S. HRG. 111–703

FLOODING IN BISMARCK/MANDAN AREAS OF NORTH DAKOTA

HEARING

BEFORE A

SUBCOMMITTEE OF THE

COMMITTEE ON APPROPRIATIONS

UNITED STATES SENATE

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

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FLOODING IN BISMARCK/MANDAN AREAS OF NORTH DAKOTA

WEDNESDAY, NOVEMBER 11, 2009

U.S. SENATE,
SUBCOMMITTEE ON ENERGY AND WATER DEVELOPMENT,
COMMITTEE ON APPROPRIATIONS,
Bismarck, ND.

The subcommittee met at 7:15 p.m., in the Bismarck City Commission Room, Bismarck, ND, Hon. Byron L. Dorgan (chairman) presiding.

Present: Senator Dorgan.

STATEMENT OF SENATOR BYRON L. DORGAN

Senator DORGAN. Ladies and gentlemen, we'd like to begin the hearing. This is a hearing of the United States Senate Energy and Water Appropriations Subcommittee. I'm Senator Byron Dorgan, chairman of that subcommittee.

I'm joined by Roger Cockrell, who is the professional staff member on the water side of that subcommittee and works on the water issues across the United States and knows more about water than most anybody in the United States Senate.

Justin Schardin is also with me, who works on my personal staff on water and other related issues.

I wanted to indicate as well representatives of Senator Conrad's staff and Congressman Pomeroy's staff are with us, Russ Keys is in the back of the room. Russ, could you stand?

And Marty Beckell is here from Senator Conrad's office.

I appreciate both of them being with us today. Obviously on North Dakota issues I work very closely with Congressman Pomeroy and Senator Conrad.

This is a field hearing of the Energy and Water Subcommittee. What we will do is take testimony, and following that testimony we will also accept in the permanent hearing record any submissions for 2 weeks following tonight. You may submit them to the United States Senate, care of my office or to the Senate Energy and Water Appropriations Subcommittee. They will be made a part of the permanent record.

I want to explain to you what we're trying to do and why I'm here. After what happened last spring in North Dakota with a very substantial amount of flooding many parts of our State, we, of course, became very active on the Red River, particularly in the Fargo/Moorhead area and other related areas of flooding on the Red River. I'm sure it was not lost on everybody in North Dakota that we came very close to having a significant, significant devastation of the largest population center as a result of a record flood. But the levees held. Through a heroic flood fight, much less damage was done than could have been.

So we've spent a lot of time thinking about and working on and working with local government officials with respect to flood control on the Red River. We have also now, as a result of the chronic flooding that happened in Valley City and Jamestown and in other areas on the Sheyenne and the James, we've initiated certain studies with respect to both the Sheyenne River system and the James River system. And with the Corps of Engineers we are working through a reconnaissance study on both river systems right now.

I just put the money in the appropriations bill. The President just signed my legislation the Energy and Water Appropriations bill just days ago. And that includes sufficient funding for a reconnaissance study on the James River system and the Sheyenne River system. Obviously that's because substantial flooding events occurred in some very large cities, especially on both river systems.

The questions today are what happened with respect to flooding in and around Bismarck, North Dakota last spring.

What happened?

What caused it?

What were the consequences?

Was it a once in a lifetime event that was a perfect storm or was it something that could happen again?

If so, what are the odds of it happening again?

If so, what kinds of things can be done to minimize the chances of it happening again?

I was here, along with my colleagues during that period. And I understood that the folks here in the Bismarck/Mandan region spent a lot of sleepless nights trying to figure out what on earth was happening. And how do you respond to it? Ice jams and a whole series of things on this Missouri River that were very significant and could have had a devastating impact on these communities. Now it had an impact on some people's houses and so on, but the impact was less than it could have been had the worst fears been imagined.

So the questions for this hearing tonight are, what were the causes of the flooding this spring?

What was done to mitigate the flooding during the event?

What can be done in the future to prevent this type of flooding from happening again here in the Bismarck/Mandan area?

The flood control process, if in fact the conclusion of this hearing is that there needs to be some mechanism by which some flood control projects are developed or some means of flood control would be achieved, is a bottom up process. By that I mean just as in Fargo and Moorhead, the Federal Government doesn't come in and say to them here's the kind of project you ought to have. What happens is the local people decide here's the kind of project that we think we need.

Then we begin a reconnaissance study then a feasibility study to determine whether or not there is a Federal interest. If so, do we meet the cost benefit ratio? There has to be a number of criteria that are met.

If there is a project that is seen to benefit a region that would reduce the prospect of flooding, it has to be three things.

It has to be technically sound. In other words, it has to be buildable, No. 1. It must be operable by a non-Federal entity once it's built.

No. 2, it has to be environmentally sustainable. That means that the environment of the impacted area is not degraded by the construction of a project.

No. 3, it has to be economically viable. That is, for the Federal Government to participate in any kind of a project, the plan the Corps would recommend would have to have a minimum of $1 of benefit for every dollar that is invested.

So all of those things are part of a discussion that we will hear tonight, again, what happened?

What do we think caused it?

What are the consequences or what is the likelihood of it happening again?

What kinds of things can be done to minimize the chance of it happening again?

With that we have Colonel Ruch, the Commander of the Corps of Engineers Omaha District, who has come up to join us. Colonel, we appreciate your being here.

We will hear from the Honorable John Warford, the mayor of Bismarck, North Dakota.

We will also hear from the Honorable Tim Helbling, the mayor of Mandan.

We'll also hear from Ken Royse, the Chairman of the Missouri River Joint Water Resources Board and Mike Gunsch, the engineer for the Burleigh County Water Resource District.

I appreciate very much all of you being here on time and ready to go. We will begin with you, Colonel Ruch and then we'll go down the line. I intend to ask a series of questions. Hopefully we can get on the record all that we need to have on the record.

I will, depending on time, be willing to entertain some comments from the audience following the statements and my questions. I would do that on the basis that you would give us your name and put your statement on the record. I would want to do that with a minimum number if we can.

But I'm here because I want to hear all of you. We've selected the witnesses that I think will represent the opinion and the interest of the region.

Colonel Ruch, thank you. You may proceed. Your entire statement, as will be the case with all witnesses, will be part of the permanent record, so you may summarize.

STATEMENT OF COLONEL ROBERT J. RUCH, DISTRICT COMMANDER, OMAHA DISTRICT, CORPS OF ENGINEERS—CIVIL, DEPARTMENT OF THE ARMY, DEPARTMENT OF DEFENSE—CIVIL

Colonel RUCH. Thank you, Senator. Chairman Dorgan, my name is Colonel Robert J. Ruch, Commander of the Omaha District, U.S. Army Corps of Engineers. Thank you for the opportunity to testify today on 2009 flooding in central and south——

Senator DORGAN. Is your microphone turned on, Colonel?

Colonel RUCH. It is.

Senator DORGAN. It is? Ok. Would you pull it a little closer?

Colonel RUCH. I wanted to show you that emergency operations in disaster response have the utmost importance at the Corps of Engineers. It was identified by the Chief of Engineers as our number one campaign goal. And we stand ready to respond on a moment's notice to contingency operations worldwide in support of natural disasters as well as combat and stabilizing operations.

I'd like to give you a brief run down on the conditions leading to this year's floods.

How the Corps responded to the request for assistance.

And the summary to post flood coordination.

This year's flooding in North Dakota was a direct result of historic snow over the winter of 2008–09. Many communities in the central part of the State, including Bismarck, recorded more than 100 inches of snow. Rapid melting and spring rains resulted in widespread flooding on the Missouri River, the Knife River, the Cannonball and Beaver Creek as well as other streams and tributaries.

With forecasts for high tributary runoff below Garrison Dam, the Missouri River Water Management Office in Omaha began with close coordination with the State of North Dakota and managers of water supply intakes, powerplants and other interest along the river upstream from Bismarck. A substantial ice jam in the Missouri River south of Bismarck on March 23, 2009 prompted a request for Corps technical assistance. We deployed ice jam experts from both the Omaha District and the Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire to advise North Dakota emergency management officers on blasting the jam and other measures to relieve flooding.

Concurrently another significant ice jam formed upstream from Bismarck raising concerns that this jam could break free and move downstream to join the other one. To alleviate the threat, the Corps collaborated with the State to make the unprecedented decision to cut all releases from the Garrison Dam, while the downstream jam was blasted and allowed to break up.

One hundred miles east of Bismarck rapid snow melt exacerbated by spring rains resulted in projected runoff in the James River in excess of the 1997 record pool elevation of both Pipestem and Jamestown reservoirs. Engineers from the Corps, the Bureau of Reclamation and the National Weather Service analyzed mountain runoff scenarios. The forecast predicted that both dams would see elevations which would overtop the spillway crests resulting in unregulated releases downstream and the potential for significant flooding.

Due to early coordination with the State, the city of Jamestown and other communities in North Dakota officially requested assistance from the Corps in early March. In response we constructed advance measures in Jamestown, LaMoure and Ludden. These measures consisted of temporary levees and flood walls, interior drainage pumps and 24 hour surveillance and monitoring on both of the dams.

Forecasts for combined releases from both reservoirs were projected to exceed 4,000 cubic feet per second which was more than double the record of 1,800 cubic feet per second set during the 1997 event. Releases were gradually increased to a maximum of 3,200 cubic feet per second in late April. They were held steady at that level due to serious infiltration problems with the city's sewer system at higher levels. Releases remained at 3,200 for approximately a month. And then were gradually reduced back to normal levels.

After the flood threat had passed and the reservoirs were sufficiently drawn back down to more normal levels, all the temporary measures were removed. Reservoir storage evacuation was completed by late August. The event lasted 133 days.

Overall the Omaha District committed 177 personnel and expended $7.7 million in emergency funding, $2.4 million in FEMA debris funding, constructed 4.5 miles of temporary levees and floodwalls in Jamestown and 4,600 feet of temporary structures in LaMoure.

We deployed more than 1.35 million sandbags, 10 pumps, and 14,000 feet of Hesco Bastions, 3,300 feet of Rapid Deployable Floodwall, and Portadam products as well.

These efforts prevented an estimated $70 million in damages.

Homes and businesses in Jamestown and LaMoure were not flooded.

As the reservoirs dropped and the James River receded, personnel from our Garrison and Oahe projects were instrumental in opening the lines of communications regarding Corps authorities and programs, which could address flood risks on a long-term basis. The Corps has an array of authorities and programs that may assist local communities with addressing flood risks. As a result of this year's flooding, the Omaha District has received numerous requests from communities in North Dakota, Jamestown, Stutsman County, Emmons County and Mercer County. We have initiated coordination meetings with these communities and have already conducted site visits to a few with more scheduled in the weeks to come.

Also the State of North Dakota, FEMA, and the Corps have been developing a charter to establish a Silver Jackets Program for the State. The Silver Jackets Program will establish a coordinating committee to help maintain communications and serve as a clearinghouse for prioritizing activities among the various agencies. I want to commend the State for taking this initiative. I believe that the visibility that comes with this designation will position the various projects within the State to better compete for the limited State and Federal resources.

The Energy and Water Development Appropriations Act of 2010 includes $150,000 for the Upper James River. We will soon begin coordination with State and local officials to decide how best to proceed with the study.

Also on the James, the Corps allocated $127,000 from the American Recovery and Reinvestment Act funding, which has been used to develop a new hydrologic forecasting model for the James River upstream from the Jamestown and Pipestem Dams and downstream to LaMoure.

The dam safety program has received funding for detailed topographic mapping of the shorelines of the two reservoirs and along the entire James River floodplain from the dams downstream to the North Dakota/South Dakota State line. The new mapping is scheduled for acquisition this fall with final delivery of the maps in June 2010.

In addition we continue to work with the North Dakota Task Force on Missouri River Restoration initiatives. Under that authority we completed an assessment report this past June to help identify sedimentation issues and concerns along the Missouri River. We are currently working with the Task Force to develop a plan for moving forward with projects.

Finally on October 1, 2009 we initiated a new study to re-examine the original authorized purposes of the Missouri River of the Flood Control Act of 1944, also known as the Pick-Sloan Plan. The study was authorized by section 108 of the Omnibus Appropriations Act of 2009. It is anticipated that the cost will be $25 million to complete.

PREPARED STATEMENT

The overall purpose of the study is to "review the original project purposes based on the Flood Control Act of 1994 . . . to determine if changes to the authorized project purposes and existing Federal water resource infrastructure may be warranted." We are currently developing a Project Management Plan and are in the midst of collecting preliminary stakeholder and public input on the engagement strategies in order to develop a comprehensive, public involvement plan. Formal scoping of the project is scheduled to commence in April 2010. This study will be a major Corps undertaking, co-led by the Omaha and Kansas City Districts. And we plan to work with State, local, tribal and public interests throughout its duration.

Chairman Dorgan, I appreciate the opportunity to be here today. And I'd be happy to answer any questions.

[The statement follows:]

PREPARED STATEMENT OF COLONEL ROBERT J. RUCH

Chairman Dorgan, my name is Colonel Robert J. Ruch, Commander of the Omaha District, U.S. Army Corps of Engineers. Thank you for the opportunity to testify today on the 2009 flooding in central and southeastern North Dakota.

I want to assure you that emergency operations and disaster response are of upmost importance to the Corps of Engineers. It was identified by the Chief of Engineers as our No. 1 Campaign Goal, and we stand ready to respond on a moments notice to contingency operations worldwide in support of natural disasters as well as combat and stabilizing operations.

I would like to give a brief rundown of the conditions leading to this year's floods, how the Corps responded to requests for assistance, and a summary of post flood coordination.

This year's flooding in North Dakota was a direct result of historic snow over the winter of 2008–2009. Many communities in the central part of the State, including Bismarck, recorded more than 100 inches of snow.

Rapid melting, exacerbated by spring rains, resulted in widespread flooding on the Missouri River, the Knife River, Cannonball River, and Beaver Creek as well as many other streams and tributaries. With forecasts for high tributary runoff below Garrison Dam, the Missouri River Water Management Office in Omaha began close coordination with the State of North Dakota and managers of water supply intakes, power plants, and other interests along the river upstream from Bismarck.

A substantial ice jam in the Missouri River south of Bismarck on March 23, 2009 prompted a request for Corps technical assistance. We deployed ice jam experts from both the Omaha District and the Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire to advise North Dakota Emergency Management officers on blasting the jam and other measures to relieve flooding.

Concurrently, another significant jam formed upstream from Bismarck, raising concerns that this jam could break free and move downstream to join the other one. To alleviate the threat, the Corps collaborated with the State to make the unprecedented decision to cut all releases from Garrison Dam while the downstream jam was blasted and allowed to break up.

A hundred miles east of Bismarck, rapid snow melt, exacerbated by spring rains, resulted in projected runoff in the James River in excess of the 1997 record pool elevations of both Pipestem and Jamestown Reservoirs. As engineers from the Corps, Bureau of Reclamation, and National Weather Service analyzed melt and runoff scenarios, the forecasts predicted that both dams could see elevations, which would overtop their spillway crests resulting in unregulated releases downstream and the potential for significant flooding.

Through early coordination with the State, city of Jamestown, and other communities, North Dakota officially requested assistance from the Corps in early March. In response, we constructed Advanced Measures in Jamestown, LaMoure, and Ludden. These measures consisted of temporary levees and floodwalls, interior drainage pumps, and 24-hour surveillance and monitoring on both dams.

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Releases remained at the 3,200 cfs level for approximately a month and then were gradually reduced back to normal levels. After the flood threat had passed and the reservoirs were sufficiently drawn back to more normal levels, all the temporary measures were removed. Reservoir storage evacuation was completed by late August.

The event lasted 133 days. Overall, Omaha District committed 177 personnel and expended $7.7 million in emergency funding, $2.4 million in FEMA debris funding, constructed 4.5 miles of temporary levees and floodwalls in Jamestown and 4,600 feet of temporary structures in LaMoure. We deployed more than 1.35 million sandbags, 10 pumps, and 232 rolls of plastic sheeting, as well as 14,000 feet of Hesco Bastions, 3,300 feet of Rapid Deployable Floodwall, and 1,250 linear feet of Portadam products. These efforts prevented an estimated $70 million in damages.

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Chairman Dorgan, I appreciate the opportunity to be here today and I will be happy to answer any questions you may have.

Senator DORGAN. Colonel, thank you very much.

The study of the Missouri River in section 108 is a study that I wrote and have funded. I look forward to substantial results from that study. I know it's going to take several years, but at last, at long, long last we need to understand what the management of this river should be given the realities of the use of the river.

I would just observe that in circumstance and at times when we've been short of water and we're moving water out of the upstream dams in order to support one barge that's floating downstream hauling sand and gravel. You scratch your head and ask yourself, you know, where's the common sense here? So that's a study that I wrote and am funding. I look forward to have some results for the next several years.

Mayor Warford, welcome. It's good to see you. You may proceed.

STATEMENT OF HON. JOHN WARFORD, MAYOR, BISMARCK, NORTH DAKOTA

Mr. WARFORD. Thank you very much, Senator Dorgan and members of the subcommittee, I want to thank you for allowing me to share Bismarck's spring 2009 Missouri River flooding experiences with you this evening.

I'm proud to tell you that Bismarck's emergency responders performed well during our flood crisis. They used their training and abilities to deal effectively with our emergency. Invaluable assistance was also received throughout the flood event from North Dakota Disaster Response and Water Management agencies. However since the subject of this hearing is the Federal response to the event my comments will be directed primarily for the Federal resources utilized in dealing with the flood.

Bismarck benefitted greatly from superb communication between the North Dakota State Water Commission and the U.S. Army of Corps of Engineers. This communication resulted in a very timely decision by the Corps to hold releases from Garrison Dam to an absolute minimum for several days to allow ice jams in the Bismarck/Mandan area of the Missouri River to clear. This quick response potentially saved lives and unquestionably averted major property damage.

Bismarck and its citizens benefitted from the quick attention of the Federal Emergency Management Agency also who arrived as soon as the flood emergency was evident. They came ready to help with expertise and financial resources. The National Weather Service and the Army Corps of Engineers gave Bismarck immediate assistance in those most difficult days when the river and the weather were foremost in everyone's minds.

Bismarck benefitted greatly from the assistance of the Congressional delegation of the Governor. Several times each day phone calls were received from political leaders offering to help. Senators Dorgan and Conrad, Congressman Pomeroy and Governor Hoeven and yes, President Obama were available, although the President did require the use of a cell phone. The attention given to our citizens of our city at that time by our political leaders was greatly appreciated and showed concern and support during some pretty tough days.

The superb report of the North Dakota National Guard is worthy of special recognition. Given the opportunity to utilize Federal and State resources the National Guard was invaluable in our flood response. The Guard's presence was visible, accommodating and steady throughout the disaster. From sandbag operations to evacuation to aerial recognizance to bringing in an explosives team, the Guard provided for many pressing needs.

In the time available I cannot begin to thank everyone who went out of their way to assist us in this most difficult time. They helped pave the way for the recovery we have enjoyed. This was an amazing team effort, one that I'm intensely proud of to claim on behalf of our city.

As in the case with every crisis, part of our responsibility is to look at what might have been done to lessen the severity of the crisis and to prevent a reoccurrence. This is always done in 20/20 hindsight. But it is a necessary part of a disaster autopsy.

So the spring 2009 Missouri flood in the Bismarck area was largely caused by ice jamming and heavy spring runoff, much of it from the Missouri River tributaries such as the Heart and Knife Rivers. Apple Creek, though not a factor in 2009 could potentially impact an ice jam crisis. If the ice conditions in the tributaries could be more closely monitored and their impacts on the Missouri anticipated and possibly mitigated. I think we could avoid an ice jam event of this proportion.

If the tributary contribution to Missouri were able to be managed more completely an additional advantage would be gained. However, if no physical event were changed. A more thorough monitoring of tributary conditions would allow an earlier warning of problems that could affect the Missouri.

A second recommendation of an aide might be the addition of a Missouri River State Management Device or devices. So an ice jam in the headwaters of the Oahe stretch of the river could more quickly be detected. Lowland flood warnings could be given on a more accurate and timely basis. Since ice jams are very difficult and hard to predict additional river condition monitoring systems may allow officials to issue earlier warnings to residents.

Another recommendation would involve the preparation and testing of an ice jam response plan. The city would be a very willing contributor to the development of this plan. But it lacks the expertise in ice jam fighting or response to rapid river stage increases caused by flooding associated with ice jams. The assistance of Federal and State resources would aid greatly in this planning effort.

A fourth suggestion would involve a study of the vulnerable areas south of Bismarck and ways in which either a temporary or permanent dike system might aid in the prevention of flooding from the Missouri River or Apple Creek. This study should focus on a catastrophic ice jam on the Missouri similar to the spring of 2009 event and consider the additive effect of a high Apple Creek flow that might not be able to discharge into the Missouri River.

A final recommendation recognizes that prevention of a disaster is a proven desire of everyone who has experienced the pain and loss caused by such an event. While this is never entirely possible, it is reasonable to consider actions that will eliminate the event or make it less costly. It would be desirable to consider dredging the headwaters of the Oahe. Chronic bank erosion and resulting siltation of the quiet waters of the Oahe have caused many sandbars and a winding river channel. This makes ice jamming an increasingly frequent phenomenon.

PREPARED STATEMENT

Senator Dorgan, again, thank you once again for the opportunity to discuss this spring 2009 flood event in the Bismarck area. The resources you have provided to us have done a great deal to mitigate the problem. And your willingness to assist with further mediation of the threat is deeply appreciated. Thank you.

[The statement follows:]

PREPARED STATEMENT OF HON. JOHN WARFORD

Thank you for allowing me to share Bismarck's spring 2009 Missouri River flood experiences with you this evening.

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In the time available I cannot begin to thank everyone who went out of their way to assist us in this most difficult time. They helped pave the way for the recovery we have enjoyed. This was an amazing team effort; one that I am intensely proud to claim on behalf of the city. As is the case with every crisis, part of our responsibility is to look at what might have been done to lessen the severity of the crisis and to prevent a recurrence. This is always done with 20 by 20 hindsight, but it is a necessary part of a disaster autopsy.

