

**Devils Lake Flood Risk Management Project  
Alternatives Screening Documentation**

**U.S. ARMY CORPS OF ENGINEERS  
ST. PAUL DISTRICT**

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### INTRODUCTION

The “Emergency Supplemental Appropriations Act, 2007” provided the Corps with \$5 Million to evaluate the next course of action at the City of Devils Lake should Devils Lake continue to rise. The purpose of this document is to present the results of the screening process for the initial array of alternatives and to identify the alternatives that will be considered in greater detail. All elevations are in NGVD of 1929 adjustment.

**Background:** Devils Lake is a closed basin that has a history of widely fluctuating lake levels. First recorded measurements began in the late 1800’s. The lake elevation was as low as 1400.9 ft. in 1940 and reached its peak-recorded elevation of 1449.2 in May 2006. For the past 4 years lake levels have ranged between 1446.5 ft. and 1449.2 ft. as flows made their way to Stump Lake. Devils Lake has now equalized with Stump Lake, reducing available storage for large flood events. The elevation of both lakes in April 2008 was 1447 ft. If the lake reaches elevation 1459 ft., it will overtop the high point between the lake and Tolna Coulee and flow down the coulee to the Sheyenne River.

Many initiatives have been undertaken in the basin to mitigate for rising lake levels including; numerous road raises, relocation of affected structures, the construction of embankments at the City of Devils Lake, buyouts of some affected property owners, implementation of a Basin Water Management Plan developed by the Devils Lake Joint Board to improve watershed management in the upper basin, wetland restoration through a variety of agency programs, an experimental irrigation program, and the construction of an outlet from the West Bay of Devils Lake to the Sheyenne River. Some of these efforts have had limited success due to lack of participation, funding constraints or operational constraints.

Initial embankments to protect the City of Devils Lake were constructed in the 1980’s to an elevation of 1445 under the Corps of Engineers’ Section 205 program. Since 1996, the embankments have been raised/extended three times, due to rising lake levels, at a total cost of \$53 million. In 1996 embankments were raised to 1450, again in 1997 to 1457, with the most recent raise completed in 2007 with a top of embankment elevation of 1460. The current embankment system is about 8 miles in length along the west, south and east side of the city.

In 2005, an initial evaluation indicated that should the lake continue to rise, the next embankment raise would likely require a substantial extension of the existing embankment to tie into high ground and may require a substantial increase in the existing project footprint. A rough order of magnitude estimate completed at that time indicated that the potential solutions could cost between \$100 – 400 million.

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Studies have shown that the climate condition affecting the lake is currently in a “wet state”, causing Devils Lake to rise. Geological studies have shown that Devils Lake has spilled to Stump Lake at least five times and reached the natural spill elevation to the Sheyenne River twice in the past 2,500 years. Regardless of the water management measures implemented in the upper basin, or the size of the outlet constructed to the Sheyenne River, Devils Lake could continue to rise and eventually overflow from the east end down Tolna Coulee, as identified to have occurred during pre-settlement conditions. While the current probabilities are low, the possibility of such conditions recurring still exists.

The existing embankment system at the City of Devils Lake has a top elevation of 1460. If embankments were going to be retained as the primary approach to reducing flood risk at the City of Devils Lake, construction would need to be initiated several years before the lake reached 1454 due to the length and magnitude of earthwork that would be involved with another embankment raise. The primary purpose of this project is to manage the risk to public safety and flood damages in the City of Devils Lake. The expected product of this effort is to have a defined implementable plan, including plans and specifications if necessary, that can be instituted once the lake reaches a set trigger elevation with a forecast to rise further.

The initial development and screening of alternatives relies primarily on existing information and studies that were conducted as part of Corps of Engineers 2003 outlet study. Much of the information presented or referenced in the Devils Lake North Dakota Integrated Planning Report and Environmental Impact Statement, dated April 2003, (Devils Lake IPR-EIS) was used as a basis for describing potential effects and identifying issues and potential cost for some features or mitigation. While there may have been some changes in resource conditions or lake levels since the completion of that report, the information and analysis presented in that report still reflects current conditions. As such, use of this information is appropriate for the initial screening of alternatives.

**Alternative Development:** Several alternatives have been identified for consideration in evaluating future possible actions at the City of Devils Lake. Input provided at public meetings and directly from stakeholders indicated a desire that the array of alternatives should include actions that would preclude the need for additional embankment raises, or at least minimize the cost of the next embankment raise. The alternatives identified initially for evaluation are; Embankment Raises/Extensions, Relocation, Combination of Embankment Raises/Extensions and Relocation, Modify Elevations at Tolna Coulee, and Upper Basin Storage.

**Alternative Screening Criteria:** Screening criteria were developed to focus evaluation and design efforts on the most implementable alternatives. Given the primary focus of the project, alternatives were initially evaluated to determine if the alternative was effective in maintaining a reliable level of flood risk management at the City of Devils Lake. Other criteria include environmental effects, social effects, expected acceptability, Implementability, risk, and cost.

## **ALTERNATIVES DEVELOPMENT**

Comments from public meetings indicated a desire by several interests to develop basin wide approaches in an effort to prevent or attenuate future lake level rises and prevent an overflow from Devils Lake. Others have suggested that the best approach would be to construct an outlet capable of passing enough flows to prevent the lake from rising further. There are numerous opinions as to whether or not drainage permits have been inappropriately issued or adequately monitored, whether or not past decisions in the upper basin should be reversed, whether or not the Boundary Waters Treaty is even applicable to Devils Lake and why a control structure at Tolna Coulee isn't being developed. Many felt that with the right amount of upper basin storage and the right outlet operation plan, all future damages around Devils Lake may be avoided. Many of these opinions and issues may never be resolved. The development of a basin wide management plan is beyond the scope of this effort. (Note: The Devils Lake Basin Joint Board updated its basin wide plan in 2006) The primary purpose of this effort is identify/develop a plan that can be implemented to reduce the flood risk at the City of Devils Lake should the lake continue to rise.

Six broad categories of alternatives have been identified for initial consideration and evaluation. Cost estimates for each alternative are based on extrapolations or updates of past studies or efforts, and should be considered primarily as representing an order of magnitude first costs estimate for comparison purposes only. They do not include operation and maintenance costs.

