  • Aquatic – Same as lake full.<br>  • Cultural – Same as 100-year.<br>• RE Requirements – None required. | • Flood Damages –Minimal.<br>• WQ Impacts<br>  • WQ standards exceeded on Sheyenne and Red Rivers for as long as 80% of time.<br>  • Some agricultural uses unsuitable at times.<br>• Environmental Impacts<br>  • Terrestrial – Moderate; adverse.<br>  • Aquatic – High; adverse.<br>  • Cultural – Low.<br>• RE Requirements – None. | 1 in 7,000 |

# TABLE 1 (Continued)
## Devils Lake Summary Tables
## Scenarios

| # | Conditions | Devils Lake Impacts | Downstream Impacts | Probability Over 20 Years |
|---|---|---|---|---|
| 5. | Prevent Overtopping from SPF (with a 350 cfs pump running full-time seven months per year) | • **Flood Damages** - $42.2 million.<br>• **Local Protection Cost-** $238 million<br>• **WQ Impacts** – Slight freshening of lake chain.<br>• **Environmental Impacts**<br>  • Terrestrial – Possible beneficial.<br>  • Aquatic – Possible adverse.<br>  • Cultural – Possible beneficial.<br>• **RE Requirements** - $785,000 (620 acres, fee and easement) | • **Flood Damages** - minimal<br>• **WQ Impacts** – Upper Red River TDS standard exceeded but in ambient range.<br>• **Environmental Impacts**<br>  • Terrestrial – Low.<br>  • Aquatic – Moderate; adverse.<br>  • Cultural – Moderate; adverse.<br>• **RE Requirements**<br>• Unknown, but greater than $4,000,000 (16,000 acres flowage easement) | 1 in 16,000 |
| 6. | Armor Stump Lake Outlet (assume Lake full) | • **Flood Damages** - $42.2 million.<br>• **Local Protection Cost**- $525 million<br>• **WQ Impacts** – Lake chain freshens, especially East Devils Lake and Stump Lake<br>• **Environmental Impacts** –<br>  • Terrestrial – 155,000 acres inundated.<br>  • Aquatic – Beneficial and adverse impacts.<br>  • Cultural – High adverse, 23 known sites affected.<br>• **RE Requirements** – Real estate is questionable: if a taking, the cost will be $43,000,000; if not, $10,000 or less | • **Flood Damages *Prevented*** - $35.0 million and protect 100,000-150,000 acres of agricultural land.<br>• **WQ Impacts** – WQ standards directly proportional to any volumes released..<br>• **Environmental Impacts**<br>  • Positive impacts by avoiding flows and sedimentation.<br>• **RE Requirements** – None. | N.A. |

## TABLE 1 (Continued)
## Devils Lake Summary Tables
## Scenarios

| # | Conditions | Devils Lake Impacts | Downstream Impacts | Probability Over 20 Years |
|---|---|---|---|---|
| 7. | Don't Armor Stump Lake Outlet (assume Lake fills, overflows, and erodes outlet) | • **Flood Damages** - $42.2 million.**<br>• **Local Protection Cost**- $525 million<br>• **WQ Impacts** – Significant freshening of lake chain. TDS levels drop below 900 throughout chain.<br>• **Environmental Impacts** – Devils Lake similar to current conditions, but Stump Lake significantly higher than current level.<br>• **RE Requirements** – None. | • **Flood Damages** - $35.0 million and some loss associated with temporary inundation of 100,000-150,000 acres of agricultural land.<br>• **WQ Impacts** – WQ standards exceeded at all downstream stations, unusable for municipal or industrial use.<br>• **Environmental Impacts**<br>  • High and adverse impacts from increased velocities and sedimentation on terrestrial, aquatic, and cultural resources.<br>• **RE Requirements** – None. | N.A. |

* Conditions 2-5 assume no erosion between Stump Lake and the Sheyenne. Emergency Plan 4 (Scenario 6) would be required to assure that assumption.

** As the lake recedes to elevation 1450, lands with a total value of approximately 37.2 million will be returned to production.

# TABLE 2
## Emergency Plans Investigated for Devils Lake Levee and Outlet

| # | Plan | Feature | Lead Time * (Years) | Trigger Point (Elev./Time) | Cost ($1,000) | | Probability |
|---|---|---|---|---|---|---|---|
| | | | | | First Cost | O&M Cost | |
| 1. | **Prevent Overtopping from SPF** | Devils Lake Raise Levees, (1457 + 6 = 1463) | 0/1/1 | 1453.0/2006 | 39 | | 1/16,000 |
| | (Hold lake @ 1454.2, begin operating in 2008) | Outlet Pump – (350 cfs) | ** 3/1/2 | 1450.0/2002 | 64 | 2 | |
| | | Raise Levees and Pump | ** 3/1/2 | 1450.0/2002 | 103 | 2 | |
| 2. | **Prevent Overtopping from 100-Year** | Devils Lake Raise Levees, (1459 + 6 = 1465) | 0/1/1 | 1456.0/2010 | 53 | | 1/7,000 |
| | (Hold lake @ 1456.6, begin operating in 2011) | Pump – (300 cfs) | 3/1/2 | 1452.0/2005 | 59 | 2 | |
| | | Raise Levees and Pump | 3/1/2 | 1452.0/2005 | 112 | 2 | |
| 3. | **Prevent Overtopping from average of recent high inflows** | Devils Lake Raise Levees, (1460 + 6 = 1466) | 0/1/1 | 1458.5/2016 | 58 | | 1/5,000 |
| | (Hold lake @ 1457.8, begin operating in 2014) | Pump – (250 cfs) | 3/1/2 | 1454.5/2008 | 54 | 2 | |
| | | Raise Levees and Pump | 3/1/2 | 1454.5/2008 | 112 | 2 | |
| 4. | **Raise Devils Lake Levee to 1460** | Devils Lake Raise Levee, (1455 + 5 = 1460) | 0/1/1 | Not Applicable | 7 to 9 | | 3 percent chance of 1451 in 2000 |
| 5 | **Armor Stump Lake Outlet** | Sheet pile and Riprap (400 feet) | 3/1/1 | 1457.5/2013 | 1 | | |

* (Typical NEPA Process/Design/Construction).

** Five and one half years (6/1999 through 2004) rather than three years, to complete the NEPA process, is more realistic for such a complex project.

TABLE 3

FEATURES AND ASSOCIATED TRIGGER POINTS

| FEATURE NUMBER | FEATURE | TRIGGER POINT (ELEV./TIME) | | FEATURE DESCRIPTION | COST FEATURED | COMPLETED | DAMAGES PREVENTED |
|---|---|---|---|---|---|---|---|
| | | | | | $'000 | | |
| 1 | CHURCHS FERRY | 1445 | | LEVEE RAISE | | 3,387 | 5,142 |
| | | 1450 | 2003 | LEVEE RAISE | 200 | | 885 |
| | | 1455 | | RELOCATE | 10,277 | | 1,132 |
| 2 | CITY OFDEVILS LAKE | 1446 | | LEVEE RAISE | | 6,113 | 98,750 |
| | | 1447 | | LEVEE RAISE | | 9,491 | 14,990 |
| | | 1449 | | LEVEE RAISE | 9,052 | | 23,600 |
| | | 1452 | | LEVEE RAISE | 43,845 | | 39,440 |
| | | 1457 | | LEVEE RAISE | 23,935 | | 57,600 |
| 3 | FORT TOTTEN | 1446 | | RELOCATION | | 18 | |
| | | 1451 | | RELOCATION | 88 | | |
| | | 1455 | | RELOCATION | 140 | | |
| 4 | MINNEWAUKAN | 1446 | | Relocation | | 371 | 400 |
| | | 1448 | 2001 | Levee | 100 | | |
| | | 1451 | 2004 | Relocation | 2,400 | | 2,900 |
| | | 1456 | | Relocation | 4,328 | | 4,950 |
| 5 | ST MICHAEL | 1445 | | Relocation | | 150 | 150 |
| | | 1450 | | Relocation | 18 | | 25,000 |
| | | 1455 | | Relocation | 420 | | 600 |
| 6 | GRAFTON MILITARY RESERVATION | 1446 | | Road & Levee Raise | | 2,973 | 45 |
| | | 1451 | | Road & Levee Raise | 2,948 | | 0 |
| | | 1456 | | Road & Levee Raise | 5,621 | | 0 |
| | | 1461 | | Road & Levee Raise | 12,257 | | 27,271 |
| 7 | GRAHAM STATE PARK | 1443 | | Levee Raise | | 265 | 300 |
| | | 1449 | | Levee Raise | 3,660 | | 400 |
| | | 1454 | | Levee Raise | 2,103 | | 0 |
| | | 1456 | | Levee Raise | 5,381 | | 0 |
| | | 1461 | | Levee Raise | | 5,944 | 15 |
| *8.1 | DEVIL LAKE RURAL | 1443 | | Structure Relocate | | 1,737 | |
| | | 1444 | | Structure Relocate | | 1,432 | |
| | | 1445 | | Structure Relocate | | 1,432 | |
| | | 1447 | | Structure Relocate | | 1,432 | |
| | | 1448 | | Structure Relocate | | 1,409 | |
| | | 1450 | | Structure Relocate | 1,397 | | |
| | | 1451 | | Structure Relocate | 1,397 | | |
| | | 1453 | | Structure Relocate | 1,315 | | |
| | | 1554 | | Structure Relocate | 1,151 | | |
| | | 1556 | | Structure Relocate | 3,096 | | |
| | | 1460 | | Structure Relocate | | 3,185 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| "8.2 | STUMP LAKE RURAL | | 1443 | | Struct. Relocate | | 339 | |
| 9 | CPR DEVILS LAKE TO HARLOWE | | 1449 | | Raise Tracks | 15,835 | | |
| | | | 1454 | | Raise Tracks | 19,462 | | |
| | | | 1459 | | Raise Tracks | 34,523 | | |
| 10 | CPR ALONG US HWY 2 | | | | TEMP CLOSURE DURING FLOODING | | | |
| 11 | BN ALONG US HWY 2 | | 1455 | | ROAD RAISE | 10,403 | | |
| | | | 1460 | | ROAD RAISE | | 26,902 | |
| 12 | BN CHURCHS FERRY TO CANDO | | 1453 | | Raise Tracks | 9,997 | | |
| | | | 1458 | | Raise Tracks | 18,886 | | |
| | | | 1463 | | Raise Tracks | | 16,319 | |
| 13 | US HWY 2 | | 1453 | | ROAD RAISE | 31,647 | | |
| | | | 1458 | | ROAD RAISE | 33,137 | | |
| | | | 1463 | | ROAD RAISE | | 31,998 | |
| 14 | HWY 57;HWY 20 TO BIA 1 | | 1454 | | ROAD RAISE | 4,103 | | |
| | | | 1459 | | ROAD RAISE | 4,955 | | |
| 15 | HWY 57; BIA 1 TO HWY 281 | | 1446 | | ROAD RAISE | | 8,839 | |
| | | | 1451 | | ROAD RAISE | 7,113 | | |
| | | | 1456 | | ROAD RAISE | 9,536 | | |
| | | | 1461 | | ROAD RAISE | | 11,722 | |
| 16 | HWY 281 SOUTH OF US HWY 2 | | 1443 | | ROAD RAISE | | 11,805 | |
| | | | 1448 | | ROAD RAISE | | 24,603 | |
| | | | 1453 | | ROAD RAISE | 27,199 | | |
| | | | 1458 | | ROAD RAISE | 31,241 | | |
| | | | 1463 | | ROAD RAISE | | 28,249 | |
| 17 | HWY 281 NORTH OF US HWY 2 | | 1451 | | ROAD RAISE | 8,776 | | |
| | | | 1456 | | ROAD RAISE | 16,254 | | |
| | | | 1461 | | ROAD RAISE | | 23,843 | |
| 18 | HWY 19- Devils Lake to Hwy 281 | | 1446 | | Road Raise | | 22,203 | |
| | | | 1451 | | Road Raise | 16,184 | | |
| | | | 1456 | | Road Raise | 24,568 | | |
| | | | 1461 | | Road Raise | | 29,042 | |
| 19 | HWY 1 | | 1409 | | Relocate | | 7,205 | |
| 20 | HWY 20 N DEVILS LAKE LEVEE | | 1459 | | Raise Road | 22,170 | | |
| 21 | HWY 20 BTWN DEVILS LAKE LEVEE & HWY 57 | | 1446 | | ROAD RAISE | | 6,757 | |
| | | | 1451 | | ROAD RAISE | 4,508 | | |
| | | | 1456 | | ROAD RAISE | 6,364 | | |
| | | | 1461 | | ROAD RAISE | | 6,889 | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 20 BTWN 57 AND TOKIO | | | | 1446 | | ROAD RAISE | | 19,592 | |
| | | | | | 1451 | | ROAD RAISE | 13,090 | | |
| | | | | | 1456 | | ROAD RAISE | 15,437 | | |
| | | | | | 1461 | | ROAD RAISE | | 19,642 | |
| | | | | | | | | | | |
| 23 | BIA 1 BTWN HWY 57 AND BIA 6 | | | | 1446 | | ROAD RAISE | | 2,311 | |
| | | | | | 1451 | | ROAD RAISE | 2,381 | | |
| | | | | | 1456 | | ROAD RAISE | 2,859 | | |
| | | | | | 1461 | | ROAD RAISE | | 3,698 | |
| | | | | | | | | | | |
| 24 | BIA 6 BTWN HWY 20 AND FORT TOTTEN | | | | 1443 | | ROAD RAISE | | 131 | |
| | | | | | 1448 | | ROAD RAISE | | 1,102 | |
| | | | | | 1453 | | ROAD RAISE | 3,040 | | |
| | | | | | 1458 | | ROAD RAISE | 3,661 | | |
| | | | | | 1463 | | ROAD RAISE | | 3,433 | |
| | TOTAL | | | | | | | 545,138 | 345,963 | |
| | | | | | | | | | | |