The spring 2009 Missouri River flood in the Bismarck area was largely caused by ice jamming, much of it from Missouri River tributaries such as the Heart and Knife Rivers. Apple Creek, though not a factor in 2009, could potentially impact an ice jam crisis. If the ice conditions in the tributaries could be more closely monitored and their impacts on the Missouri anticipated and possibly mitigated, I think we could avoid an ice jam event of this proportion. If the tributary contribution to the Missouri were able to be managed more completely, an additional advantage would be gained. However, if no physical event were changed, a more thorough monitoring of tributary conditions would allow an earlier warning of problems that could affect the Missouri.

A second aid might be the addition of a Missouri River stage measurement device or devices so an ice jam in the headwaters of the Oahe stretch of the river could be more quickly detected. Lowland flood warnings could be given on a more accurate and timely basis. Since ice jams are very hard to predict, additional river condition monitoring systems may allow officials to issue earlier warnings to residents.

Another recommendation would involve the preparation and testing of an ice jam response plan. The city will be a very willing contributor to the development of this plan, but it lacks expertise in ice jam fighting or response to rapid river stage increases caused by flooding associated with ice jams. The assistance of Federal and State resources would aid greatly in this planning effort.

A fourth suggestion would involve a study of the vulnerable areas of south Bismarck and ways in which either a temporary or permanent dike system might aid in the prevention of flooding from the Missouri River or Apple Creek. This study should focus on a catastrophic ice jam on the Missouri, similar to the spring 2009 event, and consider the additive effect of a high Apple Creek flow that might not be able to discharge into the Missouri.

A final recommendation recognizes that prevention of a disaster is the fervent desire of everyone who has experienced the pain of loss caused by such an event. While this is never entirely possible, it is reasonable to consider actions that will eliminate the event or make it less costly. It would be desirable to consider dredging the headwaters of Oahe. Chronic bank erosion and resulting siltation in the quiet waters of Oahe have caused many sand bars and a winding river channel. This makes ice jamming an increasingly frequent phenomenon.

Thank you once again for the opportunity to discuss the spring 2009 flood event in the Bismarck area. The resources you have provided to help us deal with this problem and your willingness to assist with further remediation of this threat are deeply appreciated.

Senator DORGAN. Mayor Warford, thank you. And thank you for allowing us to use this facility here in Bismarck. I know you spend a fair amount of time here.

The mayor of Mandan, Mr. Tim Helbling, you may proceed.

STATEMENT OF HON. TIMOTHY A. HELBLING, MAYOR, CITY OF MANDAN, NORTH DAKOTA

Mr. HELBLING. Good evening. Thank you, Senator Dorgan for this opportunity to provide testimony on the importance of flooding issues in the Mandan/Bismarck area. There continue to be after effects of the spring flooding along the Missouri River.

The city of Mandan has spent over $100,000 in the past 3 months on a temporary rock protection of our storm and sanitary sewer outfall pipes. The cause appears to be a failure in a rock jetty directly north of these outfall pipes. Until this situation is rectified the river current will continue to erode the river bank.

And we will, in turn, spend thousands more in attempts to stabilize our infrastructure. In discussions with the Corps of Engineers in Omaha it appears funding is very limited for this type of project. We are asking for funding assistance as the damage appears to be a result of a failure in the rock jetty caused by the flooding and ice jams earlier this spring.

Flooding along the Missouri River in part was caused by tremendous amounts of water, ice and debris flowing from the Heart River. The Lower Heart Water Resource District feels there are several levee areas of concern that should be considered for structural concerns versus general maintenance items. We have lost several feet of bank protection and significant stretches of the river leaving the levee directly exposed to the water current right at its toe.

Any future washouts will directly impact the levee system in several areas. Up to this point these areas of concern have been categorized by the Corps of Engineers as general maintenance issues. If the vulnerable areas continue to be considered to be general maintenance items for the Lower Heart Water Resource District to contend with the finances of the Lower Heart Water Resource District will not be adequate.

We have identified areas we feel are structural concerns requiring repairs to protect the city of Mandan's infrastructure that could total $4 to $6 million. Typically the Lower Heart Water Resource District can reserve $15,000 to $30,000 per year for general maintenance. At that rate, even with a typical cost share program, a 25 percent match, our ability to repair the structural concerns cannot realistically be done with any reasonable time.

The value of a developed real estate in the protected areas of Mandan can easily be considered some of the highest value real estate in the area. The Memorial Highway, Marina Bay, Borden Harbor, Lakewood Harbor and the entire southside of Mandan from Highway 6 east has increased in both development and value since the construction of the levees.

We want to recognize the assistance from the Corps of Engineers has provided to date. As there are several projects that are currently underway. That assistance is greatly appreciated.

However, structural concerns should be considered for grant programs and fast track approvals. Again, these areas of concern have been categorized by the Corps of Engineers as general maintenance issues. And we respectfully disagree.

PREPARED STATEMENT

I'd like to thank you for this opportunity to provide input. And thank you for all that you have done to help the cities of Mandan and Bismarck during the spring flooding.

[The statement follows:]

PREPARED STATEMENT OF HON. TIMOTHY A. HELBLING

Thank you for this opportunity to provide testimony on the importance of flooding issues in the Bismarck-Mandan areas.

There continue to be the after effects of the spring flooding along the Missouri River. The city of Mandan has spent over $100,000 in the past 3 months on temporary rock protection of our storm and sanitary sewer outfall pipes. The cause appears to be a failure in a rock jetty directly north of these outfall pipes. Until this situation is rectified the river current will continue to erode the river bank and we in turn will spend thousands more in attempts to stabilize our infrastructure. In discussions with the Corps of Engineers in Omaha, it appears funding is very limited for this type of project.

We are asking for funding assistance as the damage appears to be the result of a failure in the rock jetty caused by the flooding and ice jams this spring.

Flooding along the Missouri River in part was caused by the tremendous amount of water, ice and debris flowing from the Heart River. The Lower Heart Water Resource District (LHWRD) feels there are several levee areas of concern that should be considered for "structural concerns" versus general maintenance items. We have lost several feet of bank protection in significant stretches of the river leaving the levee directly exposed to the water current at its toe. Any future washouts will directly impact the levee system in several areas. Up to this point, these areas of concern have been categorized by the Corps of Engineers as "general maintenance" issues.

If the vulnerable areas continue to be considered "general maintenance" items for LHWRD to contend with, the finances of LHWRD will not be adequate. We have identified areas we feel are "structural concerns" requiring repairs to protect the city of Mandan's infrastructure that could total $4 to $6 million. Typically the LHWRD can reserve $15,000–$30,000 per year for general maintenance. At that rate, even with the typical cost share program (25 percent match) our ability to repair these "structural concerns" cannot realistically be done in any reasonable time.

The value of the developed real estate in the protected areas of Mandan can easily be considered some of the highest value real estate in the area. The Memorial Highway, Marina Bay, Borden Harbor, Lakewood Harbor and the entire south side of Mandan from Highway 6 east has increased in both development and value since the construction of the levees.

We want to recognize the assistance the Corps of Engineers has provided to date, as there are several projects that are currently underway. That assistance is greatly appreciated.

However, structural concerns should be considered for grant programs and fast track approvals. Again, these areas of concern have been categorized by the Corps of Engineers as "general maintenance" issues and we respectfully disagree.

The city of Mandan provides treated water to Missouri West Water Systems for its rural customers and we also share our water intake structure with Tesoro Refinery. Our intake structure rests along the bank of the Missouri River. During the period in which water was not being released from Garrison Dam, we kept around the clock watch to ensure we had adequate flow into our intake. At one point we were hours away from having no water. The Corps of Engineers and North Dakota Department of Emergency Services worked quickly and decisively in allowing a controlled release from Garrison Dam to ensure our intake would continue to function.

This situation could easily present itself again, not only to the citizens of Mandan, its rural residents, Tesoro Refinery the other communities and power plants that rely upon water in the Missouri River for their livelihood. Horizontal collector wells, that are now being installed as part of the Bismarck water treatment plant, have been explored in Mandan, however, the geology does not support this alternative.

We believe a comprehensive review of available options should be done if releases from Garrison Dam are significantly reduced or cut off completely.

Thank you for the opportunity to provide input.

Senator DORGAN. Well, Mayor, thank you very much. And now we will hear from Mr. Ken Royse, the chairman of the Missouri River Joint Water Resource Board. Mr. Royse.

STATEMENT OF KEN ROYSE, CHAIRMAN, MISSOURI RIVER JOINT WATER RESOURCE BOARD

Mr. ROYSE. Senator Dorgan, thank you for this opportunity to provide testimony regarding the issue of flooding in the Bismarck/Mandan area was caused or contributed to by the Missouri River.

My name is Ken Royse. I'm a resident of Bismarck, North Dakota. And I currently serve as chairman of the Missouri River Joint Water Resource Board. The Missouri River Joint Water Resource Board is a legally organized joint water board authorized under the statute of the State of North Dakota. Our membership are those individual county water boards which border either Lake Sakakawea, Lake Oahe or the Missouri River.

Before I offer my testimony I would like to offer sincere thanks to you for arranging this hearing and elevating this issue to this level of discussion. We understand that this hearing allows us to formally place our concerns into a Congressional Record and provide a possible means for improvements and changes to be implemented in the river and reservoir management methods.

I am confident that the panel that you have assembled today will provide you very specific discussions on the issues of flooding which Mandan and Bismarck faced this past spring. However my testimony to you will be in broader terms of how several selected Federal programs are affecting the use of the Missouri River system in our State. And how those selected programs relate particularly to the issue of flooding in the Bismarck/Mandan area.

The Federal programs I would like to address, each of which have a relationship to the flooding issues we're discussing here today, are No. 1 the work and efforts as authorized and conducted under title VII of the Missouri River Protection and Implementation Act of 2000.

No. 2, the Corps managed program commonly referred to as the Emergent Sandbar Habitat Program, which is a program implemented due to the Missouri River biological opinion for recovery.

And No. 3, the recently passed and pending effort referred to as a MRAPS process which is a Missouri River Authorized Purposes Study as authorized under section 108 of the Omnibus Appropriations Act of 2009.

The common thread of all these programs relates to the elements of sediment siltation and bank and land erosion. All these elements had a direct impact on the flooding which occurred in March 2009. Relative to the title VII program as you are aware this program has provided for a comprehensive study to be conducted for the Missouri River system for the State of North Dakota to identify issues and effects of sedimentation and siltation.

The study was recently completed under the direction of the Omaha Division of the Corps of Engineers. In this study an attempt was made to quantify the effects siltation has had and is having on the issues of economics, recreation, hydropower production, fish and wildlife resources, flood control and Indian and non-Indian historical and cultural sites. In the section of the report under flood control the following discussion is provided.

> "Flood control issues within the Missouri River for the Bismarck, North Dakota area are caused or affected by one, open water seasonal flooding from Garrison Dam operations.
>
> "Two, open water seasonal flooding from tributaries and other residue drainage areas below Garrison Dam combining with releases from Garrison Dam.
>
> "Three, flooding resulting from ice jams and ice conditions.
>
> "And four, flooding caused by aggradation in the upper reaches of Lake Oahe."

And additionally it says, "Siltation in the reach between Garrison Dam and Lake Oahe has resulted in increased risk of flooding in the downstream reach between the Dam and the headwater of Lake Oahe. Because of this sediment aggradation the impact of ice dams on seasonal flooding has increased and is expected to increase."

Relative to the Emergent Sandbar Habitat Program, I think it first important to inform you that the Missouri River Joint Board has placed itself on the record of opposing this program. We opposed it based on the intent to the program to place or maintain sediment deposits and sandbars within the river system. The North

Dakota Water Users and the North Dakota Water Resource Association have also adopted similar resolutions in opposition to this program.

While we oppose creating or enhancing sandbars for bird habitat, we do recognize the importance of achieving ecological balance in the river and reservoir system. Water managers and folks that use and enjoy our river system are not anti-environmental. We simply believe that a balance of all needs, including a need for adequate river management for flood protection needs to be on equal footing as fish and wildlife and environmental needs.

Our opposition is based primarily on the damages that siltation and sedimentation can do to the various uses of the river.

Silt and sediment provide obvious disadvantages to the river use in terms of excess in the channel for water and irrigation supply and in terms of lessening the life of the empowerment structures.

And in terms of decreasing power generation ability.

And in terms of limiting and disrupting an accessible river system for recreation.

Sedimentation can and does contribute to flooding conditions as we have seen this past year where a large sand bar or sand bars acted as a restriction to the ice movement and flow from the Heart River into the Missouri River. It was that backed up and blocked ice which created the conditions by which the flooding of South Bismarck and South and East Mandan occurred.

Relative to the Missouri River authorized purposes study we believe this effort can and should provide a means for our area to influence a river management system which will further secure flood protection for our area. This is an effort, as you are aware, which is now in its infancy. The first scoping meeting was held on this issue in early October in Pierre, South Dakota.

At that meeting I would estimate that approximately 150 people attended. Of which, perhaps, up to one-third to one-half were from downstream States. Even though the Corps had conducted a scoping meeting in Kansas City supposedly for the benefit of those users and stakeholders of the downstream States, these downstream stakeholders apparently felt the need to attend the Pierre, South Dakota meeting, an apparent demonstration of the importance of this issue to them.

PREPARED STATEMENT

I think the MRAPS program allows all the States a platform and structure to revisit a long outdated plan of management and benefit allocation of the Missouri River system. It should be viewed as a means where all parties upstream and downstream interest included, can have an opportunity to have objective discussion on the best basin wide use of that system. And it should be a means by which the issue of the Missouri River and reservoir system management and operations can be modified to address flooding issues in the Bismarck/Mandan area.

Senator, thank you for holding this hearing and accepting this testimony, if you have any questions I would be happy to answer them.

[The statement follows:]

PREPARED STATEMENT OF KEN ROYSE

Dear Senator Dorgan and subcommittee, thank you for this opportunity to provide testimony regarding the issue of flooding in the Bismarck and Mandan, North Dakota area as caused or contributed to by the Missouri River.

My name is Ken Royse. I am a resident of Bismarck, North Dakota and I currently serve as chairman of the Missouri River Joint Water Resource Board. The MRJWRB is a legally organized joint water board authorized under the statutes of the State of North Dakota; our membership are those individual county water boards which border either Lake Sakakawea, Lake Oahe, and/or the Missouri River.

Before I offer my testimony I would like to offer sincere thanks to you for arranging this hearing and elevating this issue to this level of discussion. We understand that this hearing allows us to formally place our concerns into a Congressional Record and provides a possible means for improvements and changes to be implemented in the river and reservoir management methods.

I am confident that the panel you have assembled today will provide you with a very specific discussion on the issues of flooding which Bismarck and Mandan faced this past spring. However my testimony to you will be in broader terms of how several selected Federal programs are affecting the use of the Missouri River system in our State and how those selected programs relate particularly to the issue of flooding in the Bismarck and Mandan area.

The Federal programs I would like to address, each which have a relationship to the flooding issues we are discussing here today, are (1) the work and efforts as authorized and conducted under title VII of the Missouri River Protection and Improvement Act of 2000, (2) the Corps managed program commonly referred to as the Emergent Sandbar Habitat Program, which is a program implemented due to the Missouri River Biological Opinion for Recovery, and (3) the recently passed and pending effort referred to as the MRAPS process, which is the Missouri River Authorized Purposes Study, as authorized under section 108 of the Omnibus Appropriations Act of 2009. The common thread of all these programs relates to the elements of sediment, siltation, and bank and land erosion. All these elements had a direct impact on the flooding which occurred in March 2009.

Relative to the Title VII Program.—As you are aware this program has provided for a comprehensive study to be conducted for the Missouri River system of the State of North Dakota to identify issues and effects of sedimentation and siltation. This study was recently completed under the direction of the Omaha Division of the Corps of Engineers. In this study an attempt was made to quantify the effects siltation has had and is having on issues of economics, recreation, hydropower production, fish and wildlife resources, flood control and Indian and non-Indian historical and cultural sites. In the section of the report under Flood Control the following discussion is provided:

> "Flood control issues within the Missouri River for the Bismarck, North Dakota area are caused or affected by (1) open-water seasonal flooding from Garrison Dam operations, (2) open-water seasonal flooding from tributaries, and other residual drainage areas below Garrison Dam, combining with releases from Garrison Dam, (3) flooding, resulting from ice jams and ice conditions, and (4) flooding."

And additionally,

> "Siltation in the reach between Garrison Dam and Lake Oahe has resulted in increased risk of flooding in the downstream reach between the dam and the headwater of Lake Oahe. Because of this sediment aggradation, the impact of ice dams on seasonal flooding has increased and is expected to increase."

Reference Page 14, Impacts of Siltation of the Missouri River in the State of North Dakota, Summary Report, U.S. Army Corps of Engineers, June 2009.

Relative to the Emergent Sandbar Habitat Program.—I think it first important to inform you that the MRJWB has placed itself on the record of opposing this program; we oppose it based on the intent of the program to place or maintain sediment deposits and sandbars within the river system. The North Dakota Water Users and the North Dakota Water Resource Association have also adopted similar resolutions in opposition to this program.

While we oppose creating or enhancing sandbars for bird habitat, we do recognize the importance of achieving ecological balance in the river and reservoir system. Water managers and the folks that use and enjoy our river system are not anti-environmental; we simply believe that a balance of all needs, including the need for adequate river management for flood protection needs to be on equal footing as fish and wildlife and environmental needs.

Our opposition is based primarily on the damages that siltation and sedimentation can do to the various uses of the river. Silt and sediment provide obvious disadvantages to the river use in terms of accessing the channel for water and irrigation supply, and in terms of lessening the life of the impoundment structures, and in terms of decreasing power generating ability and in terms of limiting and disrupting an accessible river system for recreation. Sedimentation can and does contribute to flooding conditions as we have seen this past year, where a large sandbar or sandbars acted as a restriction to the ice movement and flow from the Heart River into the Missouri River. It was that backed up and blocked ice which created the conditions by which the flooding of south Bismarck and south and east Mandan occurred.

Relative to the Missouri River Authorized Purposes Study.—We believe this effort can and should provide a means for our area to influence a river management system which will further secure flood protection for our area. This is an effort which, as you are aware, is now in its infancy. The first area scoping meeting was held on this issue in early October in Pierre, South Dakota. At that meeting I would estimate that approximately 150 people attended, of which perhaps up to one-third to one-half, were from downstream States. Even though the Corps of Engineers had conducted a scoping meeting in Kansas City, supposedly for the benefit of the users and stakeholders of the downstream States, those downstream stakeholders apparently felt a need to attend the Pierre, South Dakota meeting in an apparent demonstration of the importance of this issue to them.

I think the MRAPS program allows all the States a platform and structure to revisit a long outdated plan of management and benefit allocation of the Missouri River system. It should be viewed as a means where all parties, upstream and downstream interests included, can have the opportunity to have objective discussion on the best basin wide use of that system.

And it should be a means by which the issue of Missouri River and Reservoir system Management and Operations can be modified to address flooding issues in the Bismarck and Mandan areas.

Senator and subcommittee, thank you for hearing and accepting this testimony. If you have any questions I would be happy to answer them.

Senator DORGAN. Mr. Royse, thank you very much. Let me observe as well the meeting that was held in Pierre, South Dakota came following a meeting that had been held in Kansas City, Missouri. In as much as the sponsor of this study and the person that wrote the legislation is from North Dakota, it will be advisable at some moment for the Corps of Engineers to decide to hold a hearing here in North Dakota. I expect that would happen.

Let me next call on Mr. Mike Gunsch, the Houston Engineering witness today from Bismarck, North Dakota. We appreciate very much your being here, Mr. Gunsch. You may proceed.

STATEMENT OF MICHAEL GUNSCH, DISTRICT ENGINEER, BURLEIGH COUNTY WATER RESOURCE DISTRICT

Mr. GUNSCH. Thank you, Senator for the opportunity to provide testimony today regarding the flooding concerns in the Bismarck/Mandan area. I'm currently the District Engineer for the Burleigh County Water Resource District, also an Engineering Consultant for the Morton County Water Resource District. My remarks today are twofold.

One, I've got a separate set relative to the Fox Island issue which is strictly the Burleigh County Water Resource District.

But first I want to start with a joint statement for the Burleigh County Water Resource Board, the Morton County Water Resource Board and the Lower Heart Board. And it will be primarily technical in nature. In July 2009, Houston was retained by those three boards to take a look at the flood issues and the alternatives associated with what's happening with the flood issues on the Missouri River.

Senator DORGAN. Just so that I understand you. You're employed by Houston Engineering, but testifying on behalf of these boards?

Mr. GUNSCH. Correct.

Senator DORGAN. Thank you.

Mr. GUNSCH. Yes.

The cost for the effort in reviewing the alternative of the flood mitigation issues is underwritten in part through a cost share grant for the North Dakota State Water—or North Dakota State Engineers, excuse me. The primary focus of that effort that we're looking at for those boards is to define pre-disaster mitigation alternatives that can be implemented to reduce the existing and projected flood risks for Burleigh and Morton County. After evaluating the March 2009 ice jam flood event and reviewing prior studies the following objectives were developed for further consideration.

One was a sediment debris removal from within the upper reaches of the Oahe delta formation below the Heart River confluence to mitigate the impacts and risks associated with ice jam flood events and future sediment deposition.

Two, evaluate the status of potential aggradation and ongoing changes in the stream channel conveyance downstream from Bismarck/Mandan and its impact on the risks associated with the ice jam and open water flood elevations.

Three is evaluate the feasibility of alternatives to lower the current base flood elevations through Burleigh and Morton Counties to those documented in the 1995 flood insurance study. And there's a particular focus area. The alternatives for these shall include, but not limited to, dredging, channel improvements, reservoir operations, structural measures or a combination thereof.

Four is define existing and future land uses within and proposed bank stabilization measures along the Missouri River correctional facility's property as necessary to achieve the first three objectives. There is a nexus between project construction or dredging within and along the river and the need for access for potential use of adjacent properties for the placement of dredged materials. So that's why that's included.

Five is to complete an assessment to determine the potential economic flood damages or impacts associated with future increases in the Missouri River base flood elevations and flood risks in Burleigh and Morton County. This effort to include a GIS based analysis of existing and potential flood impacts.

The tax and potential costs associated with these objectives will include State, Federal and local issues, but are still under development. So we do not have a number on those at this time.