## **FUTURE WITHOUT PROJECT CONDITION**

Before any alternatives can be evaluated the without project condition must first be established. This is considered to be the base condition against which the other alternatives are compared. It includes those most likely actions expected to be undertaken in the future in the absence of a Corps' project. Good indicators of expected future actions are those actions taken in the past. If Devils Lake continues to rise, it is assumed that some actions would be taken in an effort to maintain the level of protection afforded by the existing embankment system. It is possible that a limited raise of 1 or 2 feet of the existing embankment system could be implemented without increasing the footprint or extending the existing embankments. Such an approach may require accepting some compromises in standard design criteria for embankments and may result in a structure with more inherent risk of failure. Other selective infrastructure protection measures, such as raising roads, may also be implemented. If Devils Lake continued to rise once a limited raise of the embankments was completed, some portions of the City of Devils Lake may be relocated due to safety concerns. It is assumed that as the lake nears the existing overflow elevation of 1459, some measures to modify the natural outlet would be taken to minimize the potential for severe erosion should an overflow occur. It is assumed that the natural outlet would be altered with potential modifications to the shape, elevation, and outflow capacity of the outlet. There are many political, legal, social, and environmental considerations due to the extent of upstream and downstream interests affected by the action. However, the modified outlet condition is assumed due

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to the potential for catastrophic downstream damages if severe erosion were to occur in conjunction with an overflow event. The implementing agency or government unit can not be identified at this time. The sill elevation, shape, and outlet capacity of the modified outlet has not been defined. However, based on studies completed by the North Dakota Geologic Survey; it is possible that the sill elevation would be less than the current elevation of 1459. Currently, the United States Geological Survey estimates there is a 6 percent probability that Devils Lake will exceed the elevation of 1459 by 2040 and an 11 percent probability that it will exceed 1457.

### **RAISE/EXTEND EXISTING EMBANKMENT AT DEVILS LAKE**

Raise and extend the existing embankment at the City of Devils Lake to ensure a reliable level of risk as the lake rises. Assuming Devils Lake continues to rise, the embankments would have to eventually be raised to an ultimate top elevation potentially as high as 1470 ft. An interim raise would be between elevations 1463 and 1465. The alignment of the embankment raise/extension would depend on decisions regarding whether or not the area currently protected by the existing embankments, or areas not threatened by existing lake levels, should be included in the areas protected by future embankment modifications. Eventual alignments could range from providing the minimal area protected to include critical infrastructure, to providing the maximum area protected in order to maximize protection of all currently protected infrastructure.

**Cost:** Cost of this alternative ranges from \$100,000,000 to \$200,000,000 depending on the alignment and elevation selected for the next interim raise.

### **RELOCATION**

Incrementally relocate structures and infrastructure up to elevation 1464 at the City of Devils Lake as the lake continues to rise. Relocations would be initiated when the protection afforded by the existing embankments are no longer considered reliable.

**Cost:** The cost of this alternative is estimated to be \$412,000,000. This estimate is based on the 2001 Devils Lake Infrastructure Protection Study updated to March 2008.

### **COMBINATION EMBANKMENT RAISE/EXTENSION AND RELOCATION**

A combination of embankment extensions/raises implemented in conjunction with relocations. The type of action implemented in any given area that is currently protected by the embankment system would be based on several factors including; cost, environmental effects, land acquisition, constructability and factors such as transportation and other infrastructure considerations

**Cost:** Cost of this alternative ranges from \$100,000,000 to \$200,000,000 depending on the alignment and elevation selected for the next interim raise.

### **MODIFY ELEVATIONS AT TOLNA COULEE**

Lower the existing overflow elevation at Tolna Coulee from 1459. The final design of this alternative could range from lowering the elevation by as little as 2 feet to as much as 10 feet. Depending on the design elevation, embankments would still need to be constructed at the City of Devils Lake to provide protection at the altered overflow elevation. A comparable design for this alternative could be the construction of a gravity flow outlet from East Devils Lake at some selected elevation in lieu of modifying the overflow elevation at Tolna Coulee.

**Cost:** Cost of this alternative is estimated to range from \$110,000,000 to \$200,000,000. Cost estimates include first costs for construction and mitigation. Construction first costs are estimated to run from \$10,000,000 to \$100,000,000, depending on the design and location for the modification. If implemented as a Federal project, mitigation features must be included in the first costs and implemented concurrent with construction. The total estimated costs include estimated mitigation costs for effects on natural resources (\$40,000,000), effects on cultural resources (\$10,000,000), and effects on water users downstream (\$50,000,000). The mitigation costs are based on the estimated mitigation costs presented in the Devils Lake IPR-EIS for the proposed federal outlet. The analysis for the federal outlet assumed the freshest available water in Devils Lake was being discharged, that the water was being run through a sand filter prior to discharge, and that the outlet would not be operated in a manner that either exceeded water quality standards or channel capacity on the Sheyenne River. A detailed analysis of the effects of a Tolna Coulee or east end outlet could result in a significant increase in the mitigation cost.

### **UPPER BASIN STORAGE**

Restore up to 50 percent of the possibly drained depressions in the upper basin of the watershed to reduce inflow into Devils Lake. As described in the Devils Lake IPR-EIS, implementation of this alternative would require the placement of approximately 40,000 acres of land into an upper basin storage program.

**Cost:** Implementation of this alternative would involve acquisition or leasing of land including related administrative costs, construction of control structures where needed, and the development of an operating plan for the control structures when the lake recedes. Average cost per acre is estimated to be \$1,350, resulting in a total direct cost for a 40,000-acre program of \$54,000,000.

## ALTERNATIVE SCREENING CRITERIA

The primary purpose of this project is to focus on what actions should be taken at the City of Devils Lake to reduce risk of flood damages to the city should Devils Lake continue to rise. Studies have shown that the climate condition affecting the lake is currently in a “wet state”, causing Devils Lake to rise. Geological studies have shown that Devils Lake has spilled to Stump Lake at least five times and reached the natural spill elevation to the Sheyenne River twice in the past 2,500 years. Regardless of the water management measures implemented in the upper basin, or the size of the outlet constructed to the Sheyenne River, Devils Lake could continue to rise and eventually overflow from the east end down Tolna Coulee. While the current probabilities are low, the possibility of such conditions recurring still exists.

In order to evaluate the effectiveness of the initial array of alternatives in meeting the primary project objectives, several considerations were identified to help in screening alternatives and developing recommendations for alternatives to be considered in detail.

**Effectiveness:** Whether or not the alternative would be responsive (i.e. timely) and effective in maintaining an acceptable level of flood risk management in accordance with Corps of Engineers design criteria.

**Environmental Effects:** Direct and indirect effects on natural resources and cultural resources. Direct effects are those effects associated with the construction. Indirect effects are those effects that may occur as a result of changed environmental conditions due to the construction or operation of a project.

**Social Effects:** Direct and indirect effects on socio-economic resources such as transportation, regional growth, public safety, employment, recreation, public facilities, and public services.

**Acceptability:** Controversy and potential effects on community cohesion are indicators of acceptability. Views of other States, Nations and potential effects on Tribal Resources are also indicators of acceptability.

**Implementability:** Whether or not there are significant outstanding technical, social, legal or institutional issues that affect ability to implement the alternative.

**Cost:** The first costs of the project.

**Risk:** The uncertainties, vulnerabilities, and potential consequences of the alternative.

## **ASSESSMENT OF ALTERNATIVES AND SCREENING**

The purpose of this screening process is to summarize previous and current evaluations and present conclusions regarding alternative measures that should be evaluated in detail to reduce the risk of flood damage at the City of Devils Lake should lake levels continue to rise.