TABLE 4
COMBINED COSTS AT ALL TRIGGER POINTS

| TRIGGER POINT | COSTS | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1409 | 7205 | | | | | | | | 7,205 |
| 1443 | | 11,805 | 265 | | 1,737 | | 131 | | 13,938 |
| 1444 | | 1,432 | | | | | | | 1,432 |
| 1445 | 3,387 | 150 | 1,432 | | | | | | 4,969 |
| 1446 | 28,687 | 18 | 2,973 | | 8,839 | 6,757 | 2,311 | | 49,585 |
| 1447 | 9,491 | | 1,432 | | | | | | 10,923 |
| 1448 | | 24,603 | 1,409 | | | | 1,102 | | 27,114 |
| 1449 | 9,052 | 3,660 | 15,835 | | | | | | 28,547 |
| 1450 | 200 | 18 | 1,397 | | | | | | 1,615 |
| 1451 | 2,400 | 13,178 | 2,948 | | 7,113 | 20,692 | 11,157 | | 57,488 |
| 1452 | 43,845 | | | | | | | | 43,845 |
| 1453 | 9,997 | 27,199 | 1,315 | | 31,647 | | 3,040 | | 73,198 |
| 1454 | | 2,103 | 1151 | | 4,103 | | | | 7,357 |
| 1455 | 10,417 | 420 | | | | | | | 10,837 |
| 1456 | 4,328 | 20,818 | 5,621 | | 9,536 | 30,932 | 19,113 | | 90,348 |
| 1457 | 23,935 | | | | | | | | 23,935 |
| 1458 | 18,886 | 31,241 | | | 33,137 | | 3,661 | | 86,925 |
| 1459 | | | | | 4,955 | 22,170 | | | 27,125 |
| 1460 | | | 3,185 | | | | | | 3,185 |
| 1461 | 52,885 | 5,944 | 0 | | 11,722 | 6,889 | 3,698 | | 81,138 |
| 1462 | | | | | | | | | 0 |
| 1463 | 16,319 | 28,249 | | | 31,998 | | 3,433 | | 79,999 |
| | | | | | | | | | |
| | | | | | | | | | 451,220 279,488 |
| | | | | | | | 730,708 | | |
| | | | | | | | | | |

Trigger/action levels were assumed to occur 1 foot below the design level of protection to provide lead time for construction of protection measures before damages would occur. Additional lead time may be required for those features accepted as advance measures.

## RECOMMENDATIONS

1. Establish six (6) feet of freeboard as design standard for advance measures on Devils Lake.

2. Immediately proceed with necessary reports and PCA Amendment to raise Devils Lake Levee to TOL 1460.

3. Raise Devils Lake levee ASAP to TOL 1460.

4. Complete Interim Report to Congress within 30 days. Interim Report will target holding lake level at elevation 1454 or lower.

5. Immediately initiate Final Report to Congress and continue NEPA compliance. Plan completion to allow initiation of P&S when lake reaches elevation 1452 (about 2005) and construction at lake elevation 1453 (about 2006).

6. Continue to define trigger points for other actions around the lake. Provide incremental protection for Churchs Ferry, Minnewauken, Spirit Lake Nation, and other communities in accordance with PL 84-99 and in coordination with local, State and other Federal interests.

## ATTACHMENT 1

## DEVILS LAKE STUDY
## REAL ESTATE IMPACTS

### ASSUMPTIONS

Real estate impacts identified for this report are based on the following assumptions:

1. The "No Action" condition assumes Devils Lake is full (elevation 1459). Four possible scenarios were given: the lake is full, an SPF occurs, a 100-year flood occurs, or an average of recent high inflows occurs.

2. Four remedies were identified: prevent overtopping from the SPF, prevent overtopping from the 100-year flood, prevent overtopping from the average of recent high inflows, and armor the Stump Lake outlet.

3. The first three remedies all assume that construction and operation of an outlet from the west side of Devils Lake would prevent the overtopping to the Sheyenne River. The outlet would operate 7 months out of the year (May through November) at a constant rate of 350 cubic feet per second (cfs). This operation would prevent the lake levels from rising above elevation 1454.2.

4. The armoring of Stump Lake would consist of placement of rock at the natural Stump Lake outlet at elevation 1459 to prevent erosion of the outlet to a lower elevation.

### "NO ACTION" CONDITION

If Devils Lake rises above elevation 1459, water would be discharged through Stump Lake to the Sheyenne River. Because the increased lake levels and the overflows would be the result of natural occurrences, no real estate interests would be required for any of the four scenarios presented.

### PREVENT OVERTOPPING REMEDIES

As stated above, the prevent overtopping remedies assume an outlet from the west end of Devils Lake to the Sheyenne River. The real estate interests required for an outlet are fee acquisition, permanent channel improvement easements, utility and/or pipeline easements, flowage easements, and temporary work area easements.

In October 1998, a gross appraisal was prepared for an emergency outlet that began at the southwest corner of Devils Lake near Minnewaukan and ran southwest to the Sheyenne River. The approximate length was 13¼ miles.

The value of the fee lands, permanent channel improvement easements, permanent pipeline easements, and temporary work area easements, including administrative costs, was $373,000.

Following completion of the gross appraisal, consideration was given to altering the outlet route so that water would be withdrawn from the "6th box" of Devils Lake, which is in the northwest corner of the lake. This alternate withdrawal location is north of the location proposed in the earlier design. Moving the withdrawal point would take advantage of withdrawing fresher (lower salinity) water from Devils Lake. Real Estate prepared a cost summary for the real estate costs associated with this alignment. The assumptions were 13.77 acres of fee, 534.1 acres of permanent channel easement, 321.25 acres of permanent pipeline easement, 160.62 acres of temporary easement, and severance damages with no residential or farmstead relocations. The total real estate estimate, including administrative costs, was $785,000.

The operating plan for the outlet design evaluated in the gross appraisal restricted the flow of water through the outlet to a maximum of 300 cfs. It also adjusted outlet flows so that the total flow in the Sheyenne River would not exceed 600 cfs. At 600 cfs, the Sheyenne River would not exceed its channel capacity below the discharge point. For this reason, no flowage easements along the Sheyenne River were considered necessary.

The outlet plan being considered by the study team is not constrained by the Sheyenne River's channel capacity. A fixed discharge of 350 cfs would occur regardless of the existing flow in the Sheyenne River. Therefore, if the Sheyenne River were flowing at 250 cfs or greater, flooding due to the discharges from the outlet would occur on downstream areas. The owners of areas flooded from the discharges would need to be compensated through the acquisition of flowage easements.

At this time we have no information on the extent of the flooded area along the Sheyenne River between the Peterson-Coulee Outlet and the Tolna Coulee for the SPF and 100-year events. Acreages, timing, frequency and duration of the increased flooding are required to estimate the value of the flowage easements. A rough estimate that the fee value of agricultural lands along the Sheyenne River generally ranges between $200 and $400 per acre; however, it may vary depending on land use. The percentage of fee value that would be used for the flowage easement is dependent on the timing, frequency, and duration of the flooding and would run between a minimal 5 percent to as much as 100 percent.