Kind of a history, concerns regarding the Oahe delta have been around for many years. The 2009 event was just an eye opener. I mean, it raised significant awareness that that issue was there. There have been ice jams in the past. And there will be ice jams in the future.

In 1985 the Corps of Engineers studied this particular situation in a report entitled, Oahe Bismarck Area Studies, Analysis of Missouri River Flood Potential in Bismarck, North Dakota. They evaluated numerous alternatives in which to mitigate the flood impacts. And we are providing a copy of that report for the record for your use and reference.

[The information follows:]

U.S. ARMY CORPS OF ENGINEERS OMAHA DISTRICT—OAHE-BISMARCK AREA STUDIES

ANALYSIS OF MISSOURI RIVER FLOOD POTENTIAL IN THE BISMARCK, NORTH DAKOTA AREA, AUGUST 1985

DEPARTMENT OF THE ARMY,
OMAHA DISTRICT CORPS OF ENGINEERS,
Omaha, Nebraska, August 7, 1985.

To All Interested Parties: The Omaha District, Corps of Engineers has completed its study of the residual Missouri River flood potential at Bismarck, North Dakota, and the alternative measures for alleviating the problem. The study conclusions were presented at a meeting of the Coordinating Committee of the Bismarck-Mandan Missouri River Improvement Association on May 23, 1985. Two documents—an information paper and a more detailed technical summary—have been prepared on the study and its conclusions.

The information paper, which is enclosed, is entitled "Analysis of Missouri River Flood Potential in the Bismarck, North Dakota, Area." Its purpose is to provide the general public with a summary of the flood potential and an evaluation of the alternative measures for alleviating this flood potential.

Additional copies of the information paper are available at the Corps' Bismarck office in room 342 of the Federal Building at 3rd and Broadway. Or, a copy will be mailed to anyone requesting it by calling the Corps' Bismarck office at 255–4011, Extension 612.

The North Dakota State Water Commission has been furnished copies of the technical summary and the information paper. The Commission will be conducting a detailed technical review of this material; the review is to be completed by November 15, 1985.

A public information meeting will be held in Bismarck after the State Water Commission has completed its review. The purpose of the meeting will be to answer any further questions you may have on the study. I have invited the State Water Commission to participate in the meeting to help answer questions. A public notice of the meeting will be sent to those receiving this notice and to anyone who contacts the Corps' Bismarck office and asks to be added to the current mailing list.

Comments on the information paper may also be sent to me at the Omaha District, Corps of Engineers, ATTN: MROPD–P, 215 N. 17th Street, Omaha, Nebraska 68102–4910. The comment period will remain open until December 15, 1985.

Following the Commission's review of the material, the public information meeting, and receipt of all public comments, will consider all views and comments and make my final recommendations.

ROGER B. WHITNEY,
Lieutenant Colonel, Corps of Engineers, Acting District Engineer.

SUMMARY

A residual flood potential exists for the south Bismarck area along the Missouri River upstream from the Lake Oahe project. Based on a damage analysis of existing and projected future development, potential flood damages could average about $900,000 per year. Also, during future years, discharges from the upstream Garrison Reservoir will need to be gradually reduced from the current 20,000 c.f.s. during the winter ice-in period at Bismarck to reduce the possibility that stages do not increase above the current target ice-in stage. This constraint on winter hydropower generation at Garrison Dam is projected to increase the cost of providing power to the upper Midwest region by about $500,000 per year.

Eight alternatives for reducing the potential flood damages and hydropower constraints were evaluated. Most were not economically feasible; therefore, they could not be considered for implementation by the Corps of Engineers. The Corps will, therefore, continue to reduce releases from Garrison Reservoir at critical high discharge periods at Bismarck—when flows from tributaries downstream from Garrison Dam could cause flooding at Bismarck and during winter ice-in. The criteria for ice-in, therefore, will be to continue to target ice-in at 13 feet at the Bismarck gage. The city of Bismarck, Burleigh County, and those developing in the flood plain should also consider additional flood plain management measures in the form of raising new development more than the required 1 foot above the potential existing-conditions 100-year flood elevation and raising access roads to areas of extensive development. These flood plain management measures would reduce future flood damages and provide greater safety to persons living in the flood plain. Also, those per-

sons living or having businesses in the flood plain should continue to take advantage of the Federal Flood Insurance Program to minimize flood damage losses.

INTRODUCTION

Since the construction of the Missouri River main stem dams, flooding at Bismarck, North Dakota, has been limited to low-lying lands adjacent to the Missouri River. The last major flood, the flood of record, occurred at Bismarck in 1952—1 year before closure of Garrison Dam, which is located 75 miles upstream. Even though the main stem system has dramatically reduced flooding in the Bismarck area, a residual flood potential still exists because of runoff from the uncontrolled Missouri River drainage area between Garrison Dam and Bismarck, the influence of sediment deposition in and upstream from Lake Oahe, and ice affected river stages.

The Corps of Engineers has evaluated the potential for residual flooding since 1954, when lands were first delineated for inclusion in the downstream Lake Oahe project. At that tine, it was projected that lands as far upstream as the Bismarck Memorial Bridge (1960 river mile 1314.2) could be influenced by the deposition of sediments in the Missouri River channel. Development in the low-lying lands adjacent to the river at Bismarck has increased the potential for flood damages if a flood were to occur. Since construction of the Garrison project, the Corps of Engineers has limited discharges from the Garrison Reservoir during critical periods to minimize flooding of these low-lying lands and to minimize damages to the development.

This information paper summarizes (1) the flood potential at Bismarck before the construction of the main stem system, (2) the flood potential as it currently exists, and (3) the projected future flood potential. It also summarizes the technical evaluation of eight alternatives that would reduce the flood potential, and it presents a summary of the feasibility of these various alternatives.

SUMMARY OF THE FLOOD POTENTIAL

Before Construction of Main Stem Dams

Prior to the construction of the main stem dams, flood plain areas on both sides of the Missouri River south of Bismarck were frequently flooded to significant depths. Records dating back to 1881 indicate that major flooding occurred on an average of once every 6 or 7 years; however, no significant urban flood damages occurred before the 1939 flood. Because of the recurrent flooding, the south Bismarck area was generally unsuitable for urban development. Beginning in the 1930s, however, some people were willing to take the risk, and Bismarck extended into the Missouri River flood plain at some points.

Fort Peck Dam in Montana was the first of six dams to be constructed on the main stem of the Missouri River. Fort Peck Dam began to impound water in 1937, and the project became fully operational for flood control in 1940. Because it controlled 31 percent of the Missouri River basin drainage area upstream from Bismarck, it reduced the frequent flood threat at Bismarck to some degree. However, the flood threat was not eliminated; the 1952 flood of record at Bismarck demonstrated the continued existence of the likelihood of significant flood events in the area. The maximum stage at the Bismarck gage (1960 river mile 1314.6) reached 27.9 feet, with an estimated discharge of 500,000 cubic feet per second (c.f.s.). Based on a gage datum of zero equalling 1618.4 feet mean sea level (m.s.l.) (became 1618.3 feet m.s.l. in 1979), the flood reached an elevation of 1646.3 feet m.s.l. at the gage. The entire south Bismarck area was under up to 20 feet of water.

Table 1 presents estimated discharges for a range of flood events—from the 5-year up through the 500-year—at the Bismarck gage for the period prior to the construction of Garrison Dam. Only limited gage discharge data are available for the pre-Fort Peck Dam period; therefore, the values presented in table 1 are based on a limited period prior to 1953, when Garrison Dam began impounding water. As shown in table 1, pre-system discharges approaching 1 million c.f.s. could have occurred at Bismarck. It should also be noted that the 1952 flood of record was less than a 100-year flood event. Even though it is a very remote flood event, the 500-year flood was included in table 1 because such events have occurred at other locations within the Missouri River basin and the 500-year flood is commonly the basis for the design of flood control projects in urban areas.

Table 1 also includes the estimated flood stages and the corresponding flood elevations for the 5- through 500-year events. These stages are based on the presystem all-seasons stage-frequency curve for the Bismarck gage, which is a probabilistic combination of stages for the complete range of open-water (spring, summer, and fall) and ice-affected (winter) events.

TABLE 1.—PRESYSTEM FLOODING POTENTIAL AT THE BISMARCK GAGE

Recurrence Internal (years)	Discharge (c.f.s.)	Stage (feet)	Flood Elevation (feet m.s.l.)
5	180,000	21.6	1640.0
10	250,000	24.2	1642.6
25	360,000	26.3	1644.7
50	460,000	28.7	1647.1
100	583,000	30.3	1648.7
500	990,000	33.5	1651.9

To place the presystem flooding in perspective, potential flood depths at the Kirkwood Shopping Center, located south of the downtown area, were estimated. Although the parking lot varies in elevation, it averages 1636 feet m.s.l. Floodwaters from a 10-year event would have been about 6.5 feet deep; 50-year flood waters would have been over 11 feet deep, and 100-year flood waters would have been almost 13 feet deep. Table 2 presents pre-system flood elevations for the 5-, 10-, 50-, and 100-year floods at five locations along the river in the Bismarck area. These elevations are based on historical stage data for the Bismarck gage that were obtained prior to the construction of Garrison Dam. Based on the range of ground elevations near these locations, flood depths of from 11 to 20 feet could have occurred along the river with the 100-year flood. A 50-year flood would have ranged from 9 to 17 feet in depth, and a 10-year flood would have had depths generally from 5 to 14 feet.

TABLE 2.—POTENTIAL PRESYSTEM FLOOD ELEVATIONS IN THE BISMARCK AREA

Location	1960 River Mile	Flood Elevations (feet m.s.l.)			
		5-year	10-year	50-year	100-year
Square Butte Creek	1,322.5	1,645.0	1,647.3	1,651.9	1,653.5
Bismarck Gage	1,314.6	1,640.0	1,642.6	1,647.1	1,648.7
Heart River	1,311.0	1,637.5	1,640.2	1,644.7	1,646.3
General Sibley Park	1,307.0	1,635.0	1,637.5	1,641.9	1,643.5
Cabe Project Boundary	1,303.0	1,632.5	1,634.8	1,639.4	1,641.0

EXISTING CONDITIONS

The potential for significant flooding at Bismarck was reduced in 1953 when Missouri River flows were first controlled by Garrison Dam, which is located about 75 river miles upstream. Estimated flood discharges at the Bismarck gage for a range of events under existing conditions are presented in table 3. A comparison of these discharges with the presystem discharges shows that Garrison Dam has provided a significant reduction in Bismarck flood discharges—a reduction of from 71 to 85 percent.

TABLE 3.—EXISTING-CONDITIONS MISSOURI RIVER DISCHARGES AT THE BISMARCK GAGE

Recurrence Interval (years)	Discharge (c.f.s.)	Reduction in Discharge [1] (percent)
5	52,000	71
10	57,000	77
25	71,500	80
50	81,500	82
100	94,000	83
500	148,000	85

[1] As compared to the presystem discharges presented in table 1.

Even with the dramatic reduction in discharges, residual Missouri River flooding could still be a problem at Bismarck because of increased occupation of the 100-year flood plain. Minor lowland flooding has occurred on a few occasions since the closure of Garrison Dam in 1953. The greatest amount of flooding occurred in the summer of 1975, when heavy spring rains in Montana caused high discharges from Garrison Reservoir. Although stages reached 14.2 feet at the Bismarck gage (discharge equaled 68,900 c.f.s.), this flooding inundated only the low-lying lands along the river. No significant economic damages occurred in the south Bismarck area as a result of that event. A recurrence of that flood event today could cause some damage because many additional homes have been constructed in the area. Similar flooding also occurred in January 1983 as the result of an ice jam in the vicinity of the Heart River. These flood events showed that some flooding can still occur in the south Bismarck area, although not of the magnitude of those that occurred before construction of the main stem system of dams.

Based on cross-sectional data obtained in 1981 and 1982, potential flood depths have been determined for existing conditions. (The term "existing conditions" describes the conditions which could occur only if the assumptions underlying the hydrologic analysis in fact occur.) Table 4 presents the potential existing-conditions all-seasons flood elevations for the 5-, 10-, 50-, and 100-year floods in the Bismarck area. Flooding from major events would occur most often in the spring and summer because of the large flows from the Knife River and Heart River basins—the two major tributaries between Garrison Dam and Lake Oahe. Because the effects of discharges from the Heart River are somewhat greater than those from the Knife River and because the mouth of the Heart River is at Bismarck, the Heart River has a greater effect on the peak discharges and stages at Bismarck than the Knife River. Even though the upstream half of the Heart River basin is controlled by Heart Butte Dam, runoff from the lower, uncontrolled half of the basin would reach Bismarck in 1½ to 2 days, the same amount of time it takes for Garrison Reservoir releases to reach Bismarck. It, therefore, would be impossible to cut releases from Garrison Reservoir in time to reduce the coincident peak at Bismarck. The flood elevations presented in table 4 represent those that would result from high flows from the Knife River and Heart River basins coincident with Garrison Reservoir releases. The Corps, however, will continue to reduce Garrison releases to limit flooding at Bismarck at times of increased flood potential because, under certain circumstances, flooding could be reduced when the high discharges are primarily from the Knife River and some minor tributaries upstream from Bismarck. Table 5 shows how much lower existing-conditions stages are than those presented in table 2 for the presystem flooding conditions. Briefly, the potential existing-conditions flooding in the south Bismarck area would be is from about 7 feet lower for the 5-year event to about 13 feet lower for the 100-year event.

TABLE 4.—POTENTIAL EXISTING-CONDITIONS ALL-SEASONS FLOOD ELEVATIONS IN THE BISMARCK AREA

Location	1960 River Mile	Flood Elevations (feet m.s.l.)			
		5-year	10-year	50-year	100-year
Square Butte Creek	1,322.5	1,637.8	1,638.0	1,638.9	1,640.0
Bismarck Gage	1,314.6	1,632.7	1,633.3	1,634.5	1,635.7
Heart River	1,311.0	1,630.4	1,631.2	1,632.7	1,633.9
General Sibley Park	1,307.0	1,628.0	1,629.0	1,630.5	1,631.7
Oahe Project Boundary	1,303.0	1,625.6	1,626.5	1,628.0	1,629.2

TABLE 5.—REDUCTION IN POTENTIAL FLOOD ELEVATIONS FROM PRESYSTEM TO EXISTING CONDITIONS

Location	1960 River Mile	Flood Elevation Reduction (feet)			
		5-year	10-year	50-year	100-year
Square Butte Creek	1,322.5	7.2	9.3	13.0	13.5
Bismarck Gage	1,314.6	7.3	9.3	12.6	13.0
Heart River	1,311.0	7.1	9.0	12.0	12.4
General Sibley Park	1,307.0	7.0	8.5	11.4	11.8
Oahe Project Boundary	1,303.0	6.9	8.3	11.4	11.8

The reduced flooding since closure of Garrison Dam in 1953 encouraged considerable residential development to take place in the south Bismarck area—most of it occurring on the Bismarck side of the river—even though this area has been designated as the 100-year flood plain by the Federal Emergency Management Agency (FEMA). About 220 homes are now located in the south Bismarck area. Most of these homes—and all of the newer homes—were constructed with their first floor elevations at least 1 foot above the existing-conditions 100-year flood, as required by FEMA for flood insurance purposes. They would, therefore, be significantly affected by only the very exceptional flood events such as the existing-conditions 100-year flood, which could cause floodwaters about 5 feet deep in some residential areas.

The potential for economic flood damages was analyzed in December 1984. Using land use data obtained in 1980 and 1984 and the flood depths from the existing-conditions hydraulic analysis, potential flood damages for various flood events and, subsequently, the potential annual damages were estimated. The estimated potential existing-conditions flood damages in the south Bismarck area for the 5-, 10-, 100-, and 500-year events are presented in table 6. These damages are based on damages to structures and contents; no damages were estimated for roads, streets, utilities, lands, cleanup, or other categories. Potential annual damages were computed based on a probabilistic analysis. Even though the relatively infrequent events between the 100- and 500-year events have a very low likelihood of occurring each year, they result in about 75 percent of the existing-conditions potential annual damages. The potential annual damages to structures and contents for existing-conditions flooding in the south Bismarck area total about $300,000. This is an average figure based on all damages listed in table 6, including the 500-year event.

TABLE 6.—POTENTIAL EXISTING-CONDITIONS FLOOD DAMAGES

Recurrence Interval (years)	Estimated Flood Damages
5	$69,000
10	140,000
50	670,000
100	1,800,000
500	47,000,000

Hydropower releases from Garrison Reservoir are normally reduced to about 20,000 c.f.s. each December just prior to ice formation through the Bismarck area. This reduction in flow is made to ensure that ice-affected stages do not increase to the point of flooding lands adjacent to the river at Bismarck. After the initial ice-in, discharges can be gradually increased to an average daily discharge of about 33,000 c.f.s.; this gradual increase occurs as the streambed adjusts and the underside of the ice becomes smoother. The short-term release reduction limits the quantity of winter energy which can be produced. Subsequent increased releases provide greater freedom in meeting the hydropower needs because the Garrison powerplant can be peaked a larger part of the day without exceeding the higher daily average release rates. The river reaches downstream from Garrison Dam limit its full hydropower potential; however, the Missouri River main stem system was designed and the power is marketed in accordance with all of these conditions, which have been maintained throughout the early life of the project.

FUTURE CONDITIONS

There are two processes occurring that will reduce the capacity of the river in the study reach. First, as the sediment-carrying-water moves down the Missouri River into Lake Oahe, the flow velocities decrease and the sediment in suspension is deposited along the bottom of the channel, thereby reducing its capacity. Second, the river is responding to the new regulated flow regime by adjusting its sandy bed and banks to form a generally narrower and deeper channel. This also tends to reduce the channel capacity.

The Missouri River will continue to adjust its cross section in response to the above two processes until a quasi-state of equilibrium between the regulated flow regime and the river channel has been attained. After this adjustment is completed, the channel will remain about the same size in the Bismarck area while the delta-building process proceeds farther into the Lake Oahe pool. Fluctuations in channel size will occur as the flows and Lake Oahe pool levels vary from year to year.

A baseline condition for the future operation of the Garrison project had to be identified before the potential future-conditions residual flooding elevations could be computed for the south Bismarck area. The all-seasons flood elevations for the more frequent events are closely related to the ice-in criteria. Currently, ice-in is targeted at a 13-foot Bismarck gage stage, and this criteria will be continued. The all-seasons flood elevations for the less frequent events are affected by the assumed coincident Garrison releases during high downstream tributary inflows to the Missouri River. Garrison releases will continue to be reduced during high downstream inflow from the tributaries whenever such action would reduce peak flows at Bismarck, and the combined Garrison releases and tributary inflows will continue to be the same as assumed for the existing-conditions analysis.

Table 7 presents the flood elevations that are expected to occur once the future equilibrium condition is reached. It also presents the increases in flood elevations over the existing-conditions flood elevations. As shown, ultimate future flood elevations could be from 0.3 foot to 1.0 foot higher than those that currently could occur at locations from the Bismarck gage downstream to the current Lake Oahe project boundary.

TABLE 7.—POTENTIAL FUTURE-CONDITIONS FLOOD ELEVATIONS

Location	Flood Elevations (feet m.s.l.)				Change from Existing conditions (feet)			
	5-year	10-year	50-year	100-year	5-year	10-year	50-year	100-year
Square Butte Creek	1,638.0	1,638.2	1,639.4	1,640.6	+0.2	+0.2	+0.5	+0.6
Bismarck Gage	1,633.1	1,633.9	1,635.9	1,637.0	+0.4	+0.6	+1.4	+1.3
Heart River	1,630.7	1,631.7	1,633.5	1,634.7	+0.3	+0.5	+0.8	+0.8
General Sibley Park	1,628.3	1,629.4	1,631.3	1,632.5	+0.3	+0.4	+0.8	+0.8
Oahe Project Boundary	1,626.0	1,627.0	1,629.0	1,630.1	+0.4	+0.5	+1.0	+0.9

Table 8 shows the differences between the presystem flood elevations for various events and the potential future-conditions flood elevations. Significant reductions in stages from those that could have occurred before the main stem dams were constructed have occurred and will continue to occur in the future. The potential 5-year flood elevations would be about 6 to 7 feet lower and the potential 100-year flood elevations would be about 11 to 13 feet lower than they could have been without the construction of the main stem dams.

TABLE 8.—REDUCTION IN POTENTIAL FLOOD ELEVATIONS FROM PRESYSTEM TO FUTURE CONDITIONS

Location	Flood Elevation Reductions (feet)			
	5-year	10-year	50-year	100-year
Square Butte Creek	7.0	9.1	12.5	12.9
Bismarck Gage	6.9	8.7	11.2	11.7
Heart River	6.8	8.5	11.2	11.6
General Sibley Park	6.7	8.1	10.6	11.0
Oahe Project Boundary	6.5	7.8	10.4	10.9

Plate 1 shows the 5-year flood outlines for presystem, existing, and future conditions. Plates 2 and 3 show the same comparison for the 10- and 100-year flood events, respectively.

The flooded areas shown on these plates were developed by determining the flood elevation from the water surface profiles for a given area and then locating the limit of flooding in that area through the use of 2-foot contour interval topographic mapping. The flood outlines were then transferred from the topographic mapping onto aerial photographs; the blue shaded area represents the potential existing-conditions flooded areas. Since most of the homes in the south Bismarck area are built on mounds of earth which are elevated above the 100-year flood elevation, these homes may only be surrounded by water during a major flood event, with little or no damage resulting to the structure itself. (The means of access to many of these, however, could be flooded.) Because of the small scale of the aerial photography, it was impossible to show the area flooded around each individual residence. Therefore, the flooded areas represent only the outside limit of the flooded area, and they do not include small islands within the flooded area.