The Devils Lake North Dakota Integrated Planning Report and Environmental Impact Statement, dated April 2003, was a key source of information for this initial screening. That document was prepared to address the planning and analysis of alternatives to address flood damages related to rising lake levels in the flood-prone areas around Devils Lake. The study comprehensively evaluated upper basin storage, infrastructure protection, and a variety of outlet options to the Sheyenne River. Extensive hydraulic, hydrologic, water quality and environmental modeling was done as part of that evaluation. While existing conditions have changed somewhat since those studies were completed, most of the information is still relevant and directly applicable to current conditions. Many of the studies completed for that evaluation were used as the source information for this initial screening.

Some preliminary hydrologic analysis was needed to evaluate the effectiveness of options at Tolna Coulee. That analysis is presented in Attachment 1.

Updated information regarding upper basin storage programs was obtained from the North Dakota State Water Commission.

### **Assumptions**

1. In the absence of developing a plan of action for the City of Devils Lake (i.e., the without project condition), it is assumed that if Devils Lake continues to rise some actions will be initiated to maintain some level of protection for the city. Interim measures may involve raising the existing embankments to the extent practical. The implemented design may or may not meet Corps criteria. It is also possible that delaying design efforts may result in a plan based on expediency, not efficiency.
2. If the lake continues to rise to the point of overflow, some effort will be made to minimize the potential for severe erosion at Tolna Coulee.

The potential adverse effects associated with an overflow are the basis for this assumption. There is some debate regarding the extent of erosion that could occur. Devils Lake is estimated to have spilled to the Sheyenne River within the last 1,200 years and borings in the Tolna Coulee area indicate erosion did not appreciably occur at that time. However, the topography and the amount of erosion that did occur during the last overflow are unknown and it is possible that more soil eroded than is currently in place. Analysis indicates that given the nature of the soils, should the lake rise to elevations in the range of 1460.75 ft. (which is estimated to have a 2 percent probability of occurrence by the year 2040) there is a high potential for severe erosion to occur once an overflow

from Devils Lake begins. Estimates are that, should an event of the magnitude identified using dam safety criteria (in excess of a 100-year event) occur with the initial water surface elevation at 1459.0 ft., Tolna Coulee could erode to an elevation 1450 with discharges in excess of 15,000 cubic feet per second and over 900,000 cubic yards of material being eroded. Such an event would have significant effects along the Sheyenne River all the way to Lake Ashtabula, a distance of approximately 120 river miles. The water quality effects associated with such an event could continue all the way down the Red River of the North.

The maximum design elevation of the embankments is based on the assumption that actions will be taken to limit severe erosion. While it is unlikely that the exact conditions assumed would occur, it is a valid assumption for design purposes as it represents a worst case condition.

3. To maintain an acceptable level of safety for the ultimate embankment height, the current natural outflow elevation of 1459 cannot be raised. It is assumed that no measures will be taken to elevate the existing overflow elevation at Tolna Coulee.

A discussion of the effectiveness, impacts and risk for the without project condition, and each of the alternatives is presented below. A summary is presented in Table 1. A screening criteria matrix for the alternatives to the base condition is presented in Table 2.

### **FUTURE WITHOUT PROJECT CONDITON**

#### **Effectiveness**

Base Condition. This approach may result in hastily designed protection measures that may not be as cost effective or complete as would a plan produced by a thorough planning process.

#### **Environmental Effects**

**Natural Resources:** If Devils Lake continues to rise, wetland and upland habitat would be inundated. Water quality in Devils Lake would likely get fresher as the increased inflows dilute the high concentrations of dissolved solids. The fishery resource would expand as additional habitat becomes available and natural reproduction increases. Road raises and embankment raises or relocations could result in effects on wetland, grassland, woodland and aquatic habitat in the construction area. There would be periodic effects on Sheyenne River aquatic habitat due to water quality and flow changes that would be associated with overflow events. A natural overflow event could have significant effects on the Sheyenne River with respect to the fishery, erosion, water quality and ground water. The degree of effects would be dependent on the magnitude, duration and frequency of overflow events. Current estimates are that there is a 6 percent chance that Devils Lake will reach an elevation exceeding 1459 by the year 2040.

**Cultural Resources:** Much of the area around Devils Lake has not been surveyed. However, existing information indicates that there is potential for effects on unknown cultural resources around the lake due to rising waters and wave action. Excavating borrow material, raising/extending embankments, relocating houses or utilities all have the potential of have adverse effects on cultural resources. A natural overflow could have adverse effects on cultural resources along the Sheyenne River through inundation, erosion, and deposition.

### **Social Effects**

Impacts to socio-economic resources under the without project condition are likely to be a continuation of those in the past if the lake continues to rise. Among the most significant adverse impacts to be expected are:

- Additional dislocation of residents directly and indirectly affected by flooding, resulting in disrupted neighborhoods and fractured communities.
- Continued conflicts between residents around Devils Lake and downstream along the Sheyenne River regarding the cause of the lake rise and solutions to address the problem.
- Deteriorating community cohesion resulting from the conflicts and dislocations.
- Limited community growth and development; this again is a product of population dislocation as well as the unwillingness of businesses to invest locally due to the perceived risk of the lake.
- Impairments to public health as the mental stress of the difficult conditions and physical effects of wet basements (mold and allergies) take its toll on the populace.
- Impaired public safety due to increasingly more hazardous highways (narrower shoulders, steeper road embankments) and flood protection embankments that may be less reliable if raised under emergency conditions.
- Costs at all government levels (city, county, state, and Federal) to protect infrastructure features around the lake on an incremental basis as the lake rises; as lake continues to rise, protection of infrastructure features becomes increasingly costly and expenditures become more difficult to justify.
- Loss of productive farmland, the subsequent loss of income to producers, and the ripple effect on the local economy as a whole.

### **Acceptability**

**Other States, Nations and Tribal Resources:** Since natural conditions would essentially prevail, there would be no conflict with the Boundary Waters Treaty or other states. While there may be concern with the potential introduction of undesirable biota to the Sheyenne River with an overflow, this would be viewed as a natural occurrence. Damages would continue to occur on tribal lands due to rising waters. Modifying Tolna Coulee may be a source of controversy with the Spirit Lake Nation.

## **Risk**

The design level of protection for the existing embankment was previously set at 1454. USGS estimates the chance of the lake reaching this elevation by the year 2040 is 24 percent. The difference between this elevation and the top of embankment (1460) is the freeboard range designed to accommodate potential wave action. As lake elevations rise above 1454 and the freeboard range is reduced, the chance for wave action overtopping the embankment and causing damage increases. At some point, as the lake approaches the top of embankment, overtopping wave action will overwhelm interior pumping capacity and flood levels within the protected area rise to catastrophic magnitudes. Prior to this occurrence, population loss would be expected as those not willing to evacuate to other parts of town relocate out of the area altogether. If emergency levees are built, they will likely not meet dam safety criteria and there will be increased residual risk of failure.

There is additional risk that overflow from Devils Lake to the Sheyenne River will occur resulting in adverse impacts downstream. USGS estimates the chance of this occurrence at elevation 1459 is six percent. The upside risk of doing nothing is saving the cost of project implementation and preventing the occurrence of negative impacts associated with an implemented project (to be discussed later). The probability of this is high as the probability of the lake rising to a damage causing elevation is low.