The extent of the flooded areas downstream for the 6-year repeat event requires acquisition of 16,600 acres of flowage easements along both sides of the Sheyenne River above the ordinary highwater mark. A rough estimate of the fee value of the agricultural lands was considered to be between $200 and $400 per acre with an approximation of the timing, frequency, and duration of the flooding. The real estate cost summary prepared included land and administrative costs to equal $4,309,000.

Another factor to consider for this remedy is that the Sheyenne River flows along the southern boundary of the Spirit Lake Reservation. Land on the reservation can be of three ownership types: fee lands (private ownership), trust – individually owned Indian allotment, and trust – tribally owned.

Easements on fee lands (privately owned) would be negotiated with the private landowners. If agreement could not be reached with the owners of fee lands, the project sponsor could proceed with condemnation.

Easements on trust – individually owned allotment land would be negotiated with the individual owners. Agreements are processed through the Bureau of Indian Affairs (BIA). If condemnation action were required, the condemnation would have to be filed in Federal District Court.

Easements on trust – tribally owned land would be negotiated with the tribal chairman. If agreement could not be reached, Congress would need to pass legislation authorizing acquisition of these easements.

Because of the different procedures for acquiring easements on reservation trust lands, it is likely that the acquisition would require more time and cost more than acquisition on privately owned lands.

## ARMOR STUMP LAKE OUTLET

This remedy would armor the outlet from Stump Lake to the Sheyenne River at its existing elevation of 1459. If the outlet were not armored, it would erode. Hydraulic analysis has indicated the following two effects from the armoring:

1. By armoring the Stump Lake outlet at 1459, approximately 72,679 acres would remain inundated longer. An additional 13,975 acres around Devils Lake would be similarly impacted but on an occasional basis under the lake full with SPF event.

2. With Devils Lake full and an occurrence of the SPF, the outlet would erode 9 feet in 168 days if erosion were allowed to occur naturally. With the natural outlet, the duration of flooding in Devils Lake above elevation 1450 would be decreased significantly, probably by years.

The acres in the lake basin flooded between the Stump Lake outlet elevations of 1450 and 1459 would remain inundated for a considerably longer time with the outlet armored to prevent erosion. If action is taken to prevent the outlet from eroding naturally, water will remain on these acres for a prolonged period. In this event, it may be necessary to compensate the landowners through flowage easements. The duration was measured in years; therefore, the easement value would approach the full fee value of the land. Real Estate prepared a cost summary for the additional real estate costs associated with this location. The assumptions were 72,679 acres of permanent flowage and 13,975 occasional flowage, 40 residential and 10 farmstead relocations, and approximately 1080 ownerships. The total real estate estimate, including administrative costs, was $43,464,000.

It has not been determined that such "armoring" of the Stump Lake Outlet at its current, natural elevation would necessarily effect a taking of property compensable under the Fifth Amendment to the Constitution. In light of the estimated costs ($43,464,000) associated with the purchase of real property interests, further review of this issue is advisable if this alternative warrants further consideration.

The Fifth Amendment provides that private property shall not be taken for public use without just compensation; nevertheless, where the damage, if any, is merely the incidental consequence of the lawful and proper exercise of a government power, then compensation may not be justly payable. Such a situation is described in a case decided by the United States Supreme Court in Bedford v. United States, 192 U.S. 217, wherein the Federal Government had a revetment created along the banks of the Mississippi River to prevent erosion of the banks from natural causes, which erosion would have worsened a cut-off, leaving the canal to Vicksburg, Mississippi, dry. In turn, some 2,000 acres of land downstream were flooded. The landowners claimed a compensable taking had occurred by reason of the fact that the revetment built to stop the natural erosion near Vicksburg had caused water to continue to inundate their land. The Court held such damages to be an incidental consequence not constituting a taking of the lands flooded within the meaning of the Constitution.

No real estate is required for the downstream effects with the armored outlet.

As with the outlet alternatives, some of the lands affected would be within the reservation. The same procedures would need to be followed to acquire these easements.

## RELATED ISSUES

The North Dakota State Water Commission (NDSWC) is the potential non-Federal Sponsor. General real estate concerns for any alternative requiring acquisition of interests for the project are as follows:

The 1936 Flood Control Act established three major prerequisites for a non-Federal sponsor:

1. Provide the lands, easements, and rights-of-way needed to build the project.

2. Pledge to operate and maintain the constructed facilities for the anticipated life of the project.

3. Agree to indemnify and hold the United States Government harmless from any and all claims of damages resulting from construction, operation and maintenance of the project.

While the NDSWC can very capably acquire the real estate and operate and maintain the project, the ability to indemnify the United States is contravened by Article 1, Section 9, of the North Dakota Constitution. In 1955, the North Dakota legislature passed legislation that created an interim limited waiver of sovereign immunity for State agencies. This waiver remains effective only through 31 July 1997 and limits the State's liability exposure to $750,000 per occurrence. This indemnification is inadequate under the requirements of the 1936 Flood Control Act. If the NDSWC does become the non-Federal sponsor for this project, it will be incumbent upon the North Dakota legislature to pass specific language waiving the State's sovereign immunity for this project for the project to proceed.

Most of the landowners within the outlet alignment are willing to cooperate when final negotiations are conducted. A number of landowners have been devastated by the expansion of Devils Lake and are not willing to participate in the project. A number of landowners want the project moved onto the Reservation totally. It is anticipated that a larger number of condemnations will occur on this project.

A construction award date of October 2000 would require staging the project and initiating the real estate segment by October 1999 to meet the first stage. Continuing concurrently and giving 1-year intervals for completion of the remaining stages of real estate prior to each stage's contract award would allow all real estate to be acquired for the project within the allocated schedule.

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historic 1993-1998

| TABLE 6<br>Model Simulation Assumptions | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Scenario** | **SPF Spill** | **SPF Pump** | **100-year Spill** | **100-year Pump** | **HS6 Spill** | **HS6 Pump** | **SPF Erosion** |
| Starting Elevation | 1454.2 | 1454.2 | 1454.2 | 1454.2 | 1454.2 | 1454.2 | 1454.2 |
| Starting Date | 1 Jan, 2008 | 1 Jan, 2008 | 1 Jan, 2008 | 1 Jan, 2008 | 1 Jan, 2008 | 1 Jan, 2008 | 1 Jan, 2008 |
| 2008-2018 Yearly Inflow (acre-ft) | 324,500 | 324,500 | 324,500 | 324,500 | 324,500 | 324,500 | 324,500 |
| 2008-2018 Yearly Net Evap (inches) | 10.31 | 10.31 | 10.31 | 10.31 | 10.31 | 10.31 | 10.31 |
| 2018 Inflow | 1,152,000 | 1,152,000 | 606,000 | 606,000 | Table XXX | Table XXX | 1,152,000 |
| 2018 Net Evap | 10.31 | 10.31 | 7.9 | 7.9 | Table XXX | Table XXX | 10.31 |
| 2019-2023 Yearly Inflow (acre-ft) | 324,500 | 324,500 | 324,500 | 324,500 | Varies | Varies | Not Simulated |
| 2019-2023 Yearly Net Evap (inches) | 10.31 | 10.31 | 10.31 | 10.31 | Varies | Varies | Not simulated |

April 2018 – April 2019

In April 2018 the SPF, 100-year, and HS6 inflows and net evaporations were applied to the lake. The SPF inflow was loaded as 4 monthly volume inflows of 192,000, 324,000, 324,000, and 192,000 acre-ft from April though July. The 100-year event was loaded as 3 equal monthly inflows of 202,000 acre-feet in April through June. HS6 inflows occurred over the 6-year period 2018 through 2023. Scenario HS6 annual inflow and net evaporation used in the simulations are shown in Table 7. Annual inflows were input to the model as 3 equal monthly volumes during April, May, and June from 2018 through 2023. All scenarios distributed the net evaporation equally throughout the year for simplicity.

| TABLE 7<br>HS6 Yearly Inflow and Net Evaporation Applied to Years 2018 through 2023 | | | |
|---|---|---|---|
| Data Year | Simulation Year | Inflow Volume (acre-ft) | Net Evaporation (inches) |
| 1993 | 2018 | 265,500 | 1.94 |
| 1994 | 2019 | 205,600 | 4.49 |
| 1995 | 2020 | 402,000 | 19.72 |
| 1996 | 2021 | 279,700 | 11.09 |
| 1997 | 2022 | 521,900 | 10.57 |
| 1998 | 2023 | 272,400 | 14.09 |

Post Event Simulation

Average inflow and net evaporation values from the historic years 1993 through 1996 were used during the post event simulation period (years 2019 through 2023) for the SPF and 100-year event simulations. Average annual values for this period are described in Table 6. Average yearly inflows were equally distributed over the months of April, May, and June. Evaporation was assumed to occur throughout the year at equal increments for the sake of simplicity. The HS6 scenario applied in 2018 lasted through 2023, so no post event simulation was required.

Model Output

The COE 5-Box model simulations provide monthly lake elevation, pumped outflow volumes, over flow volumes, and sulfate concentrations for each of the five bays simulated (West Bay, Main Bay, East Bay, East Devils Lake, and the Stump Lake). Monthly TDS, chloride, and hardness concentrations are also computed based on historical relationships with sulfate. Daily outflow and chemical concentrations are computed from the monthly data assuming a constant daily concentration or flow throughtout the month. Daily values outflow and matching concentration data are used as input for HEC-5Q modeling of the respective scenario.

Downstream Economic Reaches

Downstream flood impacts were evaluated to estimate the flood damage potential of additional flows introduced from Devils Lake into the Sheyenne River via the Peterson Coulee outlet or the natural overflow via Tolna Coulee. The 1979 hydrograph was used as the base flow against which the impact of added flows were evaluated.

The study area extends from the point where the Peterson Coulee Outlet enters the Sheyenne River to the Red River and continuing down the Red River to the U.S. – Canadian border. Potential flood damage to urban centers and agricultural reaches within this area were considered. The following urban centers were included: Valley City, Lisbon, Halstad, Grand Forks, Drayton, Oslo, and Pembina. The agricultural reaches evaluated are defined as follows:

Reach 1 – Warwick to Baldhill Dam (referenced at Cooperstown) – note that this reach does not include the area from the outlet insertion point to Warwick; data for this area was not available.