Flood elevations shown on a water surface profile under open-water conditions normally apply laterally over most of the flood plain width. However, ice along the banks of the river will generally act as a barrier to floodwater entering some of the overbank areas under ice-affected conditions. Thus, the flooded area corresponding to a given ice-affected water surface elevation may not extend landward as far as for open-flow conditions. The extent of the area flooded for a given ice-affected stage depends to a great extent on how the river ices in. As the river ices in and the head of the ice moves through the Bismarck area, the river stages will normally shift upward because of the additional roughness of the ice cover. After the initial ice-in period, the release from Garrison Reservoir can be gradually increased. Because of the smoothing of the streambed and the underside of the ice cover, this increase in discharge can normally be made without a corresponding increase in stage in the Bismarck area. Field observations made during past ice-in periods indicate that if the river ices in as described above, then the ice which forms along the riverbanks will act as a barrier to floodwater entering scene overbank areas. However, it is possible for a small ice jam to occur during the ice-in process, and this would result in an increase in stage. If this happens, the floodwater would flow into the overbank areas in much the same manner as it would for open-flow conditions. The flood of January 1983 is an example of this type of flood event. This event was the result of an ice jam downstream from the Heart River that caused the inundation of much of the lower portion of Fox Island. For the purposes of this study, therefore, the flooded areas were drawn with the intent of showing the maximum area that could be affected for a given flood event. The flooded areas for the 5- and 10-year events were drawn by extending the channel water surface elevation laterally across the flood plain. However, it is recognized that, for ice-affected flood events, this assumption may not apply.

A review of table 8 and plates 1 through 3 demonstrates that the main stem dams will continue to significantly reduce the amount of flooding from that which could have occurred without the construction of the rain stem dams. As aggradation continues in the future, flood stages would be expected to gradually increase above the existing-conditions stages; flood damages may also increase. Additional development is expected to occur in the south Bismarck area. This development would also result in an increase in damages for most storm frequencies and in an increase in potential annual damages. The potential future-conditions flood damages presented in table 9 are based on continued development of the south Bismarck area over the next 50 years. (Population projections were used as a basis for the rate of development.) The potential annual damages would also increase over the next 100 years. Two additional assumptions were made in order to compute the flood damages. The future-conditions channel size was assumed to occur in 20 years, and the potential annual damages were discounted over the next 100 years. The potential annual flood damages were estimated to increase from $300,000 under existing conditions to a long-term average of $910,000.

TABLE 9.—POTENTIAL FUTURE-CONDITIONS FLOOD DAMAGES

Recurrence Interval	Estimated Flood Damages
5-Year	$93,000
10-year	310,000
50-year	2,700,000
100-year	12,200,000
500-year	129,000,000

Although current contractual hydropower agreements will continue to be met when future discharges are reduced during the winter months, there will be an increase in the regional power system cost. Some of the power that would have been generated with the more economical hydropower units at the dam sites has to be generated by utilities using more costly generating facilities, such as coal- or oil-fired units. The value of this constraint in terms of increased operating costs to the region's utilities is estimated to be about $500,000 per year. This value is in terms of 1985 dollars, and it was determined by discounting the increased costs over the next 100 years at an 8.375 percent discount rate. The hydropower constraint was assumed to increase from zero currently to the full value by the year 2005 (20 years). There may also be a cost in terms of reduced reliability of the main stem hydropower generating capabilities; however, the value of this cost cannot be readily determined.

Table 10 presents an economic summary of the residual flood problem at Bismarck, based on a continuation of the ice-in at a 13-foot stage. Combined potential annual flood damages and increased power costs total $1,410,000 per year. The magnitude of this annual cost warrants a formulation and evaluation of alternative solutions to reduce the impacts of the residual flood problem at Bismarck.

TABLE 10.—ECONOMIC SUMMARY OF THE POTENTIAL RESIDUAL FLOOD PROBLEM

Potential Annual Flood Damages:	
Existing Conditions	$300,000
Future Conditions (2085)	1,370,000
Composite Annual Value	910,000
Reduced Hydropower Capacity:	
Average Annual Value	500,000
Total	1,410,000

THE ALTERNATIVES

Eight basic alternatives to the continuation of the current 13-foot ice-in stage criteria—the baseline condition—have been evaluated as measures to reduce the potential residual flood problem in the south Bismarck area and to ensure the continuation of the current level of Garrison hydropower generation in the future. These alternatives include (1) channel dredging, (2) channel cutoffs, (3) bank stabilization, (4) levees, (5) Garrison operational changes, (6) Oahe operational changes, (7) land acquisition, and (8) flood plain management. All of these alternatives do not provide a complete solution to the flood potential and the continuation of the current level of Garrison hydropower generation. These alternatives were selected jointly by the Corps of Engineers and the Bismarck-Mandan Missouri River Improvement Association—a local coordinating committee—primarily because each alternative had possibilities for reducing the residual flooding potential at Bismarck. A detailed evaluation of the alternatives determined that several of them had very limited effectiveness in reducing the residual potential for further floods, the future hydropower constraint, or both.

The economic evaluation of the alternatives was based on a 100-year project life at a discount rate of 8.375 percent. All costs and benefits are in terms of 1985 dollars. As with the computation of flood damages and increased power needs, the existing conditions were assumed to occur in 1985 and the future conditions would first occur in the year 2005.

A brief discussion of each of the alternatives follows. Each discussion includes a description of the alternative, its effectiveness in addressing the problems, and the costs, benefits, and feasibility of the alternative.

CHANNEL DREDGING

Dredging the Missouri River between river miles 1315 and 1299—refer to plate 4—was evaluated because it would provide a larger channel through the south Bismarck area. Options 1 and 2 were designed to convey the 5- and 10-year all-seasons flood events, respectively, past the Bismarck gage at a 12-foot stage. The channel would be redredged when the stages for these events would exceed 14 feet. Options 3 and 4 are similar; however, redredging would be conducted when stages for the 5- and 10-year events reach 13 feet. Implementation of options 1 or 3 would initially reduce existing-conditions stages about 2.4 feet, and implementation of options 2 or 4 would initially reduce the existing-conditions stages 3.0 feet.

All four options would require frequent redredging to regain the design channel capacity. Disposal areas ranging from 220 to 660 acres, for disposal at a 10-foot depth, would be required each time redredging is necessary. Table 11 presents information on each of the four dredging options.

TABLE 11.—PERTINENT DATA—DREDGING

Item	Options			
	1	2	3	4
Design Flood	5-year	10-year	5-year	10-year
Stage Before Dredging (feet) [1]	14.4	15.0	14.4	15.0
Stage after Dredging (feet) [1]	12.0	12.0	12.0	12.0
Maximum Stage Reduction for the 5-year event [2]	2.4	3.0	2.4	3.0
Stage Before Redredging (feet) [1 3]	14.4	14.2	13.0	13.0
Minimum Stage Reduction for the 5-year event [2]	....	0.8	1.4	2.0
Redredging Frequency (years)	5	3	1.5	1
Disposal Areas (acres):[4]				
Initial	1,250	1,400	1,250	1,400
Redredging	660	530	260	220
Total [5]	14,500	18,900	18,400	23,400

[1] All-seasons flood stage at Bismarck gage.
[2] As compared to the existing-conditions 5-year, all-seasons flood stage.
[3] Expected river stage for the design flood before redredging.
[4] Disposal area estimates based on 10-foot disposal depth.
[5] Total disposal area for 100-year period of analysis.

As shown in table 11, a sizeable area would be needed for disposal areas. The disposal of the dredged material would affect more land than would be flooded by a relatively large flood, and it would have significant adverse environmental impacts.

Initially, as shown in table 11, the 5- or 10-year flood stages would be reduced by 2.4 or 3.0 feet, respectively, for the four options that were evaluated. However, the channel would fill in following each dredging; this would require frequent redredging to restore the dredged channel to its design capacity. The highest stages prior to each redredging would be equal to or lower than the existing-conditions flood elevations (refer to table 11—minimum stage reduction for the 5-year event).

The costs for the four dredging options, including land acquisition costs, are presented in table 12. The initial dredging costs exceed $30 million for all four options, while the redredging costs range from $5.8 million to $17.2 million. Based on the varying redredging intervals presented in table 11, the average annual costs range from $6.1 million to $8.6 million.

TABLE 12.—ECONOMIC SUMMARY—DREDGING

Item	Dredging Options			
	1	2	3	4
Costs:				
Initial	$32,100,000	$32,900,000	$32,100,000	$32,900,000
Redredging	$17,200,000	$13,400,000	$6,700,000	$5,800,000
Average Annual	$6,100,000	$7,200,000	$7,200,000	$8,600,000
Average Annual Benefits:				
Flood Damage Reduction	$670,000	$800,000	$800,000	$860,000
Hydropower	$500,000	$500,000	$500,000	$500,000
Fill Reduction	$40,000	$70,000	$70,000	$80,000
Total	$1,210,000	$1,370,000	$1,370,000	$1,440,000
Net Benefits	−$4,890,000	−$5,830,000	−$5,830,000	−$7,160,000
Benefit-Cost Ratio	0.2	0.2	0.2	0.2

The flood damage reduction and hydropower benefits for dredging the channel are included in table 12. Dredging would result in a channel that is as large or larger than the existing channel—depending on the option and the length of time between dredgings—and always larger than the projected future-conditions channel. The expected reduction in potential annual flood damages would be from $670,000 to $860,000 per year. This alternative would reduce the 100-year flood elevations by up to 3 feet. The requirement for fill material to elevate structures in the 100-year flood would be reduced, thereby reducing building costs by up to $80,000 per year. The larger channel would result in no future hydropower constraints; therefore, average annual hydropower benefits of $500,000 would be expected with all four dredging options. The total benefits for the dredging alternatives, therefore, range from $1,210,000 to $1,440,000 per year.

Based on the annual costs and benefits. presented in table 12, the benefit-cost ratio for each of the dredging options is 0.2.

CHANNEL CUTOFFS

Channel cutoffs, like channel dredging, would reduce flood stages by providing better conveyance of floodflows through the south Bismarck area. Two potential cutoff sites, one located within (upper) and the other downstream (lower) from the south Bismarck area, are shown on plate 5. Three options were initially considered. Only two of these options were effective in reducing stages—option 1, the upper cutoff, and option 2, both cutoffs; the lower cutoff, option 3, alone would not be effective. Therefore, only options 1 and 2 were evaluated.

Both cutoffs would require extensive modifications. The upper cutoff would require the excavation of 9,200,000 cubic yards and the lower cutoff would require the excavation of 10,300,000 cubic yards. The cutoff channels would be riprapped to protect against erosion, and channel blocks would be required across the existing channel at the upstream ends of the cutoffs. Each cutoff would require about 600 acres for disposal of excavated material to a depth of 10 feet. The upper cutoff would eliminate access to the remainder of Sibley Island.

Option 2 would be more effective than option 1. At Fox Island, option 2 would initially reduce stages by 2.0 feet for the 5- and the 10-year floods; option 1 would initially reduce those stages by 1.5 feet. Over the next 15 to 20 years, both options would lose much of their effectiveness. After 15 to 20 years, the upper cutoff would result in a net increase above the baseline-conditions stages of 0.1 foot for the future-conditions 5-year event and a net decrease of 0.1 foot for the 10-year event. Both cutoffs would result in a net decrease from the baseline conditions stages of 0.7 and 0.9 foot for the 5- and 10-year future-conditions events, respectively. With option 1, the future-conditions flood stages at Fox Island, therefore, would be 0.4 foot above the existing-conditions stages. Future-conditions flood stages would be 0.4 foot below the existing-conditions stages with option 2.

Table 13 presents an economic summary of the channel cutoff options. The first cost of option 1 would be $24.1 million, including $600,000 for acquisition of the cutoff and disposal areas. Option 2 would have a first cost of $48.7 million, which also includes $600,000 for land acquisition. The lower cutoff area is on existing Lake Oahe project lands; acquisition of additional lands would not be required. These costs do not include land acquisition for the remainder of Sibley Island, which would be inaccessible. The estimated annual costs to maintain the cutoffs is about 1 percent of the first costs of construction, or about $240,000 and $480,000 for options 1 and 2, respectively. The estimated average annual costs of options 1 and 2 are $2,300,000 and $4,600,000, respectively.

TABLE 13.—ECONOMIC SUMMARY—CHANNEL CUTOFFS

Item	Cutoff Options	
	1	2
Costs:		
Construction	$24,100,000	$48,700,000
Operation and Maintenance	$240,000	$480,000
Average Annual	$2,300,000	$4,600,000
Average Annual Benefits:		
Flood Damage Reduction	$400,000	$580,000
Hydropower	....	$500,000
Fill Reduction	....	....
Total	$400,000	$1,080,000
Net Benefits	−$1,900,000	−$3,520,000
Benefit-Cost Ratio	0.2	0.2

Option 1 would result in flood damage reduction benefits of $400,000 per year. Option 2 flood damage reduction benefits would be $580,000 per year. Neither option would result in a significant reduction in fill needs; therefore, there would be no fill reduction benefits.

Construction of only the upstream cutoff would not eliminate any of the future expected constraints on hydropower releases at the Garrison project; therefore, option 1 has no hydropower benefits. Option 2, however, would result in a channel capacity at Bismarck equivalent to the existing-conditions capacity, and it would eliminate all future hydropower constraints at the Garrison project. The hydropower benefits of option 2 would be $500,000 per year. The benefit-cost ratios for the channel cutoff options are both 0.2.

BANK STABILIZATION

The bank stabilization alternative was evaluated because it would reduce the future aggradation rate and, thereby, delay the occurrence of the higher, future-conditions flood stages. This alternative would consist of providing protection to all bank areas within the Garrison dam to Lake Oahe reach that are either actively eroding at this time, have experienced erosion in the past, or have a strong potential for erosion in the future. Basically, this alternative would result in total stabilization of all eroding banklines within the 87-mile reach. The stabilization methods used would be similar to those already constructed within this reach.

Stabilizing the banks would eliminate only one of several sources of sediment to the Missouri River upstream from Bismarck. The other sources of sediment provide the major portion of the sediment load, and they would continue to cause aggradation. The stabilization would not ultimately reduce future water levels below those that would occur for the baseline condition.

The total cost of bank stabilization is estimated to be $24,500,000. Based on experience with existing stabilization measures on the Missouri River, the annual operation and maintenance costs are estimated to be 1 percent of the first cost or approximately $250,000. The average annual costs would, therefore, be $2,300,000. An economic summary is presented in table 14.

Based on delaying the ultimate conditions an additional 10 years, the flood reduction benefits would be $40,000 per year, as shown in table 14. This alternative would have no fill reduction benefits. Land losses in the erosion areas could be reduced by as much as 50 acres per year, resulting in an annual benefit of $30,000. Also, based on the 10-year delay in reaching the projected channel size, hydropower benefits would total $200,000 per year. The total benefits would be $270,000 per year. Based on average annual costs of $2,300,000, the benefit-cost ratio is 0.1.

TABLE 14.—ECONOMIC SUMMARY—BANK STABILIZATION

	Amount
Costs:	
Construction	$24,500,000
Operation and Maintenance	$250,000
Average Annual	$2,300,000
Average Annual Benefits:	
Flood Damage Reduction	$40,000
Hydropower	$200,000
Bank Stabilization	$30,000
Fill Reduction	....
Total	$270,000
Net Benefits	−$2,030,000
Benefit-Cost Ratio	0.1

LEVEES

Levees would reduce overland flooding and, thereby, reduce potential flood damages and hydropower constraints. Levees were evaluated for only the Bismarck side of the river because of the limited development on the Mandan side of the river. Two levee alignments were evaluated for four levels of protection—5-, 10-, 100-, and 500-year protection. Construction of 5- and 10-year levees is highly questionable for an urban area such as the south Bismarck area. Normally, only high levels of protection—100-year or greater—are considered appropriate for urbanized areas. In this case, however, the 5- and 10-year levees were considered because they would reduce the more frequent and nuisance type floods while eliminating the future constraints on Garrison hydropower production in the winter. Plate 6 shows both levee alignments. Alignment 1 would provide protection to all lands north of the southeast corner of General Sibley Island, and alignment 2 would protect all lands on the Bismarck side of the river upstream from the Lake Oahe project boundary. Average levee heights would vary from 4 to 5 feet for the 5-year options to approximately 11 feet for the 500-year options.

Table 15 presents the costs and benefits of the eight levee options. The first costs, including land, vary from $8.3 million to $32.0 million. The average annual costs vary from $720,000 to $2.8 million. The construction costs are for a rural-type levee design. If a 5- or 10-year levee were constructed in an urban area it would require a relatively flat backslope, which would result in construction costs about 25 percent higher than those indicated for the 5- and 10-year levees in table 15.

The flood damage reduction benefits would vary with each option. These benefits would range from $80,000 for the 5-year, alignment 1 option to $710,000 per year for the 500-year, alignment 2 option.

The 100- and 500-year levee options would eliminate the need to provide fill material to elevate all structures in the 100-year flood plain. This cost savings is estimated to be $60,000 per year for alignment 1 and $80,000 per year for alignment 2.

TABLE 15.—LEVEES ECONOMIC SUMMARY

Item	Levee Options			
	5-year	10-year	100-year	500-year
Alignment 1				
Costs:				
Construction	$3,160,000	$3,360,000	$9,460,000	$13,800,000
Land	$5,100,000	$5,100,000	$5,500,000	$5,500,000
Operation and Maintenance	$33,000	$36,000	$47,000	$69,000
Average Annual	$720,000	$740,000	$1,300,000	$1,680,000
Average Annual Benefits:				
Flood Damage Reduction	$80,000	$110,000	$490,000	$620,000
Hydropower	$500,000	$500,000	$500,000	$500,000
Fill Reduction	....	....	$60,000	$60,000

TABLE 15.—LEVEES ECONOMIC SUMMARY—Continued

Item	Levee Options			
	5-year	10-year	100-year	500-year
Total	$580,000	$610,000	$1,050,000	$1,180,000
Net Benefits	−$140,000	−$130,000	−$250,000	−$500,000
Benefit-Cost Ratio	0.8	0.8	0.8	0.7
Alignment 2				
Costs:				
Construction	$3,910,000	$4,250,000	$15,100,000	$22,300,000
Land	$7,000,000	$7,000,000	$9,700,000	$9,700,000
Operation and Maintenance	$39,000	$42,000	$76,000	$112,000
Average Annual	$960,000	$990,000	$2,150,000	$2,790,000
Average Annual Benefits:				
Flood Damage Reduction	$90,000	$130,000	$570,000	$710,000
Hydropower	$500,000	$500,000	$500,000	$500,000
Fill Reduction	....	....	$80,000	$80,000
Total	$590,000	$630,000	$1,150,000	$1,290,000
Net Benefits	−$370,000	−$360,000	−$1,000,000	−$1,500,000
Benefit-Cost Ratio	0.6	0.6	0.5	0.5

All of the levee options would allow the continuation of the 20,000 c.f.s. ice-in. This would eliminate the potential future constraints on hydropower releases from Garrison Reservoir. The hydropower benefits would be the same for all eight options, or $500,000 per year.

Total benefits range from $580,000 to $1,290,000 per year. None of the options have positive net benefits, and the benefit-cost ratios range from 0.5 to 0.8, as shown in table 15.

GARRISON OPERATIONAL CHANGES

The all-seasons stage-frequency curve that is used to depict flood stages in the Bismarck area is composed of three separate curves—Garrison project release stages, ice-affected stages, and stages for high tributary flows combined with coincident Garrison project releases. The first curve is not as significant in computing the composite all-seasons curve as the other two are. Three Garrison operational change options were evaluated. The first option would affect the coincident release curve, and the other two would affect the ice-affected curve.

—*Maintain Year-Round "Normal" Release.*—This first option consists of maintaining the daily release from Garrison Reservoir at essentially the same level throughout the year. Currently, the average daily releases from the reservoir vary considerably throughout the year. If inflows to the Fort Peck and Garrison projects are high, releases from Garrison Reservoir are likely to be higher over the next few months to allow for adequate storage space of the high inflows. Much higher than normal inflows generally occur in the spring, and this is the same time that high tributary runoff downstream from Garrison Dam is most likely to occur. Under the current mode of operation at this time of the year, the coincident Garrison release is assumed to be 35,000 c.f.s. for the 5- and 10-year events and 40,000 c.f.s. for the less frequent events. By limiting the average daily release to a maximum of 28,000 c.f.s., the sum of the tributary and Garrison coincident discharges would be lower. The open water flood elevations would, therefore, be lower.

The average discharge at the Bismarck gage, based on the data accumulated since the filling of lake Sakakawea behind Garrison Dam, has been about 27,500 c.f.s. Because flows are reduced to about 20,000 c.f.s. each December and gradually increased during January, the average flow the remainder of the year is slightly higher—about 28,000 c.f.s.—based on a continuation of the historical flows past the Bismarck area.

Hydrologic records reveal that a average discharge of 28,000 c.f.s. would need to be exceeded on the average of 1 out of every 7 or 8 years. The higher releases would be required to move the tributary inflows to the Fort Peck and Garrison Reservoirs through the main stem dam system during years of very heavy runoff. A 28,000 c.f.s. discharge could not be guaranteed, and a higher release could coincide with high tributary inflows downstream from Garrison Dam.

Assuming that the 28,000 c.f.s. maximum Garrison Reservoir discharge could be guaranteed every year for a best-case situation, the future-conditions flood stage increases would be from 1.1 to 1.2 feet at the Bismarck gage. Under the worst-case situation, the coincident Garrison releases would stay at 35,000 to 40,000 c.f.s., and the future-conditions flood stage increases would not be reduced at all. The future stages, therefore, would be higher for this alternative than they would be under the base conditions—0.2 to 0.6 foot higher, depending on the flood recurrence interval and assumed worst- or best-case situation.

A maximum release restriction of 28,000 c.f.s. would cause the Garrison Reservoir (Lake Sakakawea) to fluctuate over wide limits. This would require a significant lowering of Lake Sakakawea to maintain an adequate flood storage capacity. For every foot that the lake would need to be lowered, the hydropower capacity would be reduced by about 5 megawatts. The value of this loss per foot of head reduction at Garrison Dam would be about $1.9 million per year. The lake level fluctuations would also have negative impacts on fish production and recreation at Lake Sakakawea. Also, it would have a significant negative impact to the rain stem system operation. These latter impacts, however, were not quantified, and table 16 includes only the lost hydropower costs.