**Conclusion:** The Future Without Project Condition (No Action) is the base condition against which other alternatives are compared to quantify and determine the significance of impacts. The alternative must be presented in the National Environmental Policy Act (NEPA) document prepared for any Corps project that may be proposed. This alternative will be carried forward for detailed evaluation.

## **RAISE/EXTEND EXISTING EMBANKMENT AT DEVILS LAKE**

### **Effectiveness**

This alternative provides a plan for maintaining an acceptable level of risk for flood damage reduction at the City of Devils Lake. Effectiveness is considered to be high.

### **Environmental Effects**

**Natural Resources:** Some upland and wetland resources would be affected by the expansion of the existing embankment width or associated extensions. As with past raises, some mitigation may be required for impacts on wetlands. There has been some minor loss of storage associated with areas protected by the existing embankments. An increase of the existing embankment height or length would have a minimal effect on eventual lake elevation as the current top of embankment elevation is 1460. Effects

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around the lake and downstream would be the same as the Future Without Project Condition.

**Cultural Resources:** There is a potential for cultural resources effects associated with the excavation of borrow material for embankment construction and construction effects along the selected alignment.

Overall, the potential environmental effects of this alternative are considered low adverse.

### **Social Effects**

The benefit to those outside the line of protection (compared to without project condition) is the assured preservation of the City of Devils Lake as the center of the regional economy and provider of essential services for local community. Those that are dislocated may be more inclined to relocate locally. There would be enhanced public safety for those inside the levee and an opportunity to maintain community and promote business investment. A planned embankment raise will have inherently less risk compared to an embankment raised under emergency conditions that may occur under the without-project condition. There are likely to be adverse effects on fiscal resources of city, county, and state. These would be offset if the raised embankment generates sufficient damage reduction benefits. Increased levee footprint will result in real estate takings, and possibly limited residential buy-outs. Depending on height and alignment of embankments, airport runways may have to be extended. Highway 2 and rail lines may also require modification.

Overall, the potential social effects of this alternative are considered moderate positive.

### **Acceptability**

**Other States, Nations and Tribal Resources:** Similar to Future Without Project Conditions.

This alternative would have potential positive effects on community cohesion. Overall, the acceptability of this alternative is considered to be high.

### **Risk**

Downside risk is that there is a good chance that the lake will not rise to a height for the raised embankment to generate sufficient damage reduction benefits. USGS estimates the chance of the lake reaching elevation 1454 by the year 2040 is 24 percent. The various government entities may spend \$100-\$200 million for a raise of the embankment that may never be needed. After construction, the perception may remain that the City of Devils Lake is a risk and business investment and economic growth would still be inhibited. The City is risking a financial burden that it may not be able to manage.

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Overall risk associated with this alternative is considered to be low.

### **Implementability**

Based on past embankment raises, it does not appear that there would be insurmountable technical, social, legal or institutional issues that would prevent this alternative from being implemented. Data needs and studies that would need to be completed during design would include cultural resources, topography, land use information, ground water studies, interior drainage and geotechnical studies. The most likely NEPA document required would be an Environmental Assessment. The City of Devils Lake, the local sponsor for the existing levee system, has expressed a concern regarding the overall project cost and their potential to fund the project. The potential inability to find a local sponsor capable of funding the non-federal portion of the project could prevent timely implementation. Implementability of some level of embankment raise is considered to be high.

**Conclusion:** This alternative meets the primary purpose of the project. This alternative should be carried over for detailed evaluation.

### **RELOCATION**

#### **Effectiveness**

This alternative would preclude the need for another embankment raise. The ability to design and implement needed infrastructure modifications in a timely manner could reduce the responsiveness of this alternative. Effectiveness is considered to be high.

#### **Environmental Effects**

**Natural Resources:** There are a variety of potential adverse effects associated with the required development of new infrastructure that would be associated with relocation. Some of these effects may be offset with the positive natural resource effects associated with vacated land along Devils Lake. Effects around Devils Lake and downstream would be similar to the Future Without Project Conditions.

**Cultural Resources:** There are numerous historic structures in and around the City of Devils Lake. Structural relocations would require cultural resource surveys and evaluation. Unavoidable effects on historic properties would have to be mitigated by formal documentation using large format photography and measured drawings, preparation of building and neighborhood histories, protection of historic architectural features, and/or data recovery excavation.

Overall, the potential environmental effects are considered to be low adverse.

### **Social Effects**

Implementing a relocation program has potential significant effects (positive and negative) on transportation, community cohesion, public facilities and services, property values, and public safety. Neighborhoods would be disrupted and a portion of the population may move away from the area altogether. Public safety is improved over the without project condition by clearing out the area of potential inundation.

Overall, the potential social effects are considered to be high adverse.

### **Acceptability**

**Other States, Nations and Tribal Resources:** Similar to the Future Without Project Conditions.

Potential effects associated with community cohesion and controversy would be varied. Overall, the acceptability of this alternative is rated moderate to low.

### **Risk**

Risk associated with relocation is primarily negative. Probability is higher that the lake will not rise high enough for the relocation plan to generate sufficient damage reduction benefits to justify financial and social costs. Some relocation features require less lead time and can be implemented in smaller increments than an embankment raise so trigger elevations can be set higher. However, lead time for major infrastructure relocations can be lengthy and affect overall responsiveness.

Overall risk associated with this alternative is considered to be high.

### **Implementability**

Relocation of a substantial portion of the City of Devils Lake could require a significant modification to the existing infrastructure system including the airport, sewage lagoons, collection lines, Highway 2, power substations and the railroad line. It is unknown at this time what percentage of the people in the City of Devils Lake would remain in the area when it came time to relocate. If adequate infrastructure or development opportunities were not in place far enough in advance, a large portion of the participants could move out of the region. Due to the significant social/economic impacts associated with this alternative, the most likely NEPA document required for this alternative would be an Environmental Impact Statement. Costs, infrastructure effects/needs, and potential social impacts associated with this alternative make it unlikely that a non-federal sponsor could be found for this alternative.

Implementability is considered moderate to low.

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**Conclusion:** It is recommended that this alternative not be carried over as a stand alone alternative.

## **COMBINATION EMBANKMENT RAISE/EXTENSION AND RELOCATION**

### **Effectiveness**

This alternative provides a plan for maintaining an acceptable level of risk for flood damage at the City of Devils Lake and could reduce the costs associated the embankment extensions. Effectiveness is considered to be high.

### **Environmental Effects**

**Natural Resources:** Effects on natural resources would be similar to those described for the Embankment Raise/Extension and Relocation alternatives. It is anticipated that relocation features would be limited and not require extensive re-design or additional investment in the existing infrastructure system.

**Cultural Resources:** Effects on cultural resources would be similar to those described for the Embankment Raise/Extension and Relocation alternatives.

Overall, the potential environmental effects of this alternative are considered low adverse.

### **Social Effects**

Effects on social resources would be similar to those described for the Embankment Raise/Extension and Relocation alternatives. Number of properties requiring relocation, and thus the associated impacts, would be significantly less than those described for the stand alone alternative of Relocation.