Reach 2 – Baldhill Dam to Kathryn (referenced at Valley City)

Reach 3 - Kathryn to Soo Line Railroad (referenced at Lisbon)

Reach 4 - Soo Line Railroad to RM 76.2 (referenced at Lisbon)

Reach 5 - RM 76.2 to Red River (referenced at Kindred)

Reach 6 - Mouth of Sheyenne to Halstad (referenced at Halstad)

Reach 7 – Halstad to Traill – Grand Forks County line (referenced at Halstad)

Reach 8 – Traill – Grand Forks County line to Grand Forks (referenced at Grand Forks)

Reach 9 – Grand Forks to Drayton (referenced at Oslo)

Reach 10 – Drayton to the border (referenced at Drayton)

The primary hydrologic input to the analysis of downstream impacts consists of discharge hydrographs at each of the reference points for each of the six scenarios considered.

## FULL LAKE SCENARIOS STUDIED (NO ACTION)

## LAKE FULL

Based on the recent high rates of inflow (average for 1993 through 1998), Devils Lake will fill to the elevation 1459 by 2018. Statistically, there is a 0.7 percent chance or 1 in 140 of this occurring in the next 20 years.

a. Basin Effects

(1) Flood Damage

Before the lake reaches elevation 1459, trigger points for the larger towns and communities, as well as rural areas and roads, around Devils Lake would be reached. Levee raises or relocations that provide flood damage protection to lake elevation 1459 are assumed to be completed. Significant resources would be required to provide protection to this level. Approximately $525.0 million in protection works would be required to provide flood damage reduction measures for features from elevations 1449 to 1459. Additional losses of farm land would occur from increases in lake levels from 1449 to 1459. These damages would total $42.2 million for lands lost to production. Damages to lands inundated by the lake were assumed to be equal to the value of the land. Based on data in the Devils Lake Limits Study the site specific flood damage reduction features would be justified.

Costs of providing protection (1449 to 1459 lake level)

| | |
|---|---|
| Churchs Ferry | $ 15.5 million |
| Devils Lake | $ 76.8 million |
| Minnewaukan | $ 6.7 million |
| Fort Totten | $ 0.2 million |
| St. Michael | $ 0.4 million |
| Rural Area | $ 8.4 million |
| State | $ 19.7 million |
| Roads | $397.3 million => all Roads? or only majors? |
| Total | $525.0 million |
| Agricultural Damages | $42.2 million |

Socioeconomic evaluation of the problem of Devils Lake

The social culture of communities could be disrupted as portions of the communities are relocated.

The social structure of communities and townships are disrupted as roads are temporarily closed and existing facilities are separated. There will impacts on local businesses if distance and travel times to these businesses are increased. Residents may be forced to shift their purchasing patterns as access is disrupted.

There may be some encroachment into wetlands by levee construction.

Levee construction may impact historic and archaeological sites, particularly in the Spirit Lake Reservation.

Loss of access to recreational facilities could result in a decrease in recreation in the area.

Tree removal would be required to lengthen and raise levees, which would remove some of the valuable forest resources in the region.

The downtown areas of project area cities contain many of the historic buildings in this area. Relocating the downtown areas would destroy much of the history of the area.

While major roads are temporarily closed due to flooding, access to hospitals is reduced and the distance and time for emergency vehicles to get to emergency care services increases.

If spur lines are closed temporarily due to flooding there may be an increase in the local truck traffic to transport grain and fertilizer. However, it is likely that at high lake levels agricultural activities in the region would be reduced significantly resulting in fewer grain and fertilizer shipments.

Safety may be an issue as roads and railroads are raised with the lake on both sides. There may be problems with soft rail and road beds due to ice and wave action. Roads may have narrower shoulders during construction and there may be damages during construction due to wave and ice action.

There might be an increase in airborne dust particles from road traffic on roads that are temporarily gravel-surfaced during road raises, hampering driver visibility.

(2) Water Quality Impacts

The water quality of the Devils Lake complex would change with increased inflows as the lake rises and dilutes the high concentrations of dissolved solids. The model used in this analysis indicates the TDS concentrations in the lake chain would range from about 850 in the West Bay to 5800 in Stump Lake. Similar patterns would be exhibited in the specific dissolved parameters including sulfate, chloride, and hardness.

(3) Environmental Impacts

**Terrestrial Communities:** If Devils Lake would continue to rise, about 155,000 additional acres would be inundated around Devils Lake and Stump Lake up to elevation 1459. Around Devils Lake, the majority of this acreage is currently cropland and fallow. Wetlands and grasslands are the next largest category of land use. Around Stump Lake, most of this area is currently grassland and wetland with cropland/fallow being the next largest category. These lands would be converted to open water wetland habitat with a corresponding change in wildlife. There are a number of Fish and Wildlife Service Wetland Easements and Waterfowl Production Areas located around the lake.

**Aquatic Communities:** As the lake continues to rise, the Devils Lake fishery resource would expand. Natural reproduction would increase, and the density and size of the aquatic resource would probably shift to larger populations of smaller fish. As the lake continues to rise, the existing waterfowl staging area, aquatic resource, and National Wildlife Refuge at Stump Lake would be lost.

**Cultural Resources:** Much of the area around Devils Lake and Stump Lake has not been surveyed. Between 1447 and 1460, known cultural resources sites that would be adversely affected with the rising lake levels include 9 prehistoric archeological sites, 3 historic archeological sites, and 11 architectural/standing structure sites. There are unverified leads on 2 prehistoric and 5 historic archeological sites, and 12 architectural sites around Devils Lake between these elevations. Known cultural resources sites between elevations 1460 and 1465 feet around Devils Lake include one prehistoric archeological site, three historic archeological sites, and six architectural/standing structure sites. One of the architectural sites is listed on the National Register (Benson County Courthouse in Minnewaukan). There are also unverified leads to two prehistoric archeological sites and three historic archeological sites. There are not any known sites between elevations 1460 and 1465 feet around the Stump Lake. However, there is an unverified lead to one prehistoric archeological site in this area.

(4) Real Estate Implications

No real estate interest acquisition is required for this scenario. Further discussion in Real Estate Attachment.

## LAKE FULL PLUS SPF

There is a 0.7 percent chance of the lake filling in the next 20 years, and an 0.2 percent chance of the occurrence of the SPF. The joint probability of both events is about 1 chance in 70,000.

a. Basin Effects

(1) Flood Damage

If the SPF flood event occurred with the lake at elevation 1459, the lake would rise to a peak level of 1462.2, and there would be significant flooding within the Devils Lake area. Based on the data from the Devils Lake Limits Study there would be no damages in the city of Devils Lake. At a lake elevation of 1457 the levees would be raised to elevation 1470 (top of levee). There would be no damages at the city of Churchs Ferry since structures would be relocated when the lake level reaches 1455. Incremental relocation would occur at an elevation of 1446, and the remaining structures in the city of Minnewaukan would be relocated. In the rural areas structures would be relocated ahead of the rising lake until elevation 1459. The SPF event would cause approximately $4.5 million in structure damage to those structures above elevation 1459. Additional agricultural damages would occur to those lands above elevation 1459. The impact of flooding these lands for six years while the flood recedes was evaluated to provide a consistent period for analyzing each of the assumed scenarios. These damages would be approximately $18.3 so that total cumulative agricultural damages in the Devils Lake basin would be $60.5 million. Damages to state facilities would total $0.4 million at Grahams Island State Park. Total damages for all categories are estimated to be $67.4 million.

| | |
|---|---|
| Structure Damage Urban (Devils Lake) | $ 0.0 million |
| Structure Damage Rural (Devils Lake) | $ 4.5 million |
| Damage to State Facilities | $ 0.4 million |
| Structures (Downstream) | $ 2.0 million |
| Agricultural Damage (Devils Lake) | $ 60.5 million |
| Agricultural Damage (Downstream) | minimal |
| Total Damages | $ 67.4 million |
| Cost of Protection Works | $525.0 million |

(2) Water Quality Impacts

The water quality of the lakes after the passage of the SPF would be substantially improved by the eastward movement of fresh water, displacing and diluting of the saltier water in East Devils Lake and Stump Lake. The TDS in East Devils Lake drops from 2300 mg/l to about 1400, and in Stump lake from 5800 to about 3800 mg/l.

(3) Environmental Impacts

The conditions would be similar to the Lake Full scenario with some improvement in overall water quality due to the outflow from the east end of the lake system. This would benefit natural reproduction in the lake. About 37,000 acres of additional land would be inundated by the surcharge to elevation 1462. This would result in the loss of some vegetation. Most of the impacts from an overflow scenario occur to the downstream ecosystem.

(4) Real Estate Implications

No real estate interest acquisition is required for this scenario. Further discussion in Real Estate Attachment.

b. Downstream Effects

In evaluating the full lake scenarios, the impacts of the natural overflow discharges over and above the base flow condition (in this case, the 1979 hydrograph) were considered. Incremental impacts of the natural overflows on downstream agricultural reaches and urban centers are discussed below.

(1) Flood Damage

Under this scenario the SPF event occurring over a full Devils Lake results in a peak outflow in the summer of 1,740 cfs. This increment of flow on top of the base flow (assumed to be 1979 conditions) will result in minor additional flooding in Reaches 1 through 4 totaling less than 500 acres. Averaged over the length of these reaches, this is an insignificant impact. The minimal effect is due to the flood storage effect of Lake Ashtabula and to the relatively low prevailing base flows. Added natural overflows are not sufficient to cause significant flooding. In Reach 5, the addition of natural overflow discharges results in minor flooding conditions also. Area flooded is estimated to range from 1,000 to 1,500 acres, still a minor impact given the size of the reach. On the Red River, no effects are anticipated since the additional flows would be contained well within the channel limits during the summer months.

In subsequent years, overflows slowly diminish from 550 cfs at the start of Year 2 to about 100 cfs at the end of Year 4. These flows will have slightly adverse impacts on flooding conditions downstream when base flows are near or exceed channel capacity. Additional area flooded in Year 2 of this scenario, the year when recessionary flows from the previous year's SPF event will be highest, is on the order of 1,000 acres scattered over the length of Reaches 1 to 4 of the Sheyenne River. This is a relatively insignificant impact. The magnitude of impacts in Reach 5 in later years are unknown but the would likely be minor in nature also.

No urban areas are affected in Year 1 by the additional discharges from the natural overflow of the SPF event on a full Devils Lake. Lake Ashtabula reservoir stores some of the peak flow thus reducing flood potential downstream. The peak outflow of 1,740 cfs occurs in the summer when the river channel can easily absorb the additional flow. However, based on hydrographs used for this analysis, additional outflows after Year 1 when base flows exceed channel capacity can induce damages. In this analysis, Devils Lake outflows of 450 cfs on top of peak base flows in April of Year 2 of about 7,000 cfs increase damages at Valley City from $14.7 million to $16.4 million, or an incremental impact of $1.7 million attributable to the Devils Lake natural outflows. Similarly, at Lisbon, additional damages due to Devils Lake outflows are estimated at $270,000. Negative effects on urban areas farther downstream may be expected but their extent would be considered negligible.