TABLE 16.—ECONOMIC SUMMARY—GARRISON RESTRAINED RELEASES

	28,000 c.f.s.	11.5-foot Ice-in	20,000 c.f.s. Ice-in
Annual Costs:			
Lost Hydropower	[1] $1,900,000	$1,200,000	....
Flood Damage Reduction	....	....	$20,000
Total	$1,900,000	$1,200,000	$20,000
Average Annual Benefits:			
Flood Damage Reduction	$20,000	....	....
Hydropower	$250,000	....	$500,000
Total	$270,000	....	$500,000
Net Benefits	−$1,630,000	−$1,200,000	−$480,000
Benefit-Cost Ratio	0.1	....	25

[1] Loss per foot of head reduction at Garrison Dam.

Because winter releases would not be constrained as much as they would be for the baseline condition, the increased annual cost for electric power production due to Garrison constraints would be reduced from $500,000 to $250,000—a benefit of $250,000 per year.

This option would also have flood damage reduction benefits of $20,000 per year. The resulting total benefits of this option would be $270,000 per year. The net benefits, however, are negative and the benefit-cost ratio is only 0.1.

—*Reduce Ice-in Stage to 11.5 Feet.*—This option was evaluated to see if it would be effective in reducing the flood depths for the more frequent events in the south Bismarck area that the previous option was not effective in reducing. The ice-in target would be reduced to an 11.5-foot stage at the Bismarck gage instead of the current 13-foot stage. By reducing discharges to 20,000 c.f.s. during the critical ice-in period when stages increase dramatically because of the formation of a rough ice-in cover, the Corps of Engineers has generally been able to maintain an approximate 13-foot stage at Bismarck during the winter. (This compares to a normal open water stage of about 8 to 9 feet.) The actual ice-in stage for this discharge can, however, range from 11 to 14 feet. By reducing the current ice-in discharge to about 13,000 c.f.s., an ice-in stage of about 11.5 feet at the Bismarck gage could be expected. This would require an average daily discharge reduction during the remainder of the winter (January to early March) of about 4,000 to 5,000 c.f.s. Average daily discharges would have to be increased about 2,000 c.f.s. during the remainder of the year to compensate for the reduced winter releases.

As aggradation continues in the future, the ice-in discharges would have to be further reduced to continue to ice-in at 11.5 feet. By the time the future-conditions channel size is reached, the ice-in discharge would need to be about 9,000 c.f.s. Hydropower releases for the remainder of the winter would be from 8,000 to 10,000 c.f.s. lower than they currently are. Releases would need to be increased the remainder of the year to compensate for the reduced winter release.

Reducing winter discharges to ice-in at 11.5 feet would be very costly. The constraints on Garrison Reservoir winter hydropower releases are estimated to be $1.7 million per year, or $1.2 million more per year than is expected for the baseline condition.

The 11.5-foot ice-in stage would only slightly reduce stages for the potential existing-conditions all-seasons flood events. The 5- and 10-year flood elevations would be reduced by 0.7 to 1.0 foot, whereas the 50- and 100-year flood elevations may increase a little because of the increased discharges in the spring, summer, and fall.

This modification would reduce the potential future-conditions 5- and 10-year flood stages by 0.2 and 0.3 foot, respectively, and the potential 50- and 100-year flood elevations would not be affected. Almost no flood damage reduction benefits would be expected. This option would provide no hydropower benefits.

Table 16 also presents the economic summary for reducing the ice-in stage to 11.5 feet. The benefit-cost ratio of this option would be essentially 0.

—*Restrain Ice-in Release to 20,000 c.f.s.*—This option was evaluated to determine if it would be feasible to continue releasing 20,000 c.f.s. during the critical ice-in period to eliminate the projected Garrison hydropower generation constraints. Under this option, the potential residual flooding for the more frequent events would be expected to increase because the ice-affected discharges would be the same as they currently are and the river stages would increase as aggradation continues.

Flood stages for the more frequent events would be higher under this option than they would be for the baseline condition. The 5-year stage at the Bismarck gage would be 0.9 foot higher than under the assumed baseline condition, and the 10-year stage would be 0.7 foot higher. Stages between the gage and the Lake Oahe project boundary would be 0.4 to 0.6 foot higher for the 5- and 10-year events. The stages for 50-year and greater events would not be affected by this restrained release option.

Potential flood damages would be increased by $20,000 per year with this alternative. Therefore, this alternative would have flood damage reduction benefits equaling a minus $20,000—or a cost of $20,000 as shown in table 16. The expected future hydropower constraint at Bismarck would be removed, and this alternative would eliminate the expected $500,000 increase in hydropower production costs for the region. The benefit-cost ratio of this alternative would be 25, as shown in table 16.

OAHE OPERATIONAL CHANGES

The Lake Oahe pool produces a backwater that affects river stages upstream from the pool. Thus, several lower pool levels were evaluated to determine if flood stages could be reduced in the south Bismarck area. These pool level reductions were 5, 10, and 15 feet.

The Lake Oahe pool effects diminish in the south Bismarck area as the Missouri River discharges increase. For example, at 28,000 c.f.s., the historic average, stage reductions of 0.7 foot would be expected at the project boundary if Lake Oahe were lowered 15 feet; a reduction of only 0.1 foot would occur at the Bismarck gage. However, the 5-year and less frequent flood stages would not be reduced upstream from the Lake Oahe project boundary with even a 15-foot lower Lake Oahe pool. Actually, the 5- and 10-year stages between the Bismarck gage and the project boundary would be 0.4 to 0.6 foot higher than those that would result from the baseline condition.

Lowering the Lake Oahe pool would reduce the hydropower generating capacity of the Oahe project. For example, a 15-foot pool level reduction would reduce the capacity from 595 megawatts to 524 megawatts—a reduction of 71 megawatts. It is estimated that it would cost in excess of $70 million for a utility to replace this lost capacity with a coal-fired unit. The average annual cost to provide the replacement capacity is estimated to be about $5.8 million.

This alternative would have negative flood damage reduction benefits of $20,000 per year and no hydropower benefits. This alternative would provide no positive benefits and would he very costly.

LAND ACQUISITION

Flood damages would be reduced by relocating development out of the flood plain. Two options were considered for relocating the development—acquire the future-conditions 5-year flood plain and to acquire the future-conditions 10-year flood plain.

The future-conditions all-seasons 5-year flood limits include 3,770 acres, and the 10-year flood limits include 4,880 acres. Acquisition of the area influenced by the future-conditions 5- and 10-year events, however, could total as much as 6,000 and 7,000 acres, respectively. Depending on location, depth of flooding, and other factors, flowage easements could be considered for some areas and fee title acquisition for others. The areas that were most likely to be considered for acquisition of flowage easements rather than fee title were not delineated.

Based on a preliminary estimate, fee title acquisition of the 5-year flood plain is estimated to cost $23.1 million. Acquisition of the 10-year flood plain is estimated to cost $34.2 million. Based on these costs, the estimated average annual costs for acquisition of the 5- and 10-year flood plains are $1.9 million and $2.9 million, respectively.

Flood damage reduction benefits are estimated to be $110,000 and $140,000 per year as a result of eliminating the development from the 5- and 10-year flood plains, respectively. Significant flood damages could continue to accrue because larger, less-frequent floods could continue to damage the structures in the remainder of the south Bismarck area. Acquisition of the 5- and 10-year flood plains would reduce the need for fill material for raising future housing construction in Bismarck; the estimated cost savings of fill material is $30,000 per year.

Hydropower benefits would accrue because potential future Garrison winter hydropower generation constraints would be removed. These benefits are $500,000 per year.

Table 17 presents the economic summary for the land acquisition alternative. Neither option has positive net benefits. The benefit-cost ratios are 0.3 and 0.2 for the 5- and 10-year options, respectively.

TABLE 17.—ECONOMIC SUMMARY—LAND ACQUISITION

Item	Options	
	5-year	10-year
Costs:		
Acquisition	$23,100,000	$34,200,000
Average Annual	$1,940,000	$2,870,000
Average Annual Benefits:		
Flood Damage Reduction	$110,000	$140,000
Hydropower	$500,000	$500,000
Fill Reduction	$30,000	$30,000
Total	$640,000	$670,000
Net Benefits	−$1,300,000	−$2,200,000
Benefit-Cost Ratio	0.3	4.2

FLOOD PLAIN MANAGEMENT

There are two flood plain management measures that could be used to minimize the flood damage potential in the south-Bismarck area These measures include (1) raising the required elevation of any future flood plain development from 1 foot above the 100-year flood level to some higher level and (2) raising the streets and access roads in flood-prone areas to assure access to and from these areas during periods of flooding. Neither of these measures would reduce the area inundated during any flood. One of the measures, raising future development, would, however, reduce damages to future development in the flood plain.

A third measure, flood proofing, was considered. It would, however, not be practical or feasible to flood proof existing structures by making structural modifications or by raising the structures. The frequency, depths, and duration of flooding would not justify the substantial structural modifications.

Currently, any development in the 100-year flood plain must be placed on fill or elevated by other means to 1 foot above the existing-conditions 100-year flood level. As the channel aggradation takes place, the 1 foot above the potential existing-conditions 100-year flood will gradually diminish. If the required fill elevation for future development were raised a total of 3.5 to 4 feet above the existing-conditions

100-year flood elevation, the future structures would be above the future-conditions 500-year flood level. Although this would not affect the existing average annual flood damages, it would provide estimated benefits of $360,000 to future development at an estimated cost of $110,000. The benefit-cost ratio of this measure is 3.3.

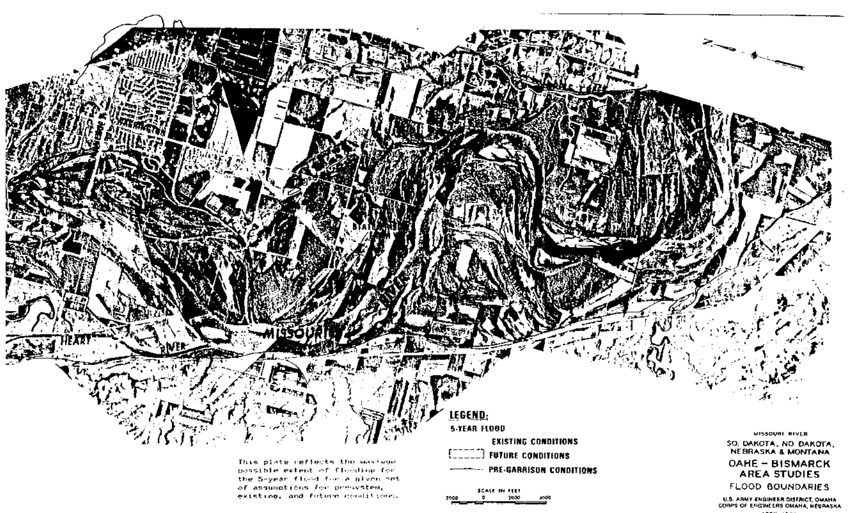
Most of the major access roads throughout the flood plain are somewhat higher than the natural ground elevations; in general, they provide access to and from most areas up to about the 5-year event under existing conditions. However, most of the streets in the subdivisions and other developed areas are basically at natural ground level and do not provide adequate access during flooding. With the additional channel aggradation that will gradually occur, these roads and streets will provide even more restricted access during periods of flooding. Raising all access roads and streets to some elevation—such as the 100-year existing-conditions flood level—would ensure that, under future channel conditions, the roads and streets would still provide access during the 50-year flood event. To raise the roads and streets to the existing-conditions 100-year flood level would require raises ranging up to 3 feet. The extent and cost of these raises have not been estimated.

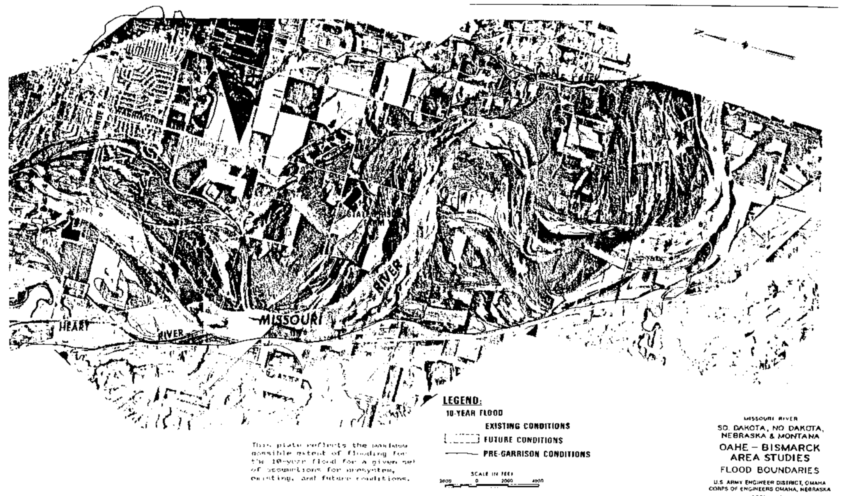
STUDY CONCLUSION

The course of action to be followed by the Corps of Engineers is to continue to reduce releases from Garrison Reservoir at critical high discharge periods at Bismarck—when flows from tributaries downstream from Garrison Dam could cause flooding at Bismarck and during winter ice-in (retain 13-foot target). Additional flood plain management measures should be considered by the city of Bismarck, Burleigh County, and those developing in the flood plain. These measures would limit future increases in flood damages and increase the safety of persons living in the flood plain. These measures include raising new development more than the required 1 foot above the potential existing-conditions 100-year flood elevation and raising the access roads to areas of extensive development. Also, those living or having businesses in the flood plain should continue to participate in the Federal Flood Insurance Program to minimize personal loss should flooding damage their property.

RECOMMENDATION

(To be prepared following public comment.)




HEART
RIVER
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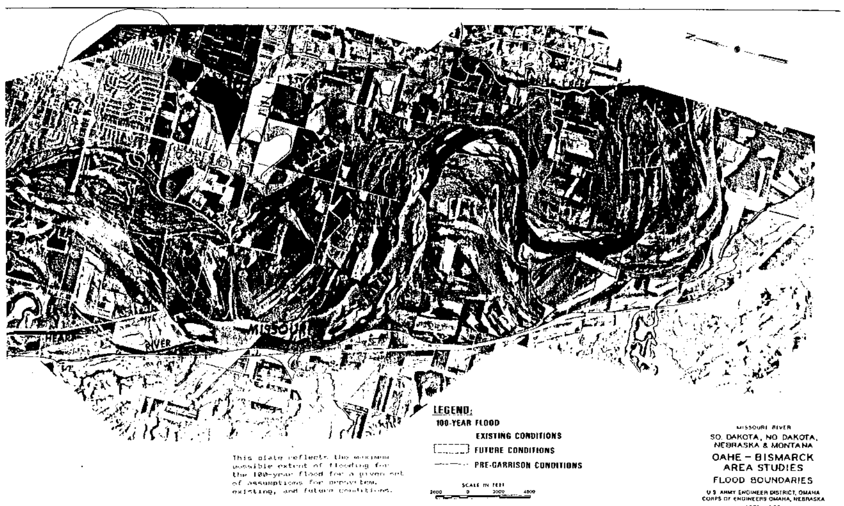
RIVER
LEGEND:
10-YEAR FLOOD
EXISTING CONDITIONS
FUTURE CONDITIONS
PRE-GARRISON CONDITIONS
This plate reflects the maximum possible extent of flooding for the 10-year flood for a given set of assumptions for presystem, existing, and future conditions.
SCALE IN FEET
2000 0 2000 4000
MISSOURI RIVER
SO. DAKOTA, NO DAKOTA, NEBRASKA & MONTANA
OAHE – BISMARCK AREA STUDIES
FLOOD BOUNDARIES
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
APRIL 1985


HEART
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LEGEND:
100-YEAR FLOOD
EXISTING CONDITIONS
FUTURE CONDITIONS
PRE-GARRISON CONDITIONS
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SCALE IN FEET
2000 0 2000 4000
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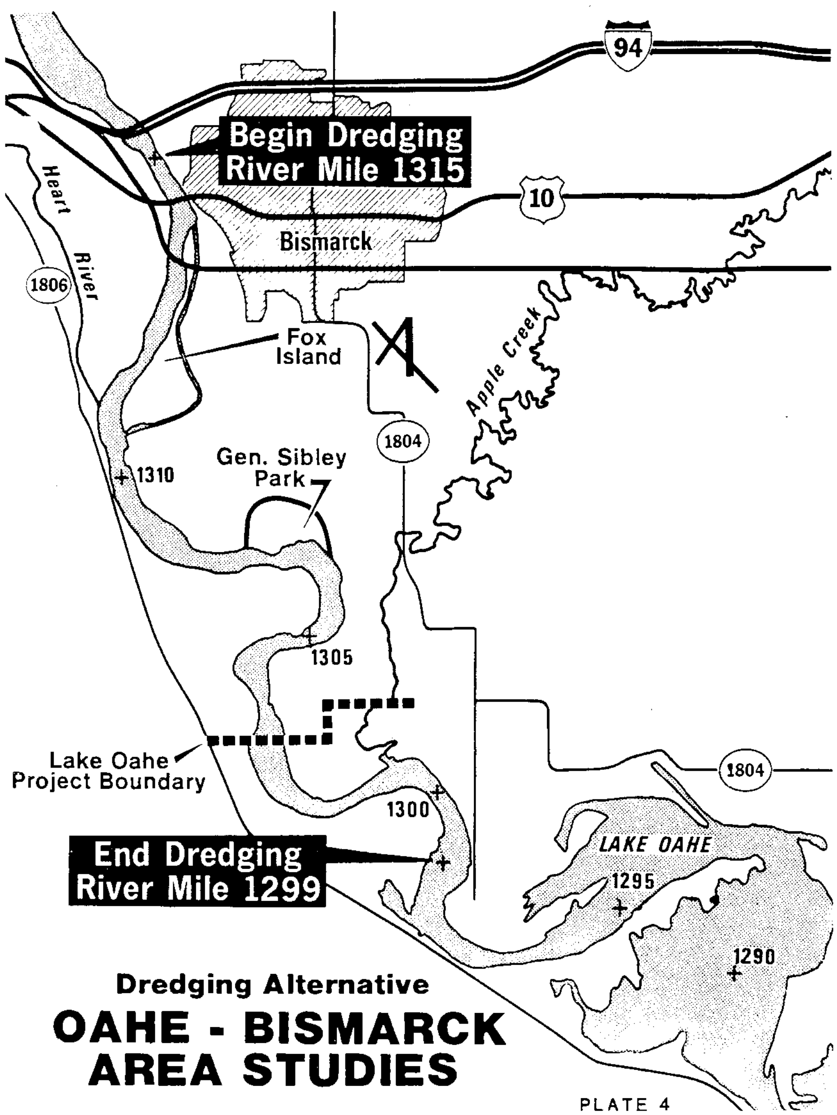
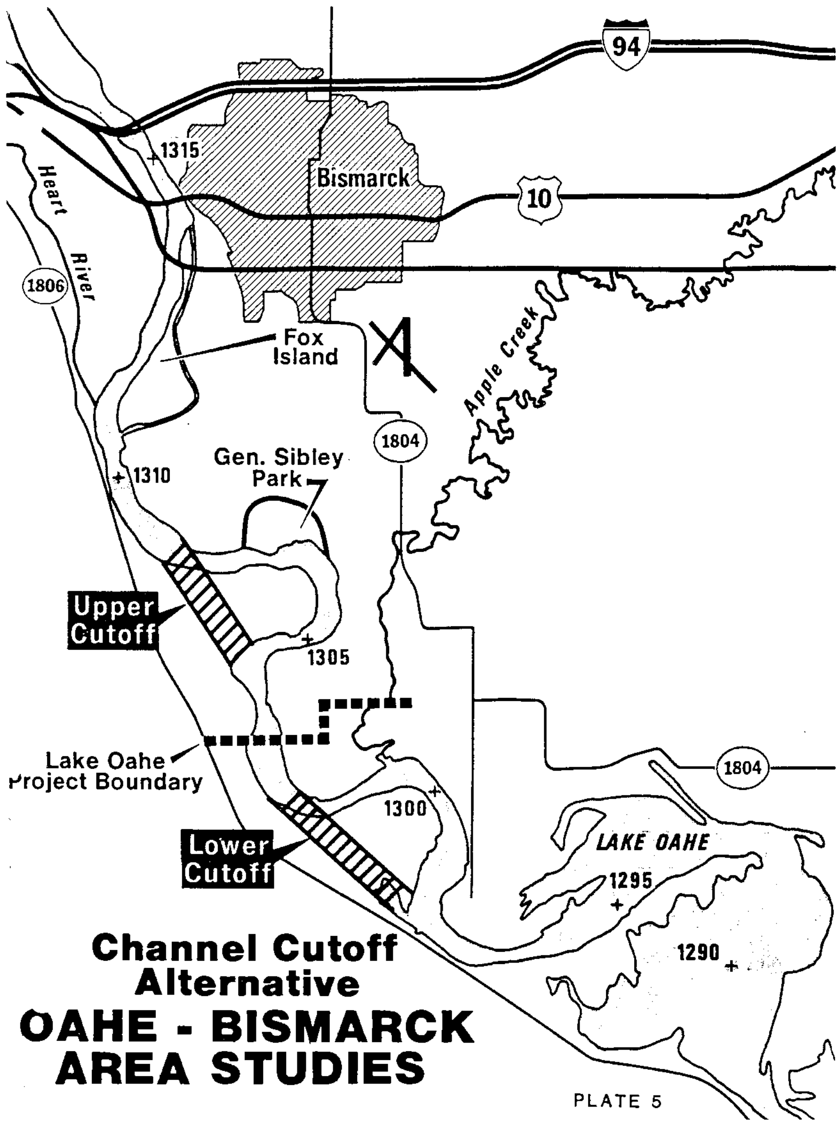
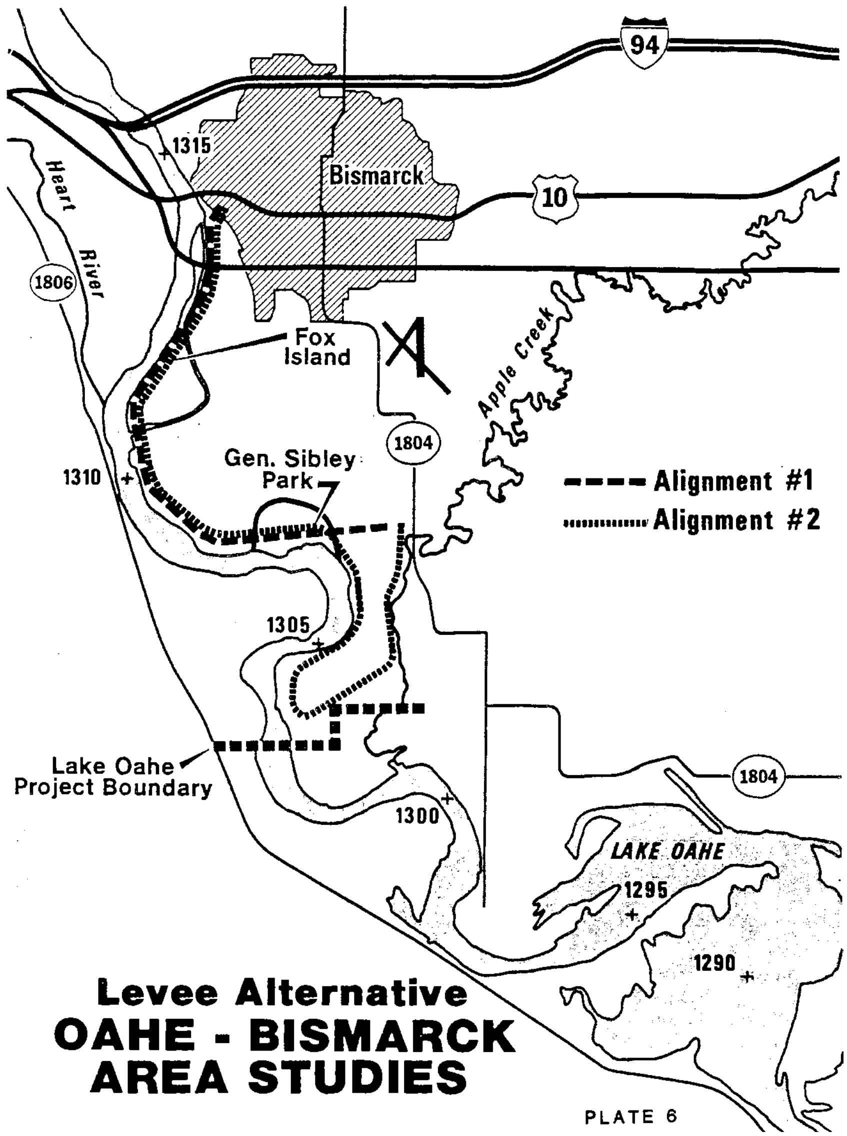