Overall, the potential social effects of this alternative are considered moderate positive.

### **Acceptability**

**Other States, Nations and Tribal Resources:** Similar to the Future Without Project Conditions.

This alternative would have potential positive effects on community cohesion. Overall, the acceptability of this alternative is considered to be high.

### **Risk**

Risks of implementing this alternative would be similar to those described for the Embankment Raise/Extension and Relocation alternatives. Overall risk associated with this alternative is considered to be low.

### **Implementability**

It does not appear that there would be insurmountable technical, social, legal or institutional issues that would prevent this alternative from being implemented. This approach would provide the ability to optimize the measures to implement in each evaluation reach. This could decrease cost and increase acceptability at the local level. Data needs and studies that would need to be completed during design would include cultural resources, topography, land use information, ground water studies, interior drainage, and geotechnical studies. The most likely NEPA document required would be an Environmental Assessment. The inability to find a local sponsor capable of funding the non-federal portion of the project could prevent timely implementation. Implementability of some level of embankment raise is considered to be high.

**Conclusion:** This alternative meets the primary purpose of the project. This alternative should be carried over for detailed evaluation.

### **MODIFY ELEVATIONS AT TOLNA COULEE**

#### **Effectiveness**

The effectiveness of this alternative is dependent on the elevation at which the sill elevation is set at Tolna Coulee. The maximum existing channel inlet elevation in Tolna Coulee is currently 1459 feet. Lowering the existing elevation to 1457, would have a small but measurable effect on embankment design considerations needed to meet Corps of Engineers dam safety criteria. A preliminary analysis (Attachment 1) indicates that excavation of a 300-foot wide channel at elevation 1457 would result in a reduction of 0.2 feet from a required intermediate Top of Embankment elevation of 1465, but could reduce the eventual maximum Top of Embankment elevation by as much as 1.5 feet. Analysis also indicates that Tolna Coulee would have to be lowered to at least elevation 1452 to preclude the need for any additional embankment raises at the City of Devils Lake. Effectiveness for this alternative is considered to be low.

#### **Environmental Effects**

**Natural Resources:** Effects associated with embankment construction or relocation could be reduced or avoided depending on the overflow elevation. Overflow events would have an effect of freshening water in Devils Lake, which would benefit the lake fishery. An overflow event could have significant effects on the Sheyenne River with respect to the fishery, erosion, water quality, and ground water. The magnitude of effects would be dependent on the quantity, duration and frequency of discharge events over the lowered outlet. There would be an increased potential for biota transfer from Devils Lake to the Sheyenne River. Lowering the overflow elevation from 1459 to 1457 would increase the probability of an overflow by the year 2040 from about 6 percent to around

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11 percent. Implementation of this alternative would likely include an extensive mitigation and monitoring plan.

**Cultural Resources:** High potential for adverse effects on cultural resources along Tolna Coulee and the Sheyenne River through erosion, inundation, or deposition.

Overall, the potential environmental effects of this alternative is considered to be high adverse.

### **Social Effects**

While there would be positive effects in and around Devils Lake, there would be the potential for significant adverse downstream effects for recreation, public health, land use, agriculture, public services, and controversy. Adverse downstream effects include impairments to environment, irrigation, increased flooding, and increased water treatment costs up to and beyond the Canadian border. This alternative is highly controversial and is among the primary issues argued by upstream and downstream interests. If lowered sufficiently, it could preclude the need for raise of embankments at the City Devils Lake. Saving of these costs would offset to some degree by downstream impacts that would require compensation / mitigation. Controversy would intensify as upstream interests would be perceived as “winners” at the expense of downstream interests.

Overall potential social effects are considered to be high adverse.

### **Acceptability**

**Other States, Nations and Tribal Resources:** There are significant institutional constraints associated with this alternative. This alternative would be viewed as an outlet from Devils Lake. Minnesota and Canada have opposed previous outlet proposals due to water quality and biota transfer concerns. In particular, the issue has been raised that in the absence of extensive treatment of water discharged from Devils Lake, such actions would violate the international Boundary Waters Treaty. Recent correspondence from Manitoba reiterated their concerns with and opposition to this alternative. The Spirit Lake Nation has expressed concerns with outlet proposals from Devils Lake in the past.

Because of the known institutional constraints and potential controversy, the acceptability of this alternative is considered to be low.

### **Risk**

Actual mitigation costs are likely to be higher than those used for this analysis. Previous studies assumed that the freshest water was being pumped from Devils Lake, filtered and operated in a manner that would not induce additional flooding on the Sheyenne River. There may be a risk that the operation of an overflow structure would be curtailed due to downstream environmental considerations. The project may generate lawsuits from downstream interests resulting in limitations on overflow structure operations. Cost

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effectiveness would be compromised and an embankment raise at the City of Devils Lake would have to be reconsidered as a solution.

Overall risk associated with this alternative is considered to be high.

### **Implementability**

While all the options under this alternative may be technically feasible, environmental, social, legal and institutional constraints make the federal implementation of this alternative unlikely in the near future. Issues raised during the planning and analysis of federally proposed outlet from Devils Lake would need to be addressed. An outlet from the east end of Devils Lake would require updated studies/modeling for water quality, hydrology, hydraulics, geotechnical, land use, topography, cultural resources, biota studies, and international/inter-state coordination. An operation plan for any control structure would also need to be developed. The most likely NEPA document required would be an Environmental Impact Statement.

The Implementability of this alternative is considered to be low.

**Conclusion:** Due to the potential for significant environmental and social impacts, and the significant institutional constraints that would affect potential implementation, this alternative should not be carried over for detailed evaluation.

## **UPPER BASIN STORAGE**

### **Effectiveness**

Numerous programs have been used to pursue storage in the upper basin with various degrees of success from year to year. These include programs by the USFWS, NRCS, and various State programs. In 2003 these programs restored/protected/enhanced about 14,000 acres of wetlands and provided about 10,000 acre feet of storage. In addition, an experimental irrigation program to utilize water before it reaches Devils Lake has been ongoing for the last several years. Their effect on runoff into Devils Lake varies, depending in the prevailing conditions going into winter and the amount of storage available in any given basin during storm events. In any event Devils Lake did continue to rise and eventually equalize with Stump Lake. The effectiveness of this alternative is dependent on the amount of drained depressions that could be enrolled in an upper basin storage program. The Devils Lake Upper Basin Storage Evaluation of 2001 (or WEST Study as it is referred to by many) that was completed as part of the DL IPR-EIS estimated that the restoration of 39,000 acres would provide 63,600 acre feet of storage. The study concluded that under the Wet Scenario, the result would be an average annual runoff reduction of almost 16,000 acre feet. (For modeling purposes, the Wet Scenario was defined as a repetition of the climatic and hydrologic conditions of the seven highest inflow years in recent history (1993-1999) over the period from 2003-2035.) This would equal about 1.3 inches at lake elevation 1450. The scope of work required would

encompass restoration of approximately 6,700 drained depressions through construction of berms, gated structures, and tie backs to high ground.