(2) Water Quality Impacts

The water quality of the Sheyenne River and downstream to the Red River are impacted by an SPF discharge from the lakes. With the overtopping of the natural outlet at Tolna Coulee in 2018, the high flows carry high concentrations of dissolved solids and associated conservative constituents typically seen in the Stump Lake and East Devils Lake basins. In the case of TDS, concentrations would exceed 4800 mg/l on the upper Sheyenne River (represented by the Cooperstown control point) and the lower Sheyenne River below Baldhill Dam (represented by the Valley City control point). On the upper Red River of the North (represented by the Halstad control point), the TDS concentrations would be elevated to 3600 mg/l, and to about 2400 mg/l on the lower Red River and at the Canadian border at Emerson, Manitoba. These high concentrations remain above the 500 mg/l water quality standards and international objectives applicable to the Red River of the North at all locations for at least 9 months during the first year. The standards for chloride and sulfate would also be exceeded for similar duration. The magnitude and duration of the exceedances on the Red River are highly dependent on the volume of spill from Stump Lake. In succeeding years, the flows from the lakes diminish, resulting in improved water quality downstream. Water quality would improve in succeeding years as flows from the lake diminished, but would remain above standards for several years. For example, chloride levels at Cooperstown would exceed standards by as much as two to three times for up to 24 months after the spill was initiated.

Downstream water users potentially affected by the project would include municipal and industrial and agricultural users. The community water supplies dependent on the affected streams include: Valley City on the Sheyenne River; Fargo, Grand Forks, Grafton, Pembina, Draton, in North Dakota; and Letellier, and Morris in Manitoba. The expected hardness conditions resulting from the natural spill scenarios would not exceed the capabilities of any of these facilities to meet their finish water objectives but would entail additional costs for chemical applications, holding times, and labor. Water may not be treatable to meet secondary drinking water standards for sulfate and TDS without resorting to an ion exchange process or an alternate raw water source. Agricultural users who may use this water for irrigation of barley, corn, or wheat; or for truck farming, nurseries, stock watering, or golf courses; may find the water unusable at times during the natural spill event.

(3) Environmental Impacts

**Flow Regime:** An overflow event of this magnitude would have a peak discharge of over 1700 cfs during the first year. Subsequent years would have an average discharge of between 250-500 cfs during the second year and 150 cfs the following 4 years. By comparison, mean monthly flows on the Sheyenne River near Cooperstown range from around 11 cfs in January to a high of 549 cfs in April. Mean monthly flows near Lisbon ND (below Baldhill Dam) range from a low of 25 cfs in October to a high of 600 in April.

**Erosion:** A natural overflow to the Sheyenne River of such magnitude and duration could have substantial erosion effects on the Sheyenne River. To estimate the potential increase erosion due to the SPF overflow hydrograph, a comparison of historic aerial photography and 1998 aerial photography was used to determine the historic rate of channel migration of the Sheyenne River. The number of days of high flow conditions from the SPF overflow hydrograph was then compared to the number from historic gage records. Estimates of erosion for various segments of the Sheyenne River (figure 16) were then made based on the ratio of these durations.

Figure 16. Sheyenne River Segments

The following table shows the mean distance of predicted channel migration, the number of acres expected to be lost due to erosion, and the equivalent number of years of erosion associated with normal flow conditions.

TABLE 8. Effects of SPF Overflow from Devils Lake on Sheyenne River Erosion

| Reaches | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Mean Channel Migration Due to SPF Overflow (feet) | 3.1 | 4.0 | 6.9 | 5.3 | 9.6 | 6.0 | 11.3 | 7.8 |
| Area Eroded in Acres | 20 | 17 | 70 | 45 | 96 | 38 | 53 | 40 |
| Number of Historical Years of Typical Erosion Equal to Predicted SPF Overflow Erosion | 12 | 12 | 14 | 14 | 18 | 20 | 19 | 20 |

This evaluation indicates that an SPF overflow event could result in the loss of about 380 acres due to erosion and a channel migration of up to 11 feet in some reaches. The equivalent of between 12 to 20 years of erosion could occur with the SPF overflow event, depending on the location along the Sheyenne River. Effects would be more pronounced above Baldhill Dam as the channel capacity is smaller. A more detailed erosion model that incorporates a fuller range of erosion mechanisms is being developed as part of the emergency outlet study. The results of that model may indicate that erosion effects would be different than stated here.

**Ground Water:** Limited groundwater studies have been conducted along the lower Sheyenne River. Based on the limited studies conducted to date, it is estimated that a 300 cfs flow event could result in an increase of up to about 1.5 feet in ground water elevations near the river. At a distance of about 1500 feet, the effect would be less than 4 inches. No effect was predicted further than 2100 feet from the Sheyenne River. Groundwater studies were modeled with a controlled outlet flow; therefore, these groundwater effects are for the subsequent years after the initial peak discharge during the first year. The magnitude and extent of the effects on ground water would decrease as the flows declined over the duration of the overflow event. This could potentially affect about 100,000 acres of riparian lands along the Sheyenne River.

**Terrestrial Communities:** Effects on the terrestrial communities would range from losses associated with erosion (380 acres) to changes in vegetation composition and density as a result of saturated soil conditions from prolonged flooding and elevated groundwater levels. The degree of change that may occur due to changes in soil conditions cannot be quantified without detailed studies. However, it is likely that a large portion of the riparian vegetation would shift from woods to a more open community type, resulting in a concurrent change in animal species composition along

the river. Changes in water quality to a more saline condition could also influence the amount and type of vegetation along the river. Some of the larger overstory forest trees may survive a year or longer but with reduced vigor. Once the SPF overflow event is completed, recovery of these areas through succession would occur, which could take decades in some areas.

**Aquatic Communities:** Depth, velocity, substrate, and cover are flow-dependent physical habitat features which play a vital role in governing the distribution and abundance of stream fishes and macroinvertebrates. Because changes in stream flow translate into changes in these habitat features, stream flow alteration can adversely alter the structure, function and composition of stream communities by altering the availability of various habitat types on both spatial and temporal scales.

Stream dwelling species are adapted to and have evolved with the natural hydrograph of the stream system they inhabit. Different life-stages of stream dwellers may require different habitat types as defined by flow. For example, the smallmouth bass is well adapted to riverine life. While preferring shallow, low velocity conditions for spawning and juvenile development, adult smallmouth bass prefer deep, moderate velocity habitat. The seasonal hydrograph of most riverine systems provides a variety of flow related habitat conditions. Alteration of the natural hydrograph often results in the loss of one or more important habitat types resulting in a habitat bottleneck with resulting reduced system productivity.

To evaluate the potential effects of overflow events on the aquatic community along the Sheyenne River, the hydraulic conditions present through selected habitat reaches on the Sheyenne River were modeled using a 2-dimensional model. These simulations provided depth averaged velocity contour and velocity maps of each habitat reach, as well as bathymetry. The velocity and bathymetry output for a variety of stream discharge conditions was then entered in a GIS database and analyzed using Arcview 3.1.

Significant adverse impacts on aquatic habitat availability and suitability would be expected with an SPF overflow event. The most flow sensitive habitat types, such as riffles where shallow, fast habitats predominate, would be almost entirely absent from the habitat matrix for an extended time period. Hydraulic and habitat modeling indicates that at discharges above approximately 400 cfs the habitat matrix would be dominated by deep pool habitat. The loss of these habitat types would adversely affect species life-stages which are dependent on shallow, fast water for spawning, feeding, or other life requisites provided by riffles. Other habitat types such as shallow, slow habitat would also be significantly reduced. The largest adverse impacts on habitat would likely occur in the Sheyenne River above Lake Ashtabula. Of the fish species present in the Sheyenne River that might be considered obligate riverine species, all have one or more life-stages that prefer shallow-pool, slow riffle or fast riffle habitat. The chronic loss of these habitat types with an SPF overflow event would have significant adverse impacts on obligate riverine species.

In addition to the adverse impacts on habitat caused by the significant changes in stream flow, the physical changes in channel geometry caused by the increased occurrence of bankfull or channel forming flows would also result in a loss of suitable habitat for many aquatic species.

The projected changes in Total Dissolved Solids (TDS) concentrations in the Sheyenne River would also contribute to adverse impacts on aquatic resources. An evaluation of the toxicity of ambient waters from the Sheyenne River, Devils Lake, and East Devils Lake on fathead minnows, *Cerodaphnia spp.* and algae, revealed that East Devils Lake water (TDS concentrations of about 5,700 ppm) was acutely lethal to *Cerodaphnia spp.* Initially, a natural overflow of Devils Lake would result in TDS concentrations approaching/exceeding 5,700 ppm. This projected TDS level would be acutely toxic to *Cerodaphnia spp.* and potentially lethal to other important food-chain organisms. The loss of food-chain organisms would cascade through the food chain, resulting in lost productivity.

The anticipated mixing of waters associated with a natural spill could result in algal blooms with significant adverse impacts on aquatic resources. Bioassay studies with various mixtures of Sheyenne River water and Devils Lake water caused a statistically significant stimulation of algal growth. Increases in algal concentrations would have synergistic effects on other water quality parameters, including dissolved oxygen concentrations, $CO_2$ concentrations, pH, alkalinity, and the carbonate-bicarbonate balance.

The loss of habitat due to increased flows, changes in channel geometry, loss of overbank cover and sedimentation, coupled with changes in water quality and algal growth would all contribute to a substantial change in the aquatic community present in the Sheyenne River. Projected TDS levels associated with the SPF overflow event would adversely influence fish reproduction and result in lost-year classes. The cumulative result of all these changes would be a decrease in diversity and density of aquatic species in the Sheyenne River. The threshold chloride levels for some aquatic species, such as mussels, would be far exceeded with a natural overflow and could, therefore, be eliminated from the system.

Erosion and sedimentation would increase with a natural overflow of this magnitude. It is expected that there would be an increase in the amount of sediment deposited in the upper end of Lake Ashtabula. This combined with the increase in sulfate and TDS levels would greatly influence the aquatic resources in the lake. A decrease in species diversity and abundance in Lake Ashtabula would be expected.