94
Begin Dredging
River Mile 1315
10
Heart River
Bismarck
1806
Fox Island
Apple Creek
1804
Gen. Sibley Park
1310
1305
Lake Oahe Project Boundary
1804
1300
End Dredging
River Mile 1299
LAKE OAHE
1295
1290
Dredging Alternative
OAHE - BISMARCK
AREA STUDIES
PLATE 4


94
1315
Bismarck
10
Heart River
1806
Fox Island
Apple Creek
1804
Gen. Sibley Park
1310
Upper Cutoff
1305
Lake Oahe Project Boundary
1804
1300
Lower Cutoff
LAKE OAHE
1295
1290
Channel Cutoff Alternative
OAHE - BISMARCK AREA STUDIES
PLATE 5



Mr. GUNSCH. The Bottom line of that study, the conclusion was to change reservoir operations to minimize releases during critical high discharge periods and to recommend communities consider implementing additional criteria for flood plain development, raising access roads, encouraging participation in the National Flood Insurance Program. Given the March 2009 event we have to question if operational changes alone are adequate to address the ice jam events at this point.

The 1985 study actually predicted increases in the base flood elevations for the Bismarck/Mandan area. And between 1981 and

1998 which is the two data sets for the 1985 and 2005 flood insurance studies which is a 17-year period, the elevations that were predicted in that report were already reached. So there are a number of professionals who agree this is not the end of the increases that will be experienced. Therefore more needs to be done before the situation deteriorates further. And we're already 10 years past the most recent data set.

More recently under section 108 Missouri River Protection Improvement Act 2000, title VII enlisted the professional engineering services of Louis Berger Group to complete a report entitled, Impacts of Siltation on the Missouri River in the State of North Dakota Report 2009. A copy of this report is also provided for the record. As it documents and justifies many of the concerns that have been expressed here this evening.

[The information follows:]

Impacts of Siltation of the Missouri River in the State of North Dakota Summary Report

1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE) tasked The Louis Berger Group Inc. (Berger) to assess impacts of sedimentation in the Missouri River Basin within the State of North Dakota. This assessment is intended to meet the level of effort defined in the Missouri River Protection and Improvement Act. The assessment had two main objectives. First, to identify sources and deposit locations of sediment within the Missouri River Basin in the State of North Dakota, utilizing existing data and information. Second, to analyze potential impacts of sedimentation on important issues and resources including: Federal, tribal, State and regional economies; recreation; hydropower generation; fish and wildlife; flood control; and Indian and non-Indian historical and cultural sites.

For each resource area identified above, Berger prepared a detailed report. This document is a summary of those efforts and presents the key findings. We encourage the reader to refer to each report, provided in full as Appendices A through G at the end of this summary report. Full details of the project analyses and discussions are presented in each of those reports.

This summary report is organized as follows: Section 2.0 describes the study area that was evaluated; Section 3.0 provides a summary of sources, deposits, and locations of erosion along the Missouri River; Section 4.0 discusses the economic impacts of sedimentation and erosion; Section 5.0 summarizes the impacts of sedimentation and erosion on recreational resources; Section 6.0 summarized the impacts of sediment and erosion on hydropower; Section 7.0 summarizes impacts to fish and wildlife; Section 8.0 summarizes impacts to flood control; Section 9.0 discusses impacts to Indian and non-Indian historical and cultural resources; and Section 10.0 discusses recommendations.

2.0 STUDY AREA

The study area was defined by the USACE to include the watershed of the main stem of the Missouri River from the North Dakota-South Dakota border on the downstream end to the Montana-North Dakota border on the upstream end. The study area includes tributaries of the Missouri River, Lake Sakakawea, and Lake Oahe.

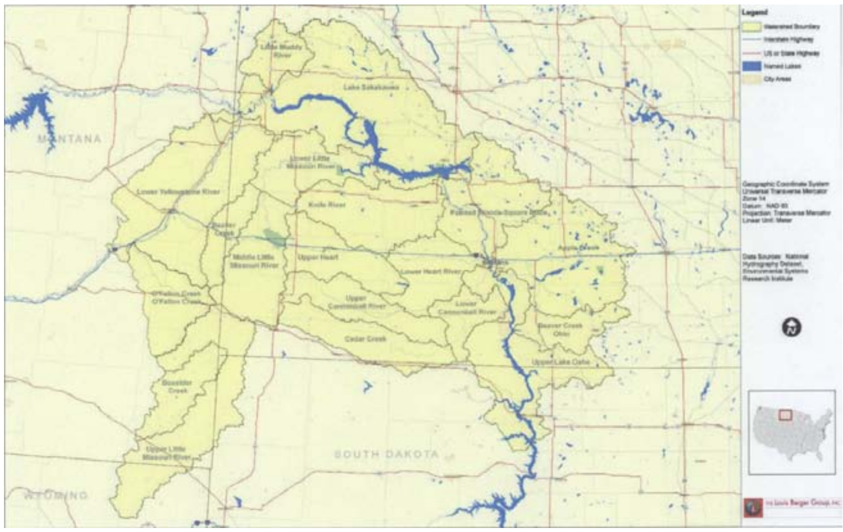


FIGURE 1.—*Location of the Study Area*

3.0 SOURCES, DEPOSITS, AND EROSION LOCATIONS

The first task of this study was to conduct an assessment of potential sediment sources, deposits, and erosion locations for the main stem Missouri River in North Dakota. The analysis showed that potential sediment sources for the Missouri River in North Dakota include: (1) upper reaches of the Missouri River in Montana; (2) the Yellowstone River watershed (largest watershed draining into the Missouri River); and (3) the remaining watersheds in North Dakota draining into the Missouri River between the Garrison Dam and the city of Bismarck.

The sediment load assessment showed that the Yellowstone River and the Missouri River in Montana delivered the largest percentage of sediment loads to the main stem Missouri River in North Dakota. The Yellowstone River and the portion of the Missouri River in Montana accounted for more than 86 percent of the total delivered sediment load, whereas the watersheds within the study area (not including the Yellowstone River watershed) accounted only for approximately 4 percent of the total delivered load in North Dakota. Sediment load from in-stream erosion within the Missouri River accounted for the remaining 10 percent. Table 1 summarizes the sediment sources and their load percentages.

TABLE 1.—SEDIMENT LOADS AND THEIR FRACTIONS IN THE MISSOURI RIVER, ND

Source	Estimated Sediment Load (million tonnes/year)	Percentage of Total Delivered Sediment Load
Yellowstone River [1]	29.1	64.7
Missouri River from Montana [2]	9.5	21.1
Watersheds within the Study Area [3]	1.7	3.8
In-stream Erosion within the Garrison Reach [4]	4.7	10.4
Total	45.0	100.0

[1] Based on estimated sediment loads by USACE at USGS station 06185500 (Missouri River at Culbertson, Montana) and reduction of 30 percent.

[2] Based on estimated sediment loads by USACE at USGS station 06329500 (Yellowstone River at Sidney, Montana) and reduction of 30 percent.

[3] Based on 5 year average sediment load using the Generalized Watershed Loading Functions Model (GWLF); Includes all watersheds draining into the Missouri River in North Dakota except for the Yellowstone River.

[4] Based on the difference between the total annual sediment load at the city of Bismarck USGS station (6342500) and the total delivered sediment load of the four sub-watersheds draining between Garrison Dam and the City of Bismarck.

Additional analysis to identify areas of low, medium, and high levels of aggradation along the main stem sections of the Missouri River was conducted, including all sources identified in Table 1. The aggradation areas were plotted on maps and presented in Appendix A, attached to this document. In addition, the following conclusions were drawn from the analysis of aggradation areas.

—The majority of the identified aggradation areas were located upstream of Lake Sakakawea close to the Montana/North Dakota border and in the vicinity of watersheds showing large amounts of delivered land-based sediments. These aggradation areas in the upper reaches of the river in North Dakota were predominantly caused by the delivery of sediment loads from the Yellowstone River and the Missouri River in Montana.

—The area between the city of Bismarck and Lake Oahe showed several aggradation areas with mostly low and moderate aggradation potential. Potential sources for sediment deposition in these areas were caused by in-stream erosion of the Missouri River below the Garrison Dam and by land-based sediments originating from the Painted Woods-Square Butte, Knife River, Heart River, and Cannonball River watersheds. The largest source of these aggradation areas are likely sediment deposits from eroded riverbeds and riverbanks, due to the impact of hydropower use at Garrison Dam.

—Areas that showed little or no aggradation were generally located within the center of the reservoirs (Lake Sakakawea and Lake Oahe) and in the stream reach between Garrison Dam and the city of Bismarck in which in-stream erosion dominates (90 percent of the total sediment load originates from in-stream erosion).

4.0 IMPACTS TO FEDERAL, TRIBAL, STATE, AND REGIONAL ECONOMIES

Berger evaluated the direct economic impacts associated with increased sedimentation and erosion along the Missouri River in the State of North Dakota. The evaluation included a qualitative discussion on whether or not the direct economic impacts are relevant in scale and location to Federal, tribal, State, and regional economies. For instance, certain impacts may be relevant to tribal or regional economies due to the location of impacts, but may not be relevant at the State or national levels due to the size of the impact. Where possible, these distinctions were made with all direct economic impacts identified.

The potential economic impacts were based in part on the impacts to other resource areas identified by the other subtasks. In addition, Berger completed a literature search and interviews with subject matter experts to identify additional economic impacts that may not have been identified by the other analyses. The resources and activities that may be impacted by sedimentation and that may have economic implications include:

—Land Use

—Coal-fired Power Production

—Hydropower Production

—Recreation

—Water Supply Intakes

Based on the analysis, Berger concluded that the most significant economic impact likely to occur is from potential increase in flooding risk caused by sedimentation in and around the Bismarck and Mandan areas, especially in winter. Other resources and activities such as electric power production (hydro and thermal), recreation, water supply and land use are also experiencing impacts. However, none of these impacts appear as significant as the potential impacts of increased flooding risk in urbanized areas. Berger was unable to fully quantify the potential economic impacts to recreation visitor use and agricultural use due to a lack of quantifiable data and would suggest these resources be studied further.

The results of the economic impact analysis are summarized in Table 2. Additional information on economic impacts is provided in Appendix B.

TABLE 2.—POTENTIAL ECONOMIC IMPACTS OF SEDIMENTATION ALONG THE MISSOURI RIVER IN NORTH DAKOTA

Resource	Potential Impact	Impact to Economy				Timeframe	Comments
		Federal	State	Local	Tribal		
Agricultural Land Use	Loss of Productivity of Agricultural Lands.	....	....	X	X	Short-term	
Flood Control	Increased Flooding	....	X	X	....	Long-term	Increased flooding potential can lead to costly buyouts, increased insurance costs, and reduction in property values.
Coal-fired Power Plants	Reduction in generation capacity.	....	....	X	....	Long-term	Loss in revenue or increase in costs to meet contract demands.
Hydropower	Reduction in generation capacity.	....	X	X	X	Long-term	Increased flooding potential can reduce hydropower production, especially during colder months.
Recreation	Increased maintenance costs for recreational facilities.	....	X	X	X	Long-term	Increased cost to dredge and maintain facilities affected by sedimentation. Impacts to visitor behavior are unknown.
Water Supply	Increase operation and maintenance costs.	....	....	X	X	Long-term	Small number of intakes are impacted by sedimentation, causing an increase in operation and maintenance costs.

Note.—Fish and wildlife resources have not been included in this table describing economic impacts of sedimentation for two reasons. First, economic impacts associated with affects of sedimentation on fish and wildlife would occur with a reduction in recreational activities (e.g. fishing, bird watching). This issue is addressed somewhat under Section 5.0—Recreation. The economic impact associated with a reduction in native species due to sedimentation cannot be quantified at this time due to lack of data.

5.0 RECREATION

The evaluation of impacts on recreation resources conducted by Berger revealed that drought conditions and sedimentation/siltation processes can result in access restrictions and temporary park or access closures. However, it appears that prolonged drought conditions have a much larger impact on recreational use than on sedimentation. However, drought was not a focus of this analysis.

Even temporary closures of recreational sites can prevent access to areas within the river and reservoirs, resulting in direct impacts to the recreation resources. The loss of boater access results in longer drives to launch boats, trip cancellation, poor aesthetics, and safety hazards to those using the Missouri River and the reservoirs in North Dakota. In addition, boat access site managers are forced to spend more time and resources operating and maintaining the boat ramps, keeping them free of sediments to maintain boater access. Bays or arms just off the main channel have historically been the primary location for boater access; however, these areas are susceptible to sediment aggradation as reported in interviews conducted for this research. It is important to note that these areas were not identified by Berger when evaluating sediment sources and locations, so the number of visitors affected by sedimentation is difficult to estimate and could likely be much higher. It is also important to note that sedimentation can be a nuisance at boat ramps, increasing operational and maintenance costs for the users; however, the reservoirs still provide the greatest amount of flat water recreation opportunities in the state of North Dakota so that once on the water, recreationists may still report satisfactory trips.

In response to drought conditions, boat ramps have been extended or relocated to accommodate for low water levels, and the State of North Dakota actively maintains access sites for the purpose of maximizing recreational opportunities. Extension or relocation would also accommodate for sedimentation build up at boat ramps within the study area, though Berger was unable to determine if any of the ramps were extended solely due to increased sedimentation. Erosion and sedimentation of boat ramps also causes problems for recreational opportunities in other areas along the reservoirs that were not identified by Berger (e.g. bay areas). Overall, however, tremendous opportunities exist in the area for flat water recreation and access to the reservoirs and rivers. From the data and information available, it was not possible to measure if increased sedimentation is causing a decline in recreational visitor days or a change in visitor behavior (e.g. visits to alternative areas). This information is needed to quantify economic impacts.

It should be noted that sediment load is critical to the formation of sandbars. Sandbars are, in turn, critical fish habitat not only for walleye but also for a host of native fish species. From an angling perspective, sand bars often provide prime fishing spots to catch walleye. Any recommendations should consider both the positive and negative impact of sedimentation.

Table 3 summarizes the key findings related to recreational resources.

TABLE 3.—IMPACT OF SEDIMENTATION ON RECREATION RESOURCES

Direct Impact	Significance	Timeline	Recommendations
Ramp or Access Closure	Lack of boater access results in longer drives to launch boats, trip cancellation, poor aesthetics, and safety hazards to those using the Missouri River. Boat access site managers are forced to spend more time and resources operating and maintaining the boat ramps, keeping them free of sediments to maintain boater access.	Parks and access areas are predominantly used in the summer; therefore, summer would have the greatest level of impact. Because sedimentation processes occur throughout the year, however, impacts to access areas would be ongoing.	For long-term planning purposes, identify and prioritize areas, that are currently susceptible to sediment aggradation and that are close to population centers (e.g. Fort Stevenson State Park), and identify alternative ramp sites that would result in less aggradation on the ramps. Conduct an additional study of visitors' willingness to travel in the event that popular boat ramps are closed. Identify the proximity to nearby alternatives. Evaluate the benefits of extending or relocating boat ramps depending on the information gathered from completing the first two recommendations. Evaluate the impact of closing ramps at sites that do not have viable alternative locations for new ramps and that have regular dredging needs.
Underwater hazards	Shallow water due to sediment deposition poses a risk to boaters and boating equipment.	Dynamic and dependent on reservoir and river elevations. Summer peak boating season with low lake and river levels poses the greatest risk.	Work with the North Dakota Game, Fish, and Parks (NDGFP) Department and recreation non-government organizations (NGOs) to evaluate options of educating the boating public. Consider: (a) Posting signage to make the public aware of the possible hazard. (b) Marking of obstructions in high-use, high-risk areas. (c) Updating bathymetric mapping efforts.

6.0 HYDROPOWER

Hydropower facilities along the Missouri River in North Dakota consist of the Garrison Dam and its reservoir, Lake Sakakawea. In addition, hydropower operations in North Dakota are affected by the operation of Oahe Dam in South Dakota because Lake Oahe extends into southern North Dakota up to just south of the city of Bismarck when the pool is full. Annual gross power production at the Garrison Dam averaged 2.29 million megawatt hours (MWh) from 1967 (2 years after Lake Sakakawea was filled) through 2007. However, hydropower operations at Garrison Dam have generally decreased over time to 1.31 MWh in 2007 due to drought. The main exception was a period in the mid-1990s with high precipitation in the upper Missouri River watershed. Peak months of outflow and the resulting energy generation are December, July, and August due to high power demand.

The electricity generated at the Garrison facility is marketed by the Western Area Power Administration (WAPA), an agency of the Department of Energy (Western). Revenues are highest during the peak generation months in winter and summer. The total revenues from energy generated at Garrison Dam in the last 5 years (2003 to 2007) ranged from $15 million to $22 million. Highest annual revenues were generated during the wet year 1996 with $43 million.

The evaluation completed by Berger focuses on three potential impacts of sedimentation and erosion on hydropower generation, including:

—*Loss of Storage in Lake Sakakawea.*—Lake Sakakawea traps nearly 100 percent of the sediment that enters the reservoir. Most of the sediment originates from the Missouri River and the Yellowstone River, a tributary to the Missouri River. This includes sediment that is eroded from the bank and bottom of the Missouri River, downstream of the Fort Peck Dam. The USACE estimated a storage loss rate of 25,900 acre-feet/year (or 0.11 percent per year. At this rate, the life expectancy of Lake Sakakawea is approximately 900 years before it is completely filled. This value is a first-order estimate only, as the life expectancy depends on a number of variables such as sediment trapping efficiency (which decreases over time), climate variability over time, and sediment contributions from the watershed of Fort Peck Dam. However, this first-order estimate indicates that this issue is not expected to be a concern to the hydropower operations at the Garrison facility during the short or intermediate term.

—*Entrainment of Sediment Into the Turbines at Garrison Dam.*—With an annual loss of storage capacity by 0.11 percent, and with most of the deposition occurring in the upper reaches of the reservoir, impacts to the hydropower facility intakes are not expected in the short or intermediate future. As a result, the USACE does not currently have specific sediment management methods or sediment control facilities at their hydroelectric facilities.

—*Reduced Releases at Garrison Dam in Winter Due to Flooding Risk From Sediment Aggradation.*—Siltation in the reach between Garrison Dam and Lake Oahe has resulted in increased risk of flooding downstream. The Missouri River typically freezes in December, remains frozen in January and February, and starts to thaw in March and April. A large consideration in flow releases is the potential formation of ice dams. As a result, aggradation of the river channel in the headwaters of Lake Oahe caused a slight decrease in electricity generation in the colder months as compared to the warmer months.

The following actions are recommended to reduce impacts of sedimentation on hydropower production at the Garrison Dam facility (Table 4).

TABLE 4.—IMPACTS OF SEDIMENTATION ON HYDROPOWER PRODUCTION

Direct Impact	Significance	Timeline	Recommendations
Sedimentation of Lake Sakakawea	Minimal	Impacts are not expected to occur until well into the future	No Action Recommended.
Turbine Impacts	Minimal	Impacts are not expected to occur until well into the future	No Action Recommended.
Reduced Releases at Garrison Dam	Major	Short to Long Term	Continue to collect monitoring data in order to apply an adaptive management approach at the Garrison Dam facility. Conduct small-scale dredging in local areas impacted by flooding. Review existing flood plain designation and zoning to reduce development in flood-prone areas. Quantitatively evaluate if higher elevations of Lake Oahe due to aggradation will reduce flow velocities.

7.0 FISH AND WILDLIFE

The Missouri River system is a complex system that includes a suite of ecological regions. North Dakota contains one dam, Garrison Dam, and its associated reservoir, Lake Sakakawea. The reservoir known as Lake Oahe, formed by the Oahe Dam in South Dakota, also extends into North Dakota from the south. From an ecological perspective, the Missouri River in North Dakota may be thought of as having four parts:

—*The Williston Reach.*—The riverine segment close to the Montana border, into which the Yellowstone River flows and which flows into Lake Sakakawea.