There is some disagreement on the number of drained depressions that currently exist in the upper basin and the estimated effectiveness of wetland restoration. U.S Fish and Wildlife comments on the DL IPR-EIS expressed a concern that the number of drained depressions calculated by the Devils Lake Upper Basin Storage Evaluation in 2001 underestimated the amount by at least 50 percent. This issue has been disputed. In addition, they noted that the Upper Basin Storage Evaluation documentation identified that the hydrologic model may underestimate net total evaporation. Given these concerns, and in lieu of additional studies for this evaluation, some changes in assumptions on effectiveness may be warranted.

As the primary purpose of this project is to focus on management of the risk to public safety and flood damages in the City of Devils Lake, the following considerations were identified when evaluating the upper basin storage alternative.

Preliminary analyses indicate the City of Devils Lake embankments will need to safely contain over 1.4 million acre feet of storage to meet dam safety criteria. Based on the existing lake elevation (1447 ft. in May 2008), the City of Devils Lake embankments currently provide protection to contain approximately 1.4 million acre feet of storage. For comparison purposes, the increase in lake volume between 1993 and 1999 was approximately 1.9 million acre feet. Hypothetically, if 40,000 acres of drained depression restoration were doubled to 80,000 acres, and the effectiveness of reducing average annual runoff were doubled (resulting in an average annual runoff reduction of 64,000 acre feet), the reduction in required storage to meet dam safety criteria would be less than 5 percent.

Upper basin storage does have the potential to change the timing and probabilities of increased lake levels. However, with the potential for acceleration in a lake level rise, as observed between 1993 and 1999, upper basin storage would not preclude the need to implement flood risk management actions at the City of Devils Lake should the lake level continue to rise. Overall effectiveness of this alternative is considered low.

### **Environmental Effects**

**Natural Resources:** Wetland habitat would be greatly enhanced. There would be reduced sedimentation and turbidity downstream of restored areas with associated benefits to natural resources. Waterfowl and the wildlife habitat in the upper basin area would be greatly enhanced with the restoration of 40,000 acres of wetland. There is a risk of potential soil salinization due to raising the water table in areas adjacent to the restored wetland and mobilizing subsoil salts. Previous studies indicate the potential hazard is low.

**Cultural Resources:** While historic literature has provided dozens of leads to historic and architectural sites in the upper basin area, no detailed cultural surveys have been

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conducted. There is a limited potential for adverse effects on cultural resources at selected storage sites.

Overall potential environmental effects are considered to be high positive.

### **Social Effects**

Due to the reduction and/or delaying of eventual peak lake elevation, there would be generally minor positive effects to most social and economic effects categories compared to without-project condition. This plan is controversial in that it is not accepted locally and is not effective as a primary alternative in reducing lake level. It is, however, seen by downstream interests as the solution to the problem. An adverse impact is the conversion of 40,000 acres of land, much of it in crop production, to runoff storage and the subsequent loss of income to the local economy. This plan is viewed primarily as a measure to be implemented in combination with other protection measures, not as a stand alone project. Impact on the lake is generally viewed as a delay of eventual rise not as a preventive measure. Some decrease in agricultural production would be expected as well as related effects on the local economy due to reduced farm expenditures.

Overall potential social effects are considered low adverse.

### **Acceptability**

**Other States, Nations and Tribal Resources:** Similar to the Future Without Project conditions.

As noted in the discussion on social effects, acceptability of this alternative varies base on location in the basin. Overall acceptability is considered to be moderate.

### **Risk**

Although timing may change, actions would still be required at the City of Devils Lake. There is a risk that the climate of the region will turn “dry” and the investment to acquire runoff storage easements will not yield a positive return. There is also a risk that downstream stakeholders may be perceived as “winners” and conflict among the local community may deepen.

Overall risk associated with this alternative is considered to be high.

### **Implementability**

There are no technical constraints that would prevent the implementation of this alternative. However the large number of acres proposed may surface some concerns on the local level. It is uncertain at this time as to how this feature would be implemented (i.e. easements, fee title or a combination). Assuming the program would rely on willing/volunteer enrollees or sellers, implementation could take some time. This

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alternative may best be pursued under a variety of existing programs. Overall Implementability is considered to be low to moderate.

**Conclusion:** This alternative has the potential to result in significant positive effects on natural resources. Studies that would be required include cultural resources, topography, hydrology and hydraulic modeling to optimize storage location, soil salinization evaluations for recommended areas. Assuming the implementation of this alternative would involve willing enrollees and sellers, the most likely NEPA document required would be an Environmental Assessment. If wet conditions persist in the basin, it is unlikely that this alternative would preclude the need for taking action at the City of Devils Lake. It is recommended that this alternative not be carried over for detailed analysis.

## **RECOMMENDATION**

The following alternatives are recommended for further evaluation: (1) Raise/Extend Existing Embankment at Devils Lake, and (2) Combination Embankment Raise/Extension and Relocation. The alternatives of Relocation, Modify Elevations at Tolna Coulee and Upper Basin Storage are not recommended for further evaluation as part of this project.

## **REFERENCES**

- Devils Lake Basin Joint Water Resources Board and North Dakota State Water Commission, 2006. Devils Lake basin watershed management plan. 47pp.
- ND SWC Memorandum dated August 14, 2003. Prepared by Michael S. Noone, Subject – Wetland restoration information for the Devils Lake basin.
- U.S. Army Corps of Engineers, 2003. Final-Devils Lake North Dakota integrated planning report and environmental impact statement – volumes 1 and 2.
- West Consultants Inc., 2001. Devils Lake upper basin storage evaluation. Prepared for the U.S. Army Corps of Engineers - St. Paul District, 79pp.