The changes in the aquatic community would persist for many years after the SPF overflow event is completed, especially on the Sheyenne River above Lake Ashtabula. The only source for recolonization in this reach of the river would be from fish populations above the insertion point of the spill as Baldhill Dam is a barrier to upstream migration of fish.

**Cultural Resources**: Less that 25 percent of the area along the banks of the Sheyenne River has been surveyed for cultural resources. There are 161 prehistoric archeological sites, 34 historic archeologic sites, and 57 architectural/standing structure sites recorded within .25 miles from the Sheyenne River between Peterson Coulee near Devils Lake and Fargo, North Dakota. Accelerated erosion associated with an SPF overflow event could result in the loss of cultural resources sites along the river.

(4) Real Estate Implications

No real estate interest acquisition is required for this scenario. Further discussion in Real Estate Attachment.

## LAKE FULL PLUS 100-YEAR

There is a 0.7 percent chance of the lake filling in the next 20 years, and a 1 percent chance of the occurrence of a 100-year event. The joint probability of both events is about 1 chance in 14,000.

a. Basin Effects

(1) Flood Damage

Assuming that a 100 year event occurred with the lake level at 1459 damages similar to those experienced in the scenario above would be expected. For this analysis a lake elevation would peak at 1461. Expected damages for the cities of Devils Lake, Churchs Ferry, and Minnewaukan are the same as for the SPF analysis. Damages for State facilities were also the same as SPF damages. Rural damages were also estimated to be the same as the SPF damage. Agricultural damages would be incurred for lands between elevations 1459 and 1460. Net returns would be lost for these lands during the time the flood continues. These damages are estimated to be $10.9 million. These damages are in addition to damages incurred between elevations 1448 and 1459. Total cumulative agricultural damages are estimated to be $53.1 million. Total cumulative damages for this scenario are estimated to be:

what about minnewaukan

| | |
|---|---|
| Structure Damage Urban (Devils Lake) | $ 0.0 |
| Structure Damage Rural (Devils Lake) | $ 4.5 million |
| Damage to State Facilities | $ 0.0 |
| Structure Damage (Downstream) | $ 1.5 million |
| Agricultural Damage (Devils Lake) | $ 53.1 million |
| Agricultural Damage (Downstream) | minimal |
| Total Damages | $ 59.1 million |
| Costs of Protection Works | $525.0 million |

(2) Water Quality Impacts

The water quality of the lakes after the passage of the 100-year spill will be improved by the eastward movement of fresh water, displacing and diluting of the saltier water in East Devils Lake and Stump Lake. The TDS in East Devils Lake drops from 2300 mg/l to about 1900, and in Stump lake from 5800 to about 5000 mg/l.

(3) Environmental Impacts

The conditions would be similar to the Lake Full scenario with some improvement in overall water quality due to the outflow from the east end of the lake system. This would benefit natural reproduction in the lake. About 24,000 acres of additional land would be inundated by the surcharge to elevation 1461. This would result in the loss of some vegetation. Most of the impacts from an overflow scenario occur to the downstream ecosystem.

> 13600-0.4

(4) Real Estate Implications

Real estate implications would be the same as those discussed for the full lake with SPF.

b. Downstream Effects

(1) Flood Damage

Under this scenario, the natural overflow resulting from a 100-year event over a full Devils Lake are not of sufficient volume to induce flood damages. Even with the overflow discharges added to the base flows of the 1979 hydrograph, river levels remain well within the channel throughout the length of the Sheyenne River and the Red River of the North.

(2) Water Quality Impacts

The water quality of the Sheyenne River and downstream to the Red River are impacted by 100-year discharge from the lakes. Compared with the SPF case described above, the impact on the Sheyenne River would be similar with respect to dissolved solids, but the effects on the Red River would be less severe. In the case of TDS, concentrations would still exceed 4800 mg/l on the upper and lower Sheyenne River. On the upper Red River, the TDS concentrations would approach 3000 mg/l, and about 1200 mg/l on the lower Red River. These concentrations are still above the 500 mg/l water quality standards and international objectives. The standards for chloride and sulfate would also be exceeded, but for a shorter duration. The effects of the outflows from the lakes in succeeding years would be the same as discussed for the SPF event.

The community water supplies would still be able to meet their finish water objectives for hardness removal, but would probably have to resort to an ion exchange process or an alternate raw water source to meet drinking water objectives for

sulfates and TDS. As with the SPF case, some agricultural users may find the water unusable at times during the natural spill event.

(3) Environmental Impacts

**Flow Regime:** An overflow event of this magnitude would have a peak discharge of over 529 cfs during the first year. Subsequent years would have an average discharge of between 100-150 cfs during the following 5 years.

**Erosion:** The potential for immediate increased erosion would only occur during the first few months following the initiation of this spill event. Average flows in the succeeding years would not result in mean channel velocity levels above 1.5 feet per second. A minor increase in erosion could occur because of the loss of bank vegetation that may result from increased river stages.

**Ground Water:** The flows associated with this event would have minor increases in river stages on the Sheyenne River and would likely have minor effects on ground water elevations and quality. Any effects would likely be restricted to areas immediately adjacent to the river.

**Terrestrial Communities:** There would likely be no measurable changes in terrestrial vegetation communities along the Sheyenne River with an overflow event of this magnitude. However, dramatic changes in the aquatic community may result in changes in animal species present along the riparian corridor. Species dependent on aquatic organisms as a food source would likely be absent from some reaches of the Sheyenne River.

**Aquatic Communities:** The extreme changes in flow immediately following the 100-year overflow event would affect the aquatic habitat on the Sheyenne River above Lake Ashtabula. However, the relatively small change in the flow regime that would result in the succeeding years would have little effect on the composition and distribution of the aquatic habitat matrix in the Sheyenne River. However, the accompanying changes in water quality could have dramatic effects on aquatic communities in the Sheyenne River. These changes would be especially noticeable above Lake Ashtabula where there would be little dilution of the overflow water after it enters the system. In this reach of the river, only species tolerant of extremely high TDS levels would remain. As with an SPF overflow event, the effects on the aquatic community would be persistent and recovery after the event would take many years. Effects on the system below Lake Ashtabula would not be as dramatic as contributing flows from the larger watershed would provide a dilution factor.

**Cultural Resources**: The types and number of cultural sites that could be adversely affected if the lake continues to rise above 1460 cannot be identified this time.

(4) Real Estate Implications

No real estate interest acquisition is required for this scenario. Further discussion in Real Estate Attachment.

## LAKE FULL PLUS 1993-1998 INFLOWS

There is a 0.7 percent chance of the lake filling in the next 20 years, and a 2 percent chance of the occurrence of the 1993-1998 inflows. The joint probability of both events is about 1 chance in 7,000.

### a. Basin Effects

(1) Flood Damage

For this condiction, Devils Lake would peak at 1460.3 feet. Based on existing data it appears that levees and other protection measures that would be put into place at appropriate trigger points up to lake elevation 1459 would provide protection to urban features within the Devils Lake area. The rural structures located at elevations 1457 to 1461 would be relocated at a lake stage of 1456. Damages to lands would be $42.2 million at a lake elevation of 1459. However, the lands between 1459and 1460 would receive flood waters for several years. These damages would total $5.3 million assuming six years of outflow at the current rate of outflow. Total agricultural damages are estimated to be $47.5 million. State facilities would not receive damages at a lake elevation of 1460.

| | |
|---|---|
| Structure Damage Urban (Devils Lake) | $ 1.5 million |
| Structure Damage Rural (Devils Lake) | $ 4.5 million |
| Damage to State Facilities | $ 0.0 |
| Structure Damage (Downstream) | $ 0.0 |
| Agricultural Damages (Devils Lake) | $ 47.5 million |
| Agricultural Damages (Downstream) | minimal |
| Total Damages | $ 53.5 million |
| Costs of Protection Works | $ 525.0 million |

(2) Water Quality Impacts

The water quality of the lakes during the passage of the 6-year historical spill sequence will slightly improve throughout the lake chain. The TDS in East Devils Lake drops from 2300 mg/l to about 1600, and in Stump lake from 5800 to about 4500 mg/l.

(3) Environmental Impacts

The lake elevation with this event, and thus the effects, would be about the same as those associated with the 100-year event.

(4) Real Estate Implications

Real estate implications would be the same as those discussed for the full lake with SPF.

b. Downstream Effects

(1) Flood Damage

Under this scenario, the natural overflow resulting from the 1993 through 1998 inflows over a full Devils Lake are not of sufficient volume to induce flood damages. Even with the overflow discharges added to the base flows of the 1979 hydrograph, river levels remain well within the channel throughout the length of the Sheyenne River and the Red River of the North.

(2) Water Quality Impacts

The water quality effects of the 6-year historical spill scenario result in TDS concentrations, in each annual episode of spill, ranging from 3000 to 4200 mg/l in the upper Sheyenne River and 1800 to 3200 mg/l on the lower Sheyenne River. On the upper Red River, the TDS peak concentrations would range from 700 to 2000 mg/l and on the lower reach from ambient (about 500) to 1000 mg/l. Approach 3000 mg/l, and about 1200 mg/l on the lower Red River. Water quality standards for TDS would be exceeded for approximately 80 percent of the time throughout the 6- year period on the upper reach of the Red River and about 40 percent of the time on the lower reach. The standards for chloride and sulfate would also be exceeded within all four reaches, but for a shorter duration.

The community water supplies would still be able to meet their finish water objectives for hardness removal, but would probably have to resort to an ion exchange process or an alternate raw water source to meet drinking water objectives for sulfate and TDS. As with the SPF case and the 100-year spill, some agricultural users may find the water unusable at times.

(3) Environmental Impacts

**Flow Regime**: An overflow event of this magnitude would have discharges ranging from 35 cfs to 245 cfs over the next 6 years. Four of the 6 years would have an average monthly flow of at least 35 cfs but less than 85 cfs. This increase in discharge would represent an increase of between 2 to 5 times of the normal low winter flow on the Sheyenne River and an increase of 1.5 to 2 times of the normal summer flow.

**Erosion**: The increased flows associated with this overflow event would not have an appreciable effect on the normal erosion along the Sheyenne River.

**Ground Water**: The flows associated with this event would have minor increases in river stages on the Sheyenne River and would likely have minor effects on ground water elevations and quality. Any effects would likely be restricted to areas immediately adjacent to the river.

**Terrestrial Communities**: There would likely be no measurable changes in terrestrial vegetation communities along the Sheyenne River with an overflow event of this magnitude. However, dramatic changes in the aquatic community may result in changes in animal species present along the riparian corridor. Species dependent on aquatic organisms as a food source would likely be absent from some reaches of the Sheyenne River.