—*Lake Sakakawea.*—The reservoir formed by Garrison Dam (closed in 1953), the entire range of which is within the State of North Dakota.

—*The Garrison Reach.*—The riverine segment from Garrison Dam to the headwaters of Lake Oahe.

—*Lake Oahe.*—The reservoir formed by Oahe Dam in South Dakota (closed in 1958) and which is in both North Dakota and South Dakota.

Analyzing the impacts of sedimentation to fish and wildlife defines species as two groups of animals: those that constitute a conservation concern, including State and federally listed species, and those that are important for recreational purposes (hunting and fishing). These are hereafter referred to as “Conservation Species” and “Recreational Species,” respectively.

An increased sediment load in the reservoirs indicates increased sediment aggradation due to decreased maximum water velocity associated with reservoirs and the resulting limited ability of reservoirs to transport sediment downstream. Aggradation would cause an increase in delta size (Palmieri et al., 2001, cited in Kaemingk et al., 2007) and could lead to sediment accumulation behind dams. An increased sediment load would also increase turbidity in the inter-reservoir reaches and in the headwaters. The remainder of the reservoir would remain clear, due to the low water velocity causing suspended sediment to settle (Blevins, 2006). The impacts on different species of fish and wildlife would not be uniform, as some species benefit in some reaches while others are negatively affected. These differences are the result of a particular species’ life-cycle characteristics as they relate to each particular portion of the river.

Many of the key recreation species of fish require clear and sediment-free water for their prosperity. Therefore, sedimentation and increased turbidity have negative impacts on their populations. Current conditions do allow, however, for abundant recreational fisheries. In addition, an increased sediment load could presumably have benefits for some of the conservation species that are adapted to life in a turbid environment. Other physical factors being equal, though, increased sediment loading alone is not likely to be sufficient to restore or support the populations of these species.

Other conservation species would benefit from an increase in the amount of sandbar habitat available. Increased sedimentation could potentially generate new sandbar habitat; in many areas, the deficit of sandbar habitat results in reduced sediment load due to sediment retention by dams (NRC, 2002). Colonization of sandbars by cottonwood and willow trees constitutes another important part of habitat generation for many species. However, such colonization would require seasonal floods of a magnitude commensurate with those of the Missouri River during pre-regulation times (Johnson, 2002; Bovee and Scott, 2002). Thus, increased sedimentation alone may not generate suitable sandbar habitat unless a hydrologic regime is allowed to occur which suits cottonwood and willow tree colonization.

The results of the analysis of impacts to fish and wildlife are summarized in Table 5.

TABLE 5.—IMPACT OF SEDIMENTATION ON KEY SPECIES

Species	Positive impact	No significant impact	Positive impact if siltation increases riparian forest habitat; otherwise no impact	Negative impact	Siltation positive, but require other environmental factors as well	Positive Impact if siltation increases sandbar habitat	River sections where species predominates
Conservation Priority Level I							
Blue sucker					X		Oahe and Garrison
Sturgeon chub					X		Williston only
Sicklefin chub					X		Williston only
Conservation Priority Level II							
Bald eagle			X				N/A
Golden eagle			X				N/A
Least tern						X	N/A
Piping plover						X	N/A
Red-headed woodpecker			X				N/A
River otter		X					N/A
Flathead chub					X		Williston only
Paddlefish					X		Williston, Sakakawea, Oahe
Pallid sturgeon					X		Yellowstone River and Williston
Conservation Priority Level III							
Smooth softshell turtle						X	N/A
False map turtle						X	N/A
Flathead catfish					X		Oahe only
Recreational Species							
Beaver							N/A
Canada goose		X					N/A
Channel catfish	X						Oahe
Chinook salmon				X			Sakakawea
Muskrat							N/A
Northern pike				X			Sakakawea
Sauger	X						Sakakawea, Oahe
Walleye				X			Sakakawea, Oahe
White bass				X			Sakakawea, Oahe

8.0 FLOOD CONTROL

Berger evaluated the potential impacts of siltation on flood control in the Missouri River Basin within the State of North Dakota. The analysis focused on a review of Flood Insurance Studies (FIS) prepared by the Federal Emergency Management Agency (FEMA) for the Bismarck, North Dakota, area to analyze changes in water surface elevation and its effects on flooding.

Flood control issues within the Missouri River for the Bismarck, North Dakota, area are caused or affected by (1) open-water seasonal flooding from Garrison Dam operations, (2) open-water seasonal flooding from tributaries, and other residual drainage areas below Garrison Dam, combined with releases from Garrison Dam, (3) flooding, resulting from ice jams and ice conditions, and (4) flooding caused by aggradation in the upper reaches of Lake Oahe.

Siltation in the reach between Garrison Dam and Lake Oahe has resulted in increased risk of flooding in the downstream reach between the dam and the headwater of Lake Oahe. Because of this sediment aggradation, the impact of ice dams on seasonal flooding has increased and is expected to continue. As a means to counter this impact, carefully sequenced water releases during the winter months are made to prevent flooding caused by ice dams. Water release from Garrison Dam is also used to provide flood control during other seasons as well.

Within the Garrison Reach, the upstream and downstream controls (mainstem dams) provide upstream clear-water release and a downstream backwater. This results in scouring and lowering of the degradation zone of the channel in the upstream reaches and an aggradational effect in the lower portion of the reach. The elevation of the channel bed is raised in the aggradation zone. The channel begins to display braided characteristics within a meandering regime as it becomes wider and shallower, a result of the backwater condition and delta formation at the headwater of Lake Oahe.

9.0 INDIAN AND NON-INDIAN HISTORICAL AND CULTURAL SITES

Berger assessed the potential types of cultural resources within Burleigh, Emmons, Mclean, Morton, Oliver, Williams, Dunn, McKenzie, Mercer, Mountrail, and Sioux Counties. The areas included USACE jurisdiction areas at Lake Oahe and Lake Sakakawea, the Standing Rock Sioux and Fort Berthold Reservations, as well as designated aggradation areas of the Missouri River corridor. The North Dakota Historical Society and USACE completed file searches between January and March 2009. Site types encountered during the files searches include prehistoric sites, historic sites, multi-component sites (sites with both prehistoric and historic materials), and sites that cannot be assigned to a specific time period ("unknown"). It should be noted that, while previous investigations have been conducted, there are portions of the project area where no surveys have been completed, particularly on private or tribal lands.

The research conducted by USACE revealed that prior investigations have been undertaken within the aggradation areas; 148 sites have been recorded within the Lake Oahe portion of the project area, and 1,216 sites have been previously recorded within the Lake Sakakawea portion of the project area. The sites at Lake Oahe consist of 90 prehistoric, 31 historic, 17 multi-component, and 10 unknown sites. The sites at Lake Sakakawea consist of 835 prehistoric, 120 historic, 54 multi-component, 2 paleontological, and 205 unknown sites.

Of the 144 sites recorded at Lake Oahe, 123 sites are eligible for inclusion in the National Register, while 21 sites remain unevaluated for eligibility. Of all sites recorded at Lake Sakakawea, the number of sites eligible for inclusion in the National Register is 22. The number of sites unevaluated for inclusion is 1,194. The research conducted by the North Dakota State Historic Preservation Offices (NDSHPO) revealed that more than 70 sites have been previously recorded on private land portions subject to aggradation along the mainstem of the river within the project area. Of the 76 sites, 4 sites are eligible for inclusion in the National Register, 4 sites are ineligible for inclusion in the National Register, and 68 sites are unevaluated.

While siltation can effectively and beneficially protect and preserve some sites, such as subsurface archaeological sites, often the subsequent wind or water erosion is destructive. Recent drought conditions have resulted in lower than normal lake levels in Lake Oahe, changing the upstream character of the reservoir from reservoir to riverine character. Of particular concern is cut bank erosion. Archaeological sites and historic structures along reservoir and river banks can slowly or drastically deteriorate as the shoreline erodes. Indian and other ethnic group traditional-use or ceremonial areas can be affected by both siltation (covering the resource or area) and erosion (depleting the resource or area). Other potentially destructive factors to cultural resources are agricultural and grazing leases close to the USACE jurisdictional boundary (Gilbert personal communication, 2009). Because Indian and non-Indian site resources are non-renewable, almost all impacts resulting from siltation and erosion are considered adverse or negative. In cultural resource terms, the integrity, or composition and cohesiveness, of a site is crucial to a site's significance and intrinsic value to understanding our history or prehistory. The magnitude of the impact to the integrity of a site can vary from minor (e.g., artifact displacement resulting from sediment movement) to substantial (e.g., complete removal of a stone circle, stone cairn, or structural foundation resulting from an erosion event).

According to USACE and NDSHPO records of known Indian and non-Indian sites along the reservoirs and mainstem of the river within potential areas of aggradation and erosion, USACE and other researchers have recorded erosion, inundation, bioturbation, and effects of farming, construction, and vandalism.

Table 6 summarizes the impacts identified in the evaluation of cultural and historic resources and suggested recommendations on how to mitigate such impacts.

TABLE 6.—SUMMARY OF IMPACTS AND RECOMMENDATIONS

Impact	Significance	Timeline	Recommendation
Inundation (partial, periodic, complete)	Substantial	Long term—for life of jurisdiction	Monitor at low water levels; data recovery as needed
Erosion (cut bank, shoreline, general)	Substantial	Long term—for life of jurisdiction	Monitor for erosion; stabilize if needed; data recovery as needed
General Disturbance	Moderate	Long-term—for life of jurisdiction	Monitor; data recovery as needed
Agriculture	Minor—Moderate	Long-term—for life of lease	Protect or mitigate with fencing, testing, or data recovery
Grazing	Minor—Moderate	Long term—for life of lease	Protect or mitigate with fencing, testing, or data recovery
Construction	Substantial	Short term—up to one year as project progresses	Protect or mitigate with fencing, testing, or data recovery
Recreation	Moderate	Long term—for life of jurisdiction	Monitor for activity and vandalism; fence as needed
Vandalism	Moderate	Long term—for life of jurisdiction	Monitor for activity and vandalism; fence as needed
All	Minor—Substantial	Short term (1 to 5 years)	Prepare research design for cultural resources along the Missouri River in North Dakota

10.0 RECOMMENDATIONS

Successfully addressing sedimentation issues within the Missouri River will likely require a holistic approach, and recommendations pertaining to multiple resources would be a part of that solution. Berger has evaluated a number of approaches to addressing impacts throughout this study and makes the following recommendations based on the results (Table 7).

TABLE 7.—RECOMMENDATIONS FOR ADDRESSING SEDIMENTATION IMPACTS ALONG THE MISSOURI RIVER IN NORTH DAKOTA

Input/Resource	Study/Product	Timeline	Cost	Remarks
Flooding Risks in Bismarck/Mandan Area	Tradeoff Analysis of Flood Controls (e.g. development restrictions vs. flow restrictions).	Short term	\$500,000–\$1,000,000	Would require local partner
	Study impacts of sedimentation on flood risks when Lake Oahe pool is full.	2 to 3 years to complete	\$500,000–\$1,000,000	Would require a cost-share sponsor
	Develop strategies for mitigating ice-affected flooding exacerbated by sediment deposition at the headwaters of Lake Oahe.	3 to 5 years to complete	\$500,000–\$1,000,000	Would require a cost-share sponsor. Detailed Environmental Assessment (EA), may be an EIS
	Conduct debris/snag removal in the Heart River confluence area. This will minimize sediment accumulation in the area and decrease the likelihood of ice-affected flooding.	Short term; Less than 2 years to complete.	\$100,000–\$150,000 for design. \$400,000–\$1,000,000 for construction.	Would require a cost-share sponsor
Garrison Reach	Complete cumulative Environmental Impacts Statement (EIS) for Garrison Reach.	2 to 3 years to complete	\$1,000,000–\$2,000,000	Would require a cost-share sponsor
	Conduct bank stabilization projects	Short term; Less than 1 year to complete.	\$300,000–\$500,000 per site	Very difficult without EIS
	Evaluate potential operational changes of the Garrison Dam and/or flow modifications.	3 to 5 years to complete	\$1,000,000–\$5,000,000	Controversial; Re-opens master manual issues; Possibly outside the scope of title VII
Fish and Wildlife	Study to evaluate the needs of multiple species along the Missouri River.		\$250,000–\$300,000 (2-year study).	Would require a cost-share sponsor. Overlap with the BiOp could be complicated
	Study the life-cycle of the pallid sturgeon on the Yellowstone River.		\$200,000–\$250,000 (2-year study).	This is part of the Missouri River Recovery Program
Cultural Resources	Prepare a research design for cultural resources along the Missouri River. Provide a framework for management and treatment of cultural resources across jurisdictions.	Short term; less than 2 years.	\$200,000–\$250,000	Would require a cost-share sponsor
	Study to access cultural and historical resource sites to determine if impacts are occurring.	Short term; less than 2 years.	\$250,000–\$500,000	Would require a cost-share sponsor
Watershed Sediment Sources	Study to determine the sediment contribution by source and approaches to reduce sediment reaching the river (watersheds and water quality).	3 to 5 years	\$500,000–\$750,000	BMPs, stream buffers, No-till farming, etc; Would require a cost-share partner
Williston Reach	Perform hydrological study of sediment impacts to groundwater in the Williston Area.	1 to 2 years	\$250,000–\$400,000	Would require a cost-share sponsor

TABLE 7.—RECOMMENDATIONS FOR ADDRESSING SEDIMENTATION IMPACTS ALONG THE MISSOURI RIVER IN NORTH DAKOTA—Continued

Input/Resource	Study/Product	Timeline	Cost	Remarks
Recreation	Dredge the Hazelton boat ramp.	Short term; Less than 1 year	$100,000–$200,000	Permits; Redeposit of sediment in river
	Study to evaluate any changes in recreational use due to sedimentation and drought.	Short term	$250,000–$500,000	Would require a cost-share partner. If the study included a survey, it would require Office of Management and Budget (OMB) approval which could impact costs and timing

APPENDIX A—IDENTIFICATION OF SOURCES AND DEPOSITS AND LOCATIONS OF EROSION AND SEDIMENTATION

1.0 INTRODUCTION

The Louis Berger Group Inc. (Berger) was tasked by the U.S. Army Corps of Engineers (USACE) to assess impacts of sedimentation in the Missouri River Basin within the State of North Dakota. This assessment is intended to meet the level of effort defined in the Missouri River Protection and Improvement Act. The assessment will have two objectives. First, Berger will identify sources and deposit locations of sediment within the Missouri River Basin in the State of North Dakota, using existing data and information. Next the team will analyze the potential impacts of sedimentation on important issues and resources including: local, regional and national as well as tribal economies; recreation; hydropower generation; fish and wildlife; flood control and Indian and non-Indian historical and cultural sites.

This report focuses on the results of Task 5A—Identification of Sources and Deposit Locations of Erosion and Sedimentation. The assessment included three important steps. First, Berger conducted an extensive literature and data search for all possible sources of information that can help determine relevant sites of erosion and sedimentation within the Missouri River Basin in North Dakota. This data and information was organized as much as possible into a GIS database that can support easy retrieval and interpretation. Second, Berger identified aggradation locations in the main stem of the Missouri River based on existing data and information. Third, Berger calibrated a planning level tool that can be used to assess and rank different sources of sedimentation in the Missouri River.

The following sections address the results of the task. Section 2.0 describes the study area that was evaluated. Section 3.0 provides the results of the literature and data search. Section 4.0 discusses the locations of aggradation along the Missouri River. Section 5.0 summarizes the sediment source evaluation and Section 6.0 compares the sources of sedimentation with the locations of aggradation evaluated for this report.

2.0 STUDY AREA

The study area was defined by the USACE to include the watershed of the main stem of the Missouri River from the North Dakota—South Dakota border on the downstream end to the Montana—North Dakota border on the upstream end. The study area includes tributaries of the Missouri River, Lake Sakakawea and Lake Oahe. Figure 2–1 provides a map of the study area as defined for this project.

FIGURE 2–1.—*Location of the Study Area*

3.0 LITERATURE AND DATA SEARCH

The parameters of the project were to evaluate all existing literature and data sources that provide information on the potential location for erosion and sedimentation in the Missouri River. Because no new data and information was sought, Berger focused efforts on an extensive literature and data search. The results are discussed in this section.

3.1 Literature Search

Berger completed a comprehensive literature search, focusing on identifying and acquiring key research papers and documents related to erosion and sedimentation in the Missouri River in North Dakota. These sources of information were further analyzed and used to develop a series of maps that identify areas and resources that may be impacted by sedimentation. These maps will be used as a basis for focusing data and information collection efforts in progress for other tasks.

The literature search included research papers and documents from USACE (Omaha District, Northwestern Division at the Reservoir Control Center, Garrison District, and Kansas City District), United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Unites States Geological Survey (USGS), Journal papers (Hydrological Science, Journal of Hydrology, Journal Spatial Hydrology, Environmental Conservation, Water Resources Management, Geomorphology), conference proceedings, and other sources.

A summary of the key documents located to date is outlined in Table 3–1. This literature search lead to the identification of locations of erosion and sedimentation in the Missouri River as described in Section 5.0.

3.2 Data Search

Berger also performed a comprehensive, in-depth data search, focusing on identifying and acquiring a wide range of information. The following summarizes the completed efforts in data acquisition.

—Retrieved land cover data from the 2001 National Land Cover Data (NLCD) for North Dakota.

—Retrieved and compiled hydrologic data (stream height and flow) and sediment data (total suspended sediments) from 15 USGS flow and water quality stations located within the study area. The locations of the USGS flow and water quality stations are shown in Figure 3–1.

—Acquired the revised 1997 National Resources Inventory (NRI) database from the NRCS. The NRI database is an extensive collection of data such as land cover, habitat, and soil erosion from non-Federal lands and water areas within 48 States in the U.S. (USDA, 2000, 2001). The soil erosion data set was used in the planning tool to provide estimates for soil loss per area in the study area.

—Acquired climatic data from the National Climatic Data Center (NCDC) over EarthInfo Inc. and compiled precipitation and temperature data from weather stations within the study area.

—Delineated the entire watershed into HUC–8 [1] areas and into HUC–10 areas (Figure 3–1). The HUC–10 delineation served as the basis for the thematic map discussed in Section 6.0

The majority of the retrieved data were integrated under a GIS platform for ease of analysis and retrieval. Table 3–2 presents the complete inventory of the various data types and sources that have been obtained to date.

[1] Acronym for Hydrologic Unit Code: Every hydrologic unit is defined by a HUC (2 to 12 digits) defining the region, sub-region, basin, sub-basin, watershed, and sub-watershed. HUC–8 consists of eight digits and describes the drainage area at sub-basin level. HUC–1 0 consists of ten digits and describes the drainage at watershed level.

TABLE 3–1.—KEY DOCUMENTS RELATED TO EROSION AND SEDIMENTATION IN THE MISSOURI RIVER

Author	Date	Title
Bhattaria, R. and D. Dutta	2007	Estimation of Soil Erosion and Sediment Yield Using GIS at Catchment Scale
Jain, M.K. and U.C. Kothyari	2000	Estimation of Soil Erosion and Sediment Yield Using GIS
Jones, D.S., Kowalski, D.G. and R.B. Shaw	1996	Calculating Revised Universal Soil Loss Estimates on Department of Defense Lands: A Review of RUSLE factors and U.S. Army Land Condition Trend Analysis (LCTA) Data Gaps
Kothyari, U.C. and M.K. Jain	1997	Sediment yield estimation using GIS
Kothyari, U.C., Jain, M.K. and K.G. Ranga Raju	2002	Estimation of temporal variation of sediment yield using GIS
Mutua, B.M. and A. Klik	2006	Estimating Spatial Sediment Delivery Ratio on a Large Rural Catchment
NRCS	2001	A Guide For Users of 1997 NRI Data Files
Ouyang, D. and J. Bartholic	1997	Predicting Sediment Delivery Ratio in Saginaw Bay Watershed
Shields, F.D., Simon, A., and L.J. Steffen	2000	Reservoir Effects on Downstream River Channel Migration
USACE (Garrison, Omaha, and Cansas City Districts)	1957	Degradation Below Garrison Dam: Observations in 1954
USACE (Omaha District)	1980	Verification of Sediment Transport Functions: Missouri River
USACE (Omaha District)	1984	Aggradation and Degradation Aspects of the Missouri River Mainstem Dams
USACE (Omaha District)	1992	Bank Recession
USACE (Omaha District)	1993	Aggradation, Degradation, and Water Quality Conditions: Missouri River Mainstem Reservoir System
USACE (Omaha District)	1993	Downstream Channel and Sediment Trends Study
USACE (Omaha District)	June 1993	Lake Oahe Aggradation Study
USACE (Northwestern Division, Reservoir Control Center)	1999	Missouri River Mainstem Reservoirs 1998–1999 Annual Operating Plan
USACE (Omaha District)	2000	Downstream Channel and Sediment Trend Study Update
USACE (Omaha District)	Dec. 2001	Missouri River—Fort Peck Dam to Ponca State Park Geomorphological Assessment Related to Bank Stabilization
USACE (Omaha District)	2008	Bank Stabilization Cumulative Impact Analysis Final Technical Report
USDA (Glymph, Louis M.)	1954	Studies of Sediment Yields from Watersheds
USDA	1983	National Engineering Handbook, Sedimentation: Sediment Sources, Yields, and Delivery Ratios
USGS	1992	Techniques for Estimating Peak Flow Frequency Relations for North Dakota Streams
USGS	1995	Transport and Sources of Sediment in the Missouri River between Garrison Dam and the Headwaters of Lake Oahe, North Dakota, May 1988 through April 1991
USGS	2000	Suspended-Sediment Loads from Major Tributaries to the Missouri River between Garrison Dam and Lake Oahe, North Dakota, 1954–98
USGS	2006	Water, Bed-Sediment, and Fish-Tissue Quality within the Standing Rock Sioux Reservation, North Dakota and South Dakota
USGS	2006	Water-Quality Characteristics of Montana Streams in a Statewide Monitoring Network, 1999–2003
Walling, D.E.	1983	The Sediment Delivery Problem
Williams, J.R.	1977	Sediment delivery ratios determined with sediment and runoff models
Wuebben, J.L. and J.J. Gagnon	1995	Ice jam flooding on the Missouri River near Williston, North Dakota

FIGURE 3–1.—*Watershed Delineation, Weather Station Locations, and USGS Stations*

TABLE 3–2.—INVENTORY OF THE ACQUIRED VARIOUS DATA AND SOURCE

Type	Description	Source(S)
Physiographic data	Watershed boundary (8-digit and 10-digit HUCs)	USGS, NRCS
	Land use/land cover	NLCD 2001
	Soil data (STATSGO/SSURGO)	NRCS
	Topographic data	30m DEM (NED)
	Slopes	Berger (Based on DEM)
	Stream network and water bodies	NHD
	River Mile Marker	USACE
	Flow data	USGS
	Stage Height	USGS
	Bluff to bluff	Berger (Based on DEM)
	Areas of Aggradations	Berger (From USACE and USGS Reports)
Weather data	Weather Station Location	NCDC
	Precipitation	NCDC
	Temperature	NCDC
Flow data	Daily flow from USGS gaging stations in North Dakota	USGS
Administrative Boundaries	Federal Lands (FWS, USACE, BLM, NPS, BIA)	ESRI, Agency Sources
	County/State Boundaries	US Census
	Tribal Lands	US Census
	Municipal Areas	USACE
Recreation	State Park and Recreational Areas	North Dakota
	Boat Ramps	USACE
	Mitigation/Recovery Site	USACE
Cultural	Lewis and Clark Campsites	USACE
	Cemetery Sites	USACE
Transportation	Major Highways	US Census
	Railroad	USACE

TABLE 3–2.—INVENTORY OF THE ACQUIRED VARIOUS DATA AND SOURCE—Continued

Type	Description	Source(S)
Soil Loss Data	1997 site-specific revised soil loss data	NRCS
Water Quality Data	Total Suspended Solids Measurements	USGS

BLM—Bureau of Land Management
BIA—Bureau of Indian Affairs
DEM—Digital Elevation Model
FWS—Fish and Wildlife Service
NCDC—National Climatic Data Center
NHD—National Hydrography Dataset
NPS—National Park Service
NRCS—Natural Resources Conservation Service
USACE—United States Army Corps of Engineers
USGS—United States Geologic Survey

3.3 Land Use Distribution

Sediment can be delivered to the river from point sources located in the watershed and it can be carried in the form of non-point source runoff from non-vegetated or protected land areas. In addition, sediment can be generated in the river through the processes of scour and deposition, which are primarily a function of river flow. During periods of high flow, erosion of the river channel occurs. The eroded materials are deposited downstream in areas where the bed material load exceeds the transport capacity. As a result, sources of sediment are mainly related to the type of land use within the watershed. As such, Berger focused on collecting the most recent information on land use for the study area as described below.