Table 1: Alternative Screening Summary

Resource Category	Future Without Condition	Embankment Construction/Extension	Relocation	Combination of Embankment-Relocation	Modify Elevations at Toha Coulee	Upper Basin Storage
Alternative Description	No further embankment extensions considered. Diverse infrastructure would be maintained for future roadways may be hardened to prevent severe erosion as lake nears natural overflow elevation.	Embankment construction, extensions/raises implemented as needed to provide protection for range from minimal protected area to maximum protected.	Relocate structures/facilities at Devils Lake as the lake continues to rise. Relocation may be required for some structures. Relocation would be initiated once the embankment is no longer considered adequate.	Embankment construction, extensions/raises implemented in conjunction with relocation. Specific area may be based on several factors (cost, environmental effects, land acquisition, constructability, etc.)	Lower existing overflow elevation from 1450 to reduce inflow into Devils Lake.	Restore up to 25% of the drained depressions in upper basin of the watershed to reduce inflow into Devils Lake.
Cost (Includes Mitigation Costs)		\$100 million - \$200 million	\$400 million	\$100 million to \$200 million	\$170 million - \$200 million	\$54 million
Natural Resources	Fishery will continue to improve to a point where construction activities would have minimal effects on aquatic resources. Risk of biota transfer from natural overflow and on Cheyenne River aquatic habitat due to water quality (WQ) and flow changes associated with a natural overflow. Natural overflow will affect riparian and wetlands on fishery, erosion, WQ and groundwater. Probability of an overflow is relatively small (a 0% chance that the lake will exceed elevation 1428 by 2049).	Resources affected along embankment would be avoided. Would have limited effect on the probability of an overflow. Around Lake and Downstream effects similar to without project conditions. Less of storage associated with flooding around the lake as DL rises.	Variety of effects possible due to required relocation. May be offset with benefits associated with effects similar to without project conditions.	Similar to effects described for Embankments and Relocation	Effects associated with embankment construction would be avoided in some areas. Potential for significant adverse effects on the Cheyenne River and the Red River. Changes in flow regime and WQ could affect terrestrial and biota transfer. Magnitude of effects would be dependent on quantity, duration and frequency of discharge events over the Without Project conditions. Magnitude of effects would be dependent on sill elevation that is selected. Extensive mitigation-monitoring likely required.	May effect timing and peak elevation of overflow. Without Condition, would result in an increase in wetland habitat in the upper basin. Some freshwater water would be retained in Devils Lake. Would prevent some inundation of lands around Devils Lake. Would modify land use at storage sites.
Cultural Resources	Excavation of borrow material and selective infrastructure protection have potential to adversely affect cultural resources. Natural resources along Toha Coulee and Cheyenne River through erosion, inundation and deposition.	Potential effects associated with borrow material areas and construction effects along selected alignment	Cultural relocations would require cultural resource surveys and evaluations. Unavoidable effects on historic properties evaluation, protection and/or data recovery.	Similar to effects described for Embankments and Relocation	High potential for significant adverse effects on cultural resources along Toha Coulee and the Cheyenne River through erosion, inundation and deposition.	Limited potential of adverse effects on cultural resources at storage sites.
Social Resources	Potential significant adverse social effects in many areas as DL continues to rise including transportation, employment, regional growth, public services, and community cohesion. Associated with rising lake levels, increasing natural outlet would increase duration of flooding of some lands around the lake.	Estimated adverse social effects similar to without project conditions. Increased positive effects for Public Safety for these in protected areas.	Potential significant effects (positive and negative) on transportation, community recreation, public facilities and services, property values and public safety.	Similar to effects described for Embankments and Relocation	While positive effects in and around Devils Lake, potential for significant adverse effects downstream for recreation, public health, land use, controversy, agriculture, and public services.	Effects around Devils Lake similar to the Future Without Condition. May require fee title acquisition which would result in high level of controversy
Other States, Nations, and Tribal Resources	Natural outflows would remain. The future no conflict with Boundary Waters Treaty. Controversy with Spirit Lake Nation (SLN) may continue. Damages due to rising lake would continue. Downstream areas could be affected by increased duration of overflow events - Biota transfer may be a concern but would be natural occurrence.	Similar to without project conditions. Timing of overflow, if it occurs, may be slightly sooner.	Similar to without project conditions. Timing of overflow, if it occurs, may be slightly sooner.	Similar to without project conditions. Timing of overflow, if it occurs, may be slightly sooner.	Similar to without project conditions.	Similar to Without Project conditions.
Risk - Downside consequences	Embankments overlap sometime in future causing millions of dollars in damage. City of DL devastated; significant portion of population relocates elsewhere; based on probability of lake reaching level for embankment ext; perception remains that this happening is low; other IP measures still needed.	Spanning between \$50 -150 million depending on the embankment alternative selected, that may never be needed; probability high as probability of lake level embankment ext; perception remains that this happening is low; other IP measures still needed.	Community disruption; commercial development potential diminished; may be "all for naught" if lake doesn't reach level where benefits may be generated; high probability of lake reaching level of consequence is low; other IP measures still needed. Major infrastructure relocations required lengthy timeline and could affect timeliness of action.	Similar to effects described for Embankments and Relocation	Primarily the same as embankment extension alternative, coupled with negative downstream impacts (water quality, biota transfer, flood plain, etc.) on the Cheyenne River, and the associated negative impacts would be increased. Change in probability would be dependent on associated sill elevation.	Although limiting may change, actions would still be required at Devils Lake to address damages associated with rising lake levels. High level of controversy on how to address agricultural productions may have economic effects on the county level.
Risk - Upside consequences	Cost savings of millions of dollars associated with construction and prevention of other negative impacts associated with any of the embankment alternatives to prevent damage to low probability of lake reaching damage-causing elevation is low.	DL will be protected from future lake rise causing embankments overtop/failure; probability of lake reaching level for embankments to prevent damage to low elevation is low.	Prevention of flood damage if existing embankment overtops (low probability of this happening); some relocation features require smaller increments than embankment so can be done at higher trigger elevations.	Similar to effects described for Embankments and Relocation	Primarily the same as the embankment extension alternative. Reducing overflow elevation would reduce required maximum construction costs.	Storage would reduce the probability of an overflow. Would be supported by downstream interests.
Environmental Document likely required	None	Environmental Assessment	Environmental Impact Statement	Environmental Assessment	Environmental Impact Statement	Environmental Assessment
Data Needs	None	Cultural Resources, Topo, Land Use, Groundwater, Interior Drainage, Geotechnical	Cultural Surveys, Topo, Land use	Cultural Resources, Topo, Land Use, Groundwater, Interior Drainage, Geotechnical	Cultural Resources, Topo, Land use, Groundwater, Interior Drainage, Geotechnical, Lake WQ modeling, operation plan, Downstream WQ/hydrology modeling, riparian habitat, biota studies, international/state coordination, stochastic modeling updates	Cultural resources, topography, H&T modeling to optimize storage locations.

Table 2: Alternative Screening Matrix

ALTERNATIVE	FIRST COST (MILLIONS)	SCREENING CRITERIA						RISK	RECOMMENDATION
		EFFECTIVENESS	ENVIRONMENTAL	SOCIAL EFFECTS	ACCEPTABILITY	IMPLEMENTABILITY	RISK		
Raise/Extend Existing Embankment	\$ 100 - 200	High	Low Adverse	Moderate Positive	High	High	Low	Carry Forward	
Relocation	\$ 400	High	Low Adverse	High Adverse	Moderate-Low	Moderate-Low	High	Drop	
Raise/Extend - Relocation	\$ 100 - 200	High	Low Adverse	Moderate Positive	High	High	Low	Carry Forward	
Modify Toha Coulee	\$ 110 - 200	Low	High Adverse	High Adverse	Low	Low	High	Drop	
Storage	\$ 54	Low	High Positive	Low Adverse	Moderate	Moderate-Low	High	Drop	

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ATTACHMENT 1  
Preliminary H&H Evaluation

Attachment 1

Devils Lake Flood Risk Management Project  
Summary of  
Preliminary Hydrologic and Hydraulic Analysis  
Tolna Coulee Outlet

**Description**

A preliminary hydrologic and hydraulic (H&H) analysis has been completed to estimate the effects of lowering the Tolna Coulee outlet on required top of embankment elevations. The analysis addresses only the H&H component and does not encompass the political, legal, environmental, social, etc... aspects associated with lowering of the coulee. The purpose of this document is to provide a brief summary of the analysis and results. Due to the preliminary nature of the analysis a detailed hydrologic and hydraulic appendix has not been completed.