**Aquatic Communities**: The minor changes in the flow regime that would result from this overflow event would have little effect on the composition and distribution of the aquatic habitat matrix in the Sheyenne River. However, the accompanying changes in water quality could have the dramatic effects on aquatic communities as described for the 100-year overflow event.

**Cultural Resources**: The types and number of cultural sites that could be adversely affected if the lake continues to rise above 1460 cannot be identified at this time.

(4) Real Estate Implications

No real estate interest acquisition is required for this scenario. Further discussion in Real Estate Attachment.

## EMERGENCY PLANS INVESTIGATED

### PREVENT OVERTOPPING FROM SPF

To prevent overtopping from a SPF, the lake must be held at elevation 1454.2. There is a 3 percent chance of the lake rising to elevation 1454.2 in the next 20 years, and a 0.2 percent chance of the occurrence of the SPF. The joint probability of both events is about 1 chance in 16,000.

a. Basin Effects

(1) Flood Damage

To hold the lake at an elevation of 1454.2 would require significant resources (approximately $238 million) to provide protection to features between 1449 and 1454. Since trigger points above 1454 are not reached there would be cost savings from providing lower lake levels (fewer levee raises and relocation ). Levees at the city of Devils Lake would be raised to elevation 1463 (top of levee). Levees around Churchs Ferry would be raised to elevation 1455 (relocate above 1455), and structures in the city of Minnewaukan would be relocated above 1464. Cost savings from not building the additional works from elevation 1455 to 1459 would be approximately $287 million. However, if an SPF event did occur the lake level would be within the freeboard of the levees of these population centers. Damages could occur if levees are overtopped. Combined damage in excess of $250 million could result if these levees are overtopped. Some rural structures not yet removed from the flood plain would be flooded. Damages to these structures are estimated to be $4.4 million. Agricultural damages for holding the lake at elevation 1454.2 would be $22.1 million. If the SPF occurred there would be agricultural damages between elevations 1455 and 1459. Since these lands would be flooded for several These damages are estimated to be $20.1 million. First costs for the outlet facility would be $64 million with annual pumping costs of $2million.

| | |
|---|---|
| Structure Damage Urban (Devils Lake) | $ 0.0 |
| Structure Damage Rural (Devils Lake) | $ 4.4 million |
| Damages State Facilities | $ 0.0 |
| Structure Damage (Downstream) | $ 0.0 |
| Agricultural Damages (Devils Lake 1449 -1554) | $ 22.1 million |
| Agricultural Damages (Devils Lake 1455-1559) | $ 20.1 million |
| Agricultural Damages (Downstream) | $ 0.0 |
| Total Damages | $ 51.1 million |

(2) Water Quality Impacts

The TDS condition of the Devils Lake chain at the beginning of the scenario in the year 2008 would range from 800 mg/l in West Bay to 6300 mg/l in Stump Lake. At the time of the modeled SPF (2018), pumping 350 cfs from West Bay to prevent overtopping would allow slight freshening of the lake chain with TDS concentrations ranging from 700 mg/l in West Bay to 6000 mg/l in Stump Lake.

here it is fresher / on pg. 55 it is less.

(3) Environmental Impacts

The operation of a constructed outlet from the west end of the lake would prevent the lake from exceeding an elevation of about 1459. This would be about 3 feet lower than without the outlet conditions and allowing a natural flow from Tolna Coulee. This would prevent the inundation of about 23,000 acres of habitat between 1459 and 1462. Some cultural sites would also be subject to less inundation. The lake would be slightly more saline with the west end outlet because it would remove some of the fresher water. This could have some effect on the aquatic resources of the lake. A number of Wetland Easements and Waterfowl Production Areas would not be inundated as a result of the outlet operation.

(4) Real Estate Implications

The prevent overtopping remedies assume an outlet from the west end of Devils Lake to the Sheyenne River. The real estate interests required for an outlet are fee acquisition, permanent channel improvement easements, utility and/or pipeline easements, flowage easements, and temporary work area easements.

In October 1998, a gross appraisal was prepared for an emergency outlet that began at the southwest corner of Devils Lake near Minnewaukan and ran southwest to the Sheyenne River. The approximate length was 13¼ miles.

The value of the fee lands, permanent channel improvement easements, permanent pipeline easements, and temporary work area easements, including administrative costs, was $373,000.

Following completion of the gross appraisal, consideration was given to altering the outlet route so that water would be withdrawn from the "6$^{th}$ box" of Devils Lake, which is in the northwest corner of the lake. This alternate withdrawal location is north of the location proposed in the earlier design. Moving the withdrawal point would take advantage of withdrawing fresher (lower salinity) water from Devils Lake. Real Estate prepared a cost summary for the real estate costs associated with this alignment. The total real estate estimate, including administrative costs, was $785,000.

For more details, see Real Estate Attachment.

b. Downstream Effects

(1) Flood Damage

Under this scenario, the outlet adds 350 cfs of flow into the Sheyenne River from May 1 to Nov 30 in order to prevent natural overflows from Devils Lake via Tolna Coulee. Like the "full lake" scenarios, the 1979 hydrograph is used as the base flow condition. The following considers the impacts of this additional flow downstream of the outlet.

Examination of the hydrographs and damage curves reveals that no damages would be induced downstream because the additional flow from the emergency outlet would be contained within the channel. If base flows were near or exceeded channel capacity during the time of year when the outlet was operating, outlet would then induce damages. This situation was not represented among the hydrographs used in this analysis. Therefore, the effects in terms of induced flood damages were not evaluated.

(2) Water Quality Impacts

The downstream impacts from the pump scnerio are minimal, with the releases from the pumps having concentrations similar to ambient conditions in the Sheyenne River. Sulfates and chloride concentrations increase in the Sheyenne River at Cooperstown and Valley City, but do not exceed state standards. Pumping operations would cause exceedances of the TDS standard on the Red River only on the upper reach, but the concentrations would remain within the normal ambient range. There would be no exceedances of sulfate or chloride standards on the Red River.

(3) Environmental Impacts

**Flow Regime:** Discharges of 350 cfs from May through November for as long as required would represent a 5 to 10 fold increase in summer/fall flows along the Sheyenne River. If the current wet cycle persisted, the outlet could be operated for as long as 30 years. If the hydrologic cycle characterized by the 1950-1996 period of record became established, the outlet could be operated for as few as 3 years.

**Erosion:** The addition of 350 cfs in the river would produce mean channel velocity to levels less than 1.5 feet per second. Due to low mean channel velocity, it is unlikely that noticeable erosion would occur during the months that pumping would be employed. However, the increased discharge would raise water surface elevations by about 1.5 feet. This long-term stage increase would kill existing vegetation in this zone. After several years, the loss of vegetation would likely increase the potential for erosion of the banks during high flow periods. The amount of erosion that could occur cannot be quantified without additional studies.

**Ground Water:** The stage increase associated with a 350 cfs discharge would be similar to the stage increase observed in the limited groundwater studies conducted in 1998. Limited groundwater studies have been conducted along the lower Sheyenne River. Based on the limited studies conducted to date, it is estimated that operation of the outlet could result in an increase of up to about 1.5 feet in ground water elevations near the river. At a distance of about 1500 feet, the effect would be less than 4 inches. No effect was predicted further than 2100 feet from the Sheyenne River. This could potentially affect about 100,000 acres of riparian lands along the Sheyenne River. There would likely be no change in ground water elevations along the Red River.

**Terrestrial Communities:** There would likely be no immediate changes to the terrestrial communities along the Sheyenne or Red Rivers. However, long-term operation of an outlet (greater than 5 years) could result in subtle changes in

vegetation composition and density due to elevated ground water levels. Changes in wildlife species composition and distribution along the Sheyenne River could be the result of these long term shifts in vegetation composition.

**Aquatic Communities**: Although there would be water quality changes associated the operation of an emergency outlet, sulfate levels would generally be below established standards. The most flow sensitive habitat types, such as riffles where shallow, fast habitats predominate, would be substantially reduced under the 350 cfs discharge alternative. Hydraulic and habitat modeling indicates that at discharges above approximately 400 cfs the habitat matrix is dominated by deep pool habitat. The loss of these habitat types would adversely affect species life-stages which are dependent on shallow, fast water for spawning, feeding or other life requisites provided by riffles. Other habitat types such as shallow, slow habitat would also be reduced. The largest adverse impacts on habitat would likely occur in the Sheyenne River above Lake Ashtabula. The long-term chronic loss of shallow, fast habitat types under the 350 cfs scenario would have similar adverse impacts on obligate riverine species, similar to those associated with an SPF overflow event.

Although the potential for physical changes in channel geometry is reduced under the 350 cfs scenario, adjustments in channel geometry may occur as the river attempts to restore a more natural hydrograph. Adverse impacts on aquatic habitats would be a result of these adjustments.

The effect of all these chronic changes in water quality, flow, and channel geometry would likely be a reduction in the diversity and abundance of aquatic species in the Sheyenne River. Species more tolerant of wider fluctuations in water quality and flow would eventually dominate the system. As with other flow events, reestablishment of existing species composition could take decades after the operation of the outlet has ceased.

**Cultural Resources:** Increased overbank flooding during storm events, due to decreased channel capacity, and the potential increase in erosion as the vegetation on the banks is lost could result in an increased potential for the loss of cultural sites located along the Sheyenne River. Because the erosion effects of the increased flow would probably occur gradually, such sites could be protected or removed before they were lost.

(4) Real Estate Implications

The operating plan for the outlet design evaluated in the gross appraisal restricted the flow of water through the outlet to a maximum of 300 cfs. It also adjusted outlet flows so that the total flow in the Sheyenne River would not exceed 600 cfs. At 600 cfs, the Sheyenne River would not exceed its channel capacity below the discharge point. For this reason, no flowage easements along the Sheyenne River were considered necessary.

Why are we "constraining" the outlet now ∴ getting less benefits, but letting her back up if gets higher?

The outlet plan being considered by the study team is not constrained by the Sheyenne River's channel capacity. A fixed discharge of 350 cfs would occur regardless of the existing flow in the Sheyenne River. Therefore, if the Sheyenne River were flowing at 250 cfs or greater, flooding due to the discharges from the outlet would occur on downstream areas. The owners of areas flooded from the discharges would need to be compensated through the acquisition of flowage easements. At this time the extent of the flooded area along the Sheyenne River between the outlets has not been determined; therefore, we are unable to submit any requirements or estimates for the downstream effects.

For more details, see Real Estate Attachment.

## PREVENT OVERTOPPING FROM 100-YEAR FLOOD

To prevent overtopping from the 100-year flood, the lake must be held at elevation 1456.6. There is a 1.4 percent chance of the lake rising to elevation 1456.6 in the next 20 years, and a 1 percent chance of the occurrence of a 100-year event. The joint probability of both events is about 1 chance in 7,000.

a. Basin Effects

(1) Flood Damage

To hold the lake at elevation 1456.6 would require significant resources (approximately $352.6 million) to provide damage reduction for all features between elevation 1449 and 1456.7. There would be cost savings from providing lower lake levels (fewer levee raises and relocation). Cost savings would be approximately $172.4 million. There are agricultural damages that would accrue for lands between elevations 1449 and 1456.7. Agricultural damages are estimated to be $42.2 million. First cost for the outlet facility is estimated to be $59 million with an annual operating cost of $2 million.

| | |
|---|---|
| Structure Damage Urban (Devils Lake) | $0.0 |
| Structure Damage Rural (Devils Lake) | $0.0 |
| Structure Damage (Downstream) | $0.0 |
| Agricultural Damage (Devils Lake) | $42.2 million |
| Agricultural Damage (Downstream) | minimal |
| Total Damages | $42.2 million |
| Cost of Protection to 1456.7 | $352.6 million |

(2) Water Quality Impacts

The TDS condition of the Devils Lake chain at the beginning of the scenario in the year 2011 would range from 800 mg/l in West Bay to 6300 mg/l in Stump Lake. At the time of the modeled 100-year event (2018), pumping 300 cfs from West Bay to prevent overtopping would allow very slight freshening of the lake chain with TDS concentrations ranging from 800 mg/l in West Bay to 6200 mg/l in Stump Lake.

(3) Environmental Impacts

The operation of a constructed outlet from the west end of the lake would prevent the lake from exceeding an elevation of about 1457. This would be about 4 feet lower than without the outlet conditions and allowing a natural flow from Tolna Coulee. This would prevent the inundation of about 51,000 acres of habitat between 1457 and 1461. Some cultural sites would also be subject to less inundation. The lake would be slightly more saline with the west end outlet because it would remove some of the fresher water. This could have some effect on the aquatic resources of the lake.

(4) Real Estate Implications

The real estate impacts within the basin are similar to the Overtopping from SPF. For more details, see Real Estate Attachment.

b. Downstream Effects

(1) Flood Damage

Based on the hydrographs used in this analysis (1979 conditions), the added flows from the emergency outlet are not of sufficient volume to induce flood damages. Even with the outlet discharges (300 cfs) added to the base flows of the 1979 hydrograph, river levels remain well within the channel throughout the length of the Sheyenne River and the Red River of the North.

(2) Water Quality Impacts

Since the pumping scenario for the 100-year event is identical to the SPF case, described above, the effects are the same.

(3) Environmental Impacts

The downstream effects of this scenario would be similar to those described for the SPF event.

(4) Real Estate Implications

The real estate impacts downstream are similar to the Overtopping from SPF. For more details, see Real Estate Attachment.

## PREVENT OVERTOPPING FROM LAST 6 YEARS AVERAGE INFLOWS

To prevent the lake from overtopping from the last 6 years of average inflows, the lake must be held at elevation 1457.8. There is a 1 percent chance of the lake rising to elevation 1457.8 in the next 20 years, and a 2 percent chance of the occurrence of the average inflows from the last 6 years. The joint probability of these events is about 1 chance in 5,000.

a. Basin Effects

(1) Flood Damage

To hold the lake at elevation 1459 would require that protection measures for structures between elevations 1449 and 1459 be completed. This would require approximately $525.0 million. Agricultural lands would be lost between 1449 and 1459 ($42.2 million). No damages would be incurred at the state facilities. First costs of the pumping facility would be $54 million with annual pumping costs of $2 million.

| | |
|---|---|
| Structure Damage Urban (Devils Lake) | $ 0.0 |
| Structure Damage Rural (Devils Lake) | $ 0.0 |
| Damages State Areas | $ 0.0 |
| Structure Damage (Downstream | minimal |
| Agricultural Damage (Devils Lake 1449-1559) | $ 42.2 million |
| Agricultural Damage (Downstream) | minimal |
| Total Damages | $ 44.2 million |
| Cost for Protection (Decision Points 1449-1459) | $525.0 million |

(2) Water Quality Impacts

The TDS condition of the Devils Lake chain at the beginning of the scenario in the year 2014 would range from 800 mg/l in West Bay to 6300 mg/l in Stump Lake. At the time of the modeled 6-year event (2018), pumping 250 cfs from West Bay to prevent overtopping would result in a slight increase of TDS throughout the lake chain ranging from 800 in West Bay to 6400 mg/l in Stump Lake.

(3) Environmental Impacts

The operation of a constructed outlet from the west end of the lake would prevent the lake from exceeding an elevation of about 1456. This would be about 5 feet lower than without the outlet conditions and allowing a natural flow from Tolna Coulee. This would prevent the inundation of about 65,000 acres of habitat between 1456 and 1461. Some cultural sites would also be subject to less inundation. The lake would be slightly more saline with the west end outlet because it would remove some of the fresher water. This could have some effect on the aquatic resources of the lake.

(4) Real Estate Implications

The real estate impacts within the basin are similar to the Overtopping from SPF. For more details, see Real Estate Attachment.

b. Downstream Effects

(1) Flood Damage

This scenario represents a situation where base flows exceed channel capacities and the added flows from the outlet induce damages. Additional area flooded attributable to the increment of outlet flows in Reaches 1 to 4 amount to about 2,000 acres and in Reach 5 approximately 15,000 acres. Effects further downstream along the Red River are considered negligible. Most of the time the additional flows may not seem noticeable from the standpoint of a flood threat. But in those instances when the river's base flow would be near channel capacity or greater, the additional flow originating from the outlet will induce measurable damages in the agricultural reaches.

(2) Water Quality Impacts

Since the pumping scenario for the 6-year event is identical to the SPF and 100-year cases, described above, the effects are the same.

(3) Environmental Impacts

The downstream effects of this scenario would be similar to those described for the SPF event.

(4) Real Estate Implications

The extent of the flooded areas downstream for the "6-year repeat" event requires acquisition of 16,600 acres of flowage easements along the Sheyenne River above the ordinary highwater mark. Real Estate prepared a cost summary which included administrative costs and has a cost estimate of $4,000,000 for this scenario on the downstream effects. Further discussion located in Real Estate Attachment.

## ARMOR STUMP LAKE OUTLET

The Stump Lake Outlet to the Sheyenne River was assumed to be armored for all the events of the lake exceeding elevation 1459. This was to prevent significant scour of the outlet and minimize outflow discharges and sediment contribution downstream.

a. Basin Effects

(1) Flood Damage

If the Stump Lake Outlet is armored the level of the combined Stump Lake-Devils Lake Outlet would not recede to elevation 1450. This would mean that $37.2 million in agricultural land value would not be restored with the lowering of the lake to 1450, since these lands would remain flooded. Roads or railroads that had been abandoned at the lower elevations would not be available to provide for area transportation. Providing this outlet would eliminate the need for any additional protection measures.

| | |
|---|---|
| Damages Prevented | |
| Urban (Downstream) | $ 35 million |
| Agricultural (Downstream) | 50k – 100k acres |
| Damages Induced | |
| Urban (Devils Lake) | $ 0.0 |
| Agricultural (Devils Lake) | $ 37.2 million |

what about in Flushing" of the lake? my guess is drains q' of poor water would greatly improve D.L. WQ

(2) Water Quality Impacts

This scenario assumes that the natural outlet channel is protected from erosion. The water quality of the Devils Lake complex will be similar to the Lake full scenario. TDS concentrations will be diluted with higher lake stages, but the spacial pattern of increasing TDS from West Bay to East Devils Lake remains. Similar spatial patterns would be seen with sulfate, chloride, and hardness.

(3) Real Estate Implications

1. By armoring the Stump Lake outlet at its maximum elevation of 1459, approximately 72,679 acres would remain inundated longer than if the alternative uncontrolled erosion were allowed to occur. An additional 13,975 acres around Devils Lake would be similarly impacted but on an occasional basis under the lake full with SPF event.

2. With Devils Lake full and an occurrence of the SPF, the outlet would erode 9 feet in 168 days if erosion were allowed to occur naturally. With the natural outlet, the duration of flooding in Devils Lake above elevation 1450 would be decreased significantly, probably by years.

The armored outlet would require a channel easement at an approximate real estate costs of $10,000 or less.

The acres in the lake basin flooded between the Stump Lake outlet elevations of 1450 and 1459 would remain inundated for a considerably longer time with the outlet armored to prevent erosion. In this event, it may conceivably be necessary to compensate the landowners through permanent and occasional flowage easements. Real estate costs associated with this scenario, including administrative costs, are approximated to be $43,000,000.

Contrary to the presumption postulated in the preceding paragraph, it has not been determined that such "armoring" of the Stump Lake Outlet at its current, natural elevation would effect a taking of property compensable under the Fifth Amendment to the Constitution. In light of the estimated costs ($43,000,000) associated with the purchase of real property interests, further review of this issue is probably advisable if this alternative warrants further consideration.

The Fifth Amendment provides that private property shall not be taken for public use without just compensation; nevertheless, where the damage, if any, is merely the incidental consequence of the lawful and proper exercise of a government power, then compensation may not be justly payable. Such a situation is described in a case decided by the United States Supreme Court in Bedford v. United States, 192 U.S. 217, wherein the Federal Government had a revetment created along the banks of the Mississippi River to prevent erosion of the banks from natural causes, which erosion would have worsened a cut-off, leaving the channel to Vicksburg, Mississippi, dry. In turn, some 2,000 acres of land downstream were flooded. The landowners claimed a compensable taking had occurred by reason of the fact that the revetment built to stop the natural erosion near Vicksburg had caused water to continue to inundate their land. The Court held such damages to be an incidental consequence not constituting a taking of the lands flooded within the meaning of the Constitution.

For further discussion, see Real Estate Attachment.

b. Downstream Effects

(1) Water Quality Impacts

The water quality downstream will depend on the volume of water discharged through the outlet. Impacts will be similar to the Lake full scenarios with SPF, 100-year, or 6-year scenarios. The higher the volume of water discharged, the greater the impact on water quality. Higher discharges will elevate TDS and associated constituents downstream, impacting water quality standards and Municipal and Industrial users. Impacts to agricultural users may also be expected.