**Conclusions**

Although the hydrologic and hydraulic (H&H) analysis is preliminary, the results provide an accurate estimate of the effects of lowering the coulee on the required top of embankment elevations. A preliminary analysis indicates that excavation of a 300-foot wide channel at elevation 1457 ft. would result in a reduction of 0.2 feet from a required intermediate Top of Embankment elevation of 1465 ft., but could reduce the eventual ultimate Top of Embankment elevation by as much as 1.5 feet. Analysis also indicates that the sill elevation at Tolna Coulee would have to be lowered to at least elevation 1452 ft. to preclude the need for any additional embankment raises at the City of Devils Lake.

Currently, the United States Geological Survey estimates there is approximately a 6 percent probability that Devils Lake will exceed the elevation of 1459 ft., a 11 percent probability of exceeding 1457 ft., and a 37 percent probability of exceeding 1452 ft. by year 2040 .

Erosion of the natural outlet in comparison to a reinforced outlet with matching geometry would result in a reduction of 0.6 feet in the required ultimate top of embankment elevation. The lake elevation would recede following an erosive event resulting in an outlet elevation possibly as low as 1450 ft. Based on evidence and data from a Tolna Coulee Outlet Erosion study completed in 2001 for the U.S. Army Corps of Engineers, a substantial event or sequence of events resulting in lake elevations in the range of 1460.75 ft. would be required for severe erosion to occur. For an inflow design flood, based on dam safety criteria, outlet discharges would be in excess of 15,000 cubic feet per second with over 900,000 cubic yards of material being eroded from Tolna Coulee.

### **Hydrologic Analysis Overview**

The preliminary hydrologic analysis has been completed using data adopted from past studies and projects in the Devils Lake Basin. Further analysis on the Devils Lake Flood Risk Management project will include evaluation, and modification as necessary, of data from past studies to ensure that the most appropriate methodology is applied in the hydrologic design of the project.

Preliminary data adapted from a U.S. Army Corps of Engineers planning report (Reference 1) indicates that the City of Devils Lake embankments will be required to safely contain between 1.45 and 2.9 million acre feet of inflow volume to meet dam safety criteria. The dam safety analysis has not yet been completed to determine the appropriate volume in the range between 1.45 and 2.9 million acre feet of storage. An inflow duration of four months with a triangular distribution was also adopted for the inflow design event from previous studies.

### **Hydraulic Analysis Overview**

A hydraulic model has been developed by updating a U.S. Army Corps of Engineers (USACE) hydraulic model of Tolna Coulee, developed in 1997, with the most recent available survey data obtained from the North Dakota State Water Commission (NDSWC). The hydraulic model is preliminary and has not been developed to design standards. A final design of outlet alternatives would require more detail and evaluation of channel characteristics (channel slope, area, base width, channel resistance, side slopes). Elevation-discharge outflow rating curves were then developed for the existing conditions and excavated outlet geometries.

The initial condition water surface elevations, inflow hydrographs and elevation-storage-outflow curves were entered into a visual basic program to calculate resulting water surface elevations for the existing conditions and excavated alternatives.

Dam safety criteria specifies that freeboard will be five feet or greater as determined by considerations that failure of the dam will not result from wind set-up, wave action, uncertainties in analytical procedures, and uncertainties in project function in combination with the most critical pool elevation. For the purpose of this analysis, the "freeboard", which is the required embankment height above the critical pool elevation, is assumed to be the minimum required five feet. The critical pool elevation is the peak water surface elevation resulting from routing of the inflow hydrograph through Devils Lake as described in the hydrologic analysis overview.

### **1457 Alternative**

The existing conditions geometry was modified with a 300-foot base width channel, cut to an invert elevation of 1457.0 ft. along the approximately 2,000 foot overflow profile.

A reduction of 0.2 feet in the required intermediate Top of Embankment elevation of 1465 ft. was computed for the 1457 alternative. The minimal reduction in the required top of embankment is due to the limited peak outlet capacity of the 1457 alternative at 1,075 cubic feet per second (2,130 acre feet per day) to evacuate, at a minimum, 1.45 million acre feet of inflow volume.

For ultimate top of embankment build elevations, the initial conditions water surface elevation prior to the flood event was assumed to be at the outflow elevation, which is 1459 ft. for existing conditions & 1457 ft. for the 1457 alternative. A maximum reduction of 1.5 feet was computed for the required ultimate Top of Embankment elevation resulting from the 1457 alternative. The reduction in the initial condition water surface elevation from 1459 ft. to 1457 ft. contributed to a reduction of 1.1 feet out of the 1.5 foot total reduction in the required top of embankment elevation. The remaining 0.4 feet is due to the increased outlet capacity.

### **Lowering of Tolna Coulee to Preclude the Need for Additional Embankment Raises**

With the assumed minimum required "freeboard" of five feet and to preclude the need for additional embankment raises above 1460 ft., the maximum allowable critical pool elevation should not exceed an elevation of 1455 ft. Preliminary computations indicate that with a channel cut to 1446 ft. and an ogee spillway crest at 1452 ft., it is possible to evacuate 1.45 million acre feet of inflow volume with the critical pool elevation held below 1455 ft. However, the event outflow would be approximately 7,600 cubic feet per second.

### **Preliminary Erosion Analysis of the Tolna Coulee Outlet**

A preliminary erosion analysis of the Tolna Coulee outlet has been completed to estimate the effects that erosion would have on water surface elevations and required top of embankment elevations on Devils Lake. Data on the outlet erosion characteristics and outlet rating curves has been obtained from previous studies. The preliminary analysis indicates that given the nature of the soils, should the lake rise to elevations in the range of 1460.75 ft., there is a high potential for severe erosion to occur. Assuming an initial lake elevation of 1459 ft., a flood event in the magnitude of 550,000 acre feet, which is comparable to the 1997 flood event, would be required for the lake to reach an elevation of 1460.75 ft. Currently, the United States Geological Survey estimates there is approximately a 2 percent probability that Devils Lake will exceed the elevation of 1460.75 ft. by year 2040. Devils Lake is estimated to have spilled to the Sheyenne River within the last 1,200 years and borings in the Tolna Coulee area indicate erosion did not appreciably occur at that time, which provides supporting evidence that a substantial event or sequence of events resulting in water surface elevations in the range of 1460.75 ft. would be required for severe erosion to occur.

In relation to dam safety criteria, the minimum possible inflow volume of 1.45 million acre feet was routed through Devils Lake with an initial lake elevation of 1459 ft. for with and without erosion conditions. The with erosion condition resulted in a 0.6 foot

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reduction in the peak water surface elevation and required ultimate top of embankment elevation. Discharges were in excess of 15,000 cubic feet per second, and over 900,000 cubic yards of material being was eroded from Tolna Coulee.

#### References

U.S. Army Corps of Engineers, St. Paul District, *Devils Lake, North Dakota Integrated Planning Report and Environmental Impact Statement*, Volume 2, Appendices A-F, April 2003.