The land use characterization for the study area of the Missouri River was based on land cover data from the 2001 National Land Cover Data (NLCD). Figure 3–2 displays a map of the land uses of watersheds draining into the Missouri River within North Dakota. The drainage area of the study area represents the entire Yellowstone River watershed and 17 HUC–8 sub-watersheds.

Table 3–3 presents the Yellowstone River and the 17 HUC–8 sub-watersheds, as shown in Figure 3–2, with their two predominant land uses. A detailed break-down of land uses for each watershed is presented in Exhibit A.

TABLE 3–3.—WATERSHEDS LOCATED IN THE STUDY AREA

Watershed	HUC–8 [1]	Predominant Land Use	
		Category	Fraction (percent)
Yellowstone River	([2])	Shrub	41.2
		Grassland/Herbaceous	31.5
Lake Sakakawea	10110101	Cultivated Crops	41.4
		Grassland/Herbaceous	37.5
Little Muddy River	10110102	Cultivated Crops	68.4
		Grassland/Herbaceous	21.9
Upper Little Missouri River	10110201	Grassland/Herbaceous	57.8
		Shrub	32.0
Boxelder Creek	10110202	Grassland/Herbaceous	64.2
		Shrub	26.8
Middle Little Missouri River	10110203	Grassland/Herbaceous	62.9
		Cultivated Crops	14.5
Beaver Creek	10110204	Grassland/Herbaceous	49.9
		Cultivated Crops	31.6
Lower Little Missouri River	10110205	Grassland/Herbaceous	55.7
		Deciduous Forest	12.5
Painted Woods-Square Butte	10130101	Grassland/Herbaceous	41.7
		Cultivated Crops	31.9
Upper Lake Oahe	10130102	Grassland/Herbaceous	66.3
		Cultivated Crops	16.7
Apple Creek	10130103	Grassland/Herbaceous	56.9
		Cultivated Crops	19.3
Beaver Creek Oahe	10130104	Grassland/Herbaceous	57.2
		Cultivated Crops	24.2
Knife River	10130201	Grassland/Herbaceous	57.3
		Cultivated Crops	28.0
Upper Heart	10130202	Cultivated Crops	42.6
		Grassland/Herbaceous	40.1

TABLE 3–3.—WATERSHEDS LOCATED IN THE STUDY AREA—Continued

Watershed	HUC–8 [1]	Predominant Land Use	
		Category	Fraction (percent)
Lower Heart River	10130203	Grassland/Herbaceous	51.3
		Cultivated Crops	33.5
Upper Cannonball River	10130204	Cultivated Crops	48.2
		Grassland/Herbaceous	32.9
Cedar Creek	10130205	Grassland/Herbaceous	42.5
		Cultivated Crops	38.1
Lower Cannonball River	10130206	Grassland/Herbaceous	77.0
		Cultivated Crops	15.3

[1] HUC–8 = Hydraulic Unit Code describing the drainage area at sub-basin level.
[2] This includes the entire Yellowstone River watershed.

The overall distribution of land uses in the study area by land area and percentage is presented in Table 3–3 and a brief description of land use classifications are presented in Table 3–4. Overall, grassland represents the dominant land use type (43.1 percent) followed by shrub and agriculture (both 21 percent). Cultivated crops showed greatest fraction in agriculture lands (16.6 percent). Forested land comprises 8.3 percent of the land cover in the study area. The smallest percentage of land cover is for perennial ice/snow that is only part of the land use distribution in the Yellowstone River (0.04 percent).

TABLE 3–4.—LAND USE CATEGORY AND DISTRIBUTION WITHIN THE STUDY AREA

Land Use Category	NLCD Land Use Type	Hectare	Fraction of Watershed's Land Use Area (percent)
Water/Wetland	Open Water	423,736	2.20
	Woody Wetlands	189,262	0.98
	Emergent Herbaceous Wetlands	205,991	1.07
Subtotal		818,989	4.25
Developed	Developed, Low Intensity	47,078	0.24
	Developed, Medium Intensity	7,105	0.04
	Developed, High Intensity	1,275	0.01
Subtotal		55,457	0.29
Agriculture	Pasture/Hay	740,443	3.84
	Cultivated Crops	3,203,883	16.62
Subtotal		3,944,326	20.46
Grassland (Prairie)	Grassland/Herbaceous	8,301,537	43.07
Forest	Deciduous Forest	177,801	0.92
	Evergreen Forest	1,412,006	7.33
	Mixed Forest	17,412	0.09
Subtotal		1,607,220	8.34
Shrub	Shrub	4,044,607	20.98
Other	Developed, Open Space	316,051	1.64
	Barren Land (Rock/Sand/Clay)	178,444	0.93
	Perennial Ice/Snow	8,417	0.04
Subtotal		502,911	2.61
Total		19,275,047	100.00

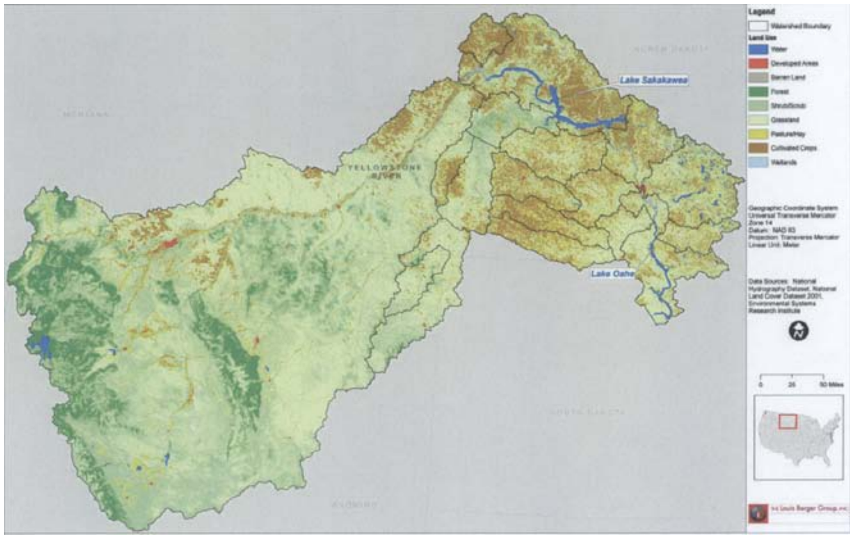


FIGURE 3–2.—*Land Use Distribution of the Study Area in the Missouri River (ND)*

TABLE 3–5.—DESCRIPTIONS OF 2001 NLCD LAND USE TYPES

Land Use Type	Description
Open Water	All areas of open water, generally with less than 25 percent cover of vegetation or soil.
Woody Wetlands	Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75–100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Developed, Open Space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Developed, Low Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20–49 percent of total cover. These areas most commonly include single-family housing units.
Developed, Medium Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50–79 percent of the total cover. These areas most commonly include single-family housing units.
Developed, High Intensity	Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Total cover is 80–100 percent impervious surfaces.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
Cultivated Crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
Grassland	Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.

TABLE 3–5.—DESCRIPTIONS OF 2001 NLCD LAND USE TYPES—Continued

Land Use Type	Description
Deciduous Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
Shrub	Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.
Barren Land	Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.

Source.—National Land Cover Data (NLCD) (http://www.epa.gov/mrlc/definitions.html).

3.4 Flow and Sediment Data

Environmental monitoring efforts in the study area include flow and total suspended solid (TSS) measurements at three monitoring stations on the mainstem of the Missouri River and six monitoring stations at tributaries flowing into the Missouri River. Additionally, monitoring stations located at the Montana/North Dakota border (USGS 06185500) and the Yellowstone River in Montana (USGS 06329500) were included as boundary stations. Monitoring efforts presented in this section were conducted by the USGS.

Figure 3–1 shows the location of the USGS stations. Table 3–6 presents an inventory of available flow and TSS data at USGS monitoring stations in the study area including the data range, number of samples, minimum, maximum, standard deviation, and average of the data type at each USGS station. Overall, historic and recent flow measurements were available for the majority of the stations. On average, the Yellowstone River delivered the largest amount of flow to the Missouri River within North Dakota followed closely by the amount of flow delivered from Montana. The remaining major tributaries discharging into the Missouri River within North Dakota had a relatively small impact on the flow budget in the Missouri River. As for TSS measurements, data were limited and no current measurements have been taken. Nonetheless, for comparison reason, the available TSS concentrations were graphed with the corresponding flow in Figures A–1 through A–7 of Exhibit A. In general, spikes of TSS levels were a direct response to high flow events.

TABLE 3–6.—INVENTORY OF FLOW (m3/sec) AND TOTAL SUSPENDED SOLIDS (mg/L) MONITORING STATIONS IN THE STUDY AREA

USGS Station Number	River/Station Name	Data Type	Data Range [1]	Number of Samples	Min	Max	Mean	STDEV
	Missouri River							
6185500	Missouri River near Culbertson, MT	Flow	07/01/1941–12/31/1951 04/01/1958-present	22,020	16.3	1,959.5	281.0	144.0
		TSS	10/01/1971–09/30/1976	1,826	30.0	2,900.0	365.1	350.7
06330000	Missouri River, Williston, ND	Flow	10/01/1928–07/31/1965	13,453	37.4	5,097.0	577.8	422.8
06338490	Missouri River, Garrison Dam	Flow	10/01/1969–09/30/2007	13,876	116.1	1,846.3	606.3	224.7
06342500	Missouri River, Bismarck, ND	Flow	10/01/1927-present	29,323	51.0	10,279.0	628.7	368.7
		TSS	10/01/1971–09/30/1981	3,653	14.0	2,800.0	173.7	180.1
	Tributaries							
06329500	Yellowstone River near Sidney MT	Flow	10/01/1910–12/31/1931 10/01/1933-present	34,888	16.1	4,021.0	349.4	358.7
		TSS	06/18/1965; 10/03/1971–05/28/08	426	10.0	15,500.0	900.0	1596.0
06340500	Knife River, at Hazen, ND	Flow	04/01/1929-present	28,798		634.3	4.3	19.6
		TSS	03/08/1946–07/31/1946 04/23/1948–09/30/1948	292	29.0	6,900.0	441.4	882.3
06341410	Turtle Creek, above Washburn	Flow	10/01/1986–09/30/2003	6,209		21.7	0.4	0.9
06342260	Square Butte Creek, below Center, ND	Flow	06/01/1965-present	15,675		75.6	0.3	2.5
06342450	Burnt Creek, near Bismarck, ND	Flow	10/01/1967-present	11,656		110.4	0.3	2.1
06349000	Heart River, near Mandan, ND	Flow	04/01/1924-present	27,822		804.2	7.2	27.4
		TSS	10/01/1971–09/30/1976	1,826	1.0	3,460.0	124.1	358.7
06349500	Apple Creek, near Menoken, ND	Flow	03/01/1905-present	22,891		158.3	1.2	4.9

[1] Data were retrieved from begin of record until June 15, 2008; Flow were continuous measured and TSS instantaneous.

TSS—Total Suspended Solids

4.0 IDENTIFICATION OF AGGRADATION LOCATIONS IN THE MAINSTEM OF THE MISSOURI RIVER

Prior to the identification of sources of erosion and sedimentation (described in Section 5), Berger conducted an analysis of aggradation areas within the main stem of the Missouri River using information from three available key documents. Sediment deposit sites located upstream from Garrison Dam were identified based on information from the Aggradation, Degradation, and Water Quality Conditions report by USACE (1993). Sediment deposit sites located between the Garrison Dam and the city of Bismarck were identified based on information from the Missouri River—Fort Peck Dam to Ponca State Park Geomorphological Assessment Related to Bank Stabilization report by USACE (December 2001). Sediment deposit sites located between the city of Bismarck and the downstream boundary of this study (Figure 3–1) were identified based on information from the Lake Oahe Aggradation Study by USACE (June 1993). However, these reports were used to identify aggradation areas only in longitudinal direction. As a result, the latitudinal extent of the aggradation areas was randomly defined between bluff to bluff of the Missouri River. The aggradation areas were classified in low, moderate, and high in order to show qualitatively the magnitude of aggradation (the classification was based on narrative and numeric description of the magnitude of aggradation reported in the above quoted literature).

Sediment Aggregation Between ND–MT State Line and Garrison Dam

The USACE (1993) report compiled a record of available sediment-related data and information that were collected at least 30 years ago (between 1946 and 1989) by the USACE (Omaha District) and USGS on the Missouri River in Montana, North Dakota, South Dakota, and Nebraska. The report also provided an evaluation of changes in channel geometry (channel width, average bed profile, thalweg profile, and cross-sectional area) in order to analyze reservoir volume, bed material gradation, stream bank erosion, and tailwater trends in terms of aggradation and degradation.

Specifically, the thalweg profiles and the average bed profiles developed between the North Dakota and Montana State line for 4 representative years (1956, 1964, 1978, and 1987) presented in the USACE report were used by Berger to locate and estimate qualitatively aggradation sites in this area. Based on this analysis, the largest continuous area of sediment aggradation were found in the upstream ends of Lake Sakakawea extending approximately over 94 miles between river mile 1564 (approximately 22 miles downstream from the Yellowstone River) and river mile 1470 (approximately 4 miles downstream from Clarks Creek) (Figures 4–1 and 4–2). The highest level of aggradation in this area were located between river mile 1534 and river mile 1521 shown in red in Figure 4–1. It should be noted that the presented location of the aggradation areas needs to be verified with more current measurements.

Sediment Aggradation Between Garrison Dam and the City of Bismarck

The USACE (Dec. 2001) report evaluated the potential impacts of bank stabilization on the morphologic processes in the Missouri River. The report analyzes four open stretches on the main stem of the Missouri River (Fort Peck to vicinity of Yellowstone River, Garrison Dam to Lake Oahe, Fort Randall Dam to the Niobrara River, and Gavins Point Dam to Ponca). The analysis is based on an extensive field investigation and data collection for sediment from banks, bars, islands, and tributaries, and includes the establishment of relationships between channel width and bars and islands, bar and island density analysis, sediment gradation analysis, bank erosion analysis, and sediment budget.

Specifically, the calculated net sediment transport presented in the USACE (Dec. 2001) for the Garrison Reach was used by Berger to locate and estimate qualitatively aggradation sites in this area. The reported net sediment transport volumes were calculated for six geomorphic reaches and were based on estimated volumes for erosion and deposition at banks and beds between 1976 and 1998. Overall, the Garrison reach is dominated by erosion with stream bed erosion playing the major role. The largest erosion was found in the upper section of the Garrison reach between Garrison Dam and river mile 1363. Downstream from this section between river mile 1362 and 1363 (geomorphic reach GR3), erosion decreased considerably which led to the only aggradation area located within the Garrison Reach. Figure 4–3 depicts the location of this aggregation area. The erosion in the remaining downstream section between river mile 1352 and 1315 increased again and reached a dynamic equilibrium in the last 24 miles (river mile 1339 to 1315) of the Garrison Reach.

Sediment Aggradation Between the City of Bismarck and the Downstream Boundary of This Study (Upper end of Lake Oahe)

The USACE (June 1993) compiled information on morphologic conditions and trends for Lake Oahe using historic survey data (profiles of the aggradation ranges, bed and suspended sediment data, density of sediment deposits, pool elevation records, capacity and sediment depletion data, and shoreline erosion information) collected during eight surveys between 1958 and 1989.

Specifically, the profiles for average bed elevation profiles, thalweg elevation, and average depth of sediment deposit presented in the USACE report were used by Berger to locate and estimate qualitatively aggradation sites in this area. Except for an approximately 10 mile stretch downstream of the city of Bismarck, aggradation areas were identified along the entire section (Figures 4–3 and 4–4). High amount of aggradation were found in four relatively small stretches of approximately 5 miles long located at approximately 20 miles downstream from the city of Bismarck and upstream and downstream of the confluence with the Grand River (RM 1190—1205). A stretch of 31 miles located between RM 1248 and 1217 showed the largest extent of medium aggradation (Figure 4–4).

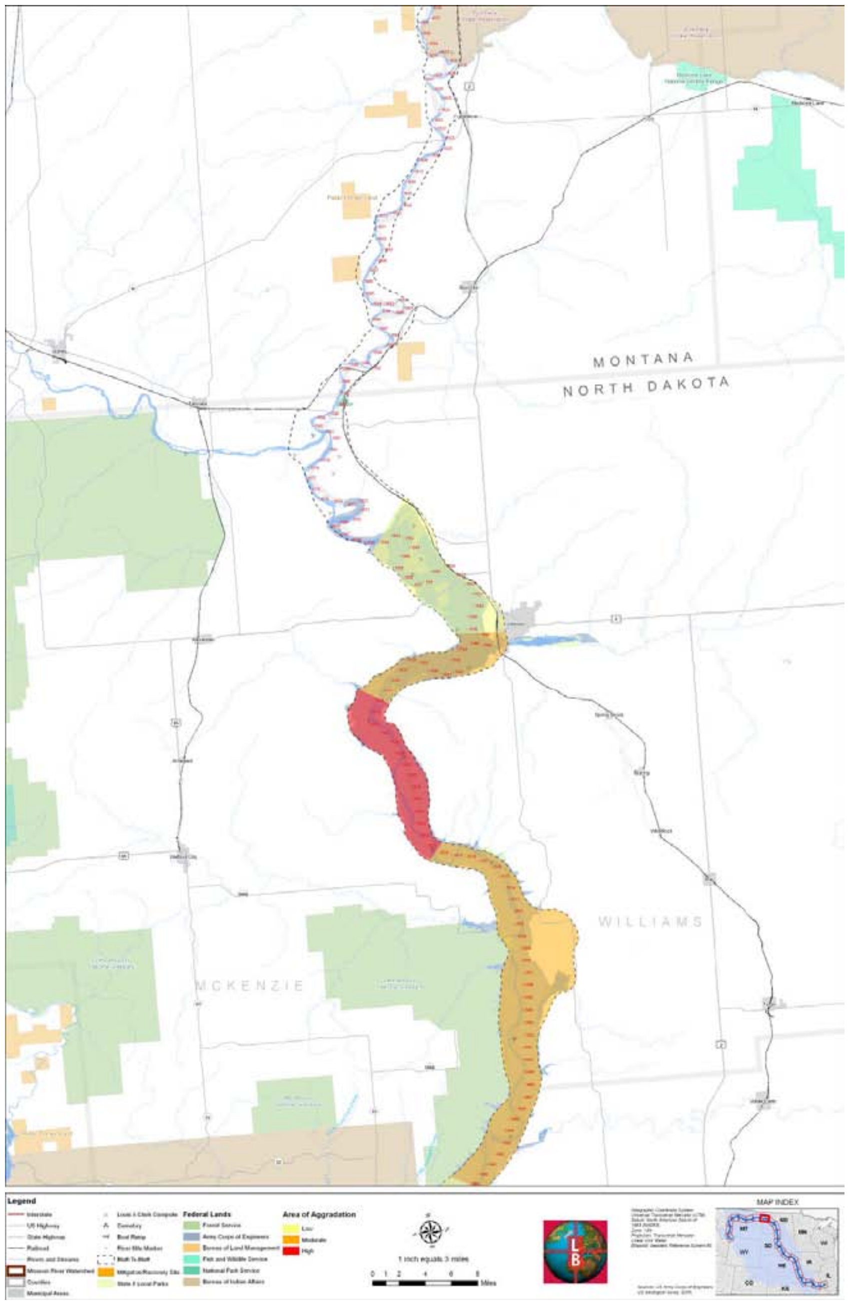


FIGURE 4–1.—*Aggradations Area Map—Lake Sakakawea upstream from Garrison Dam through Williston, ND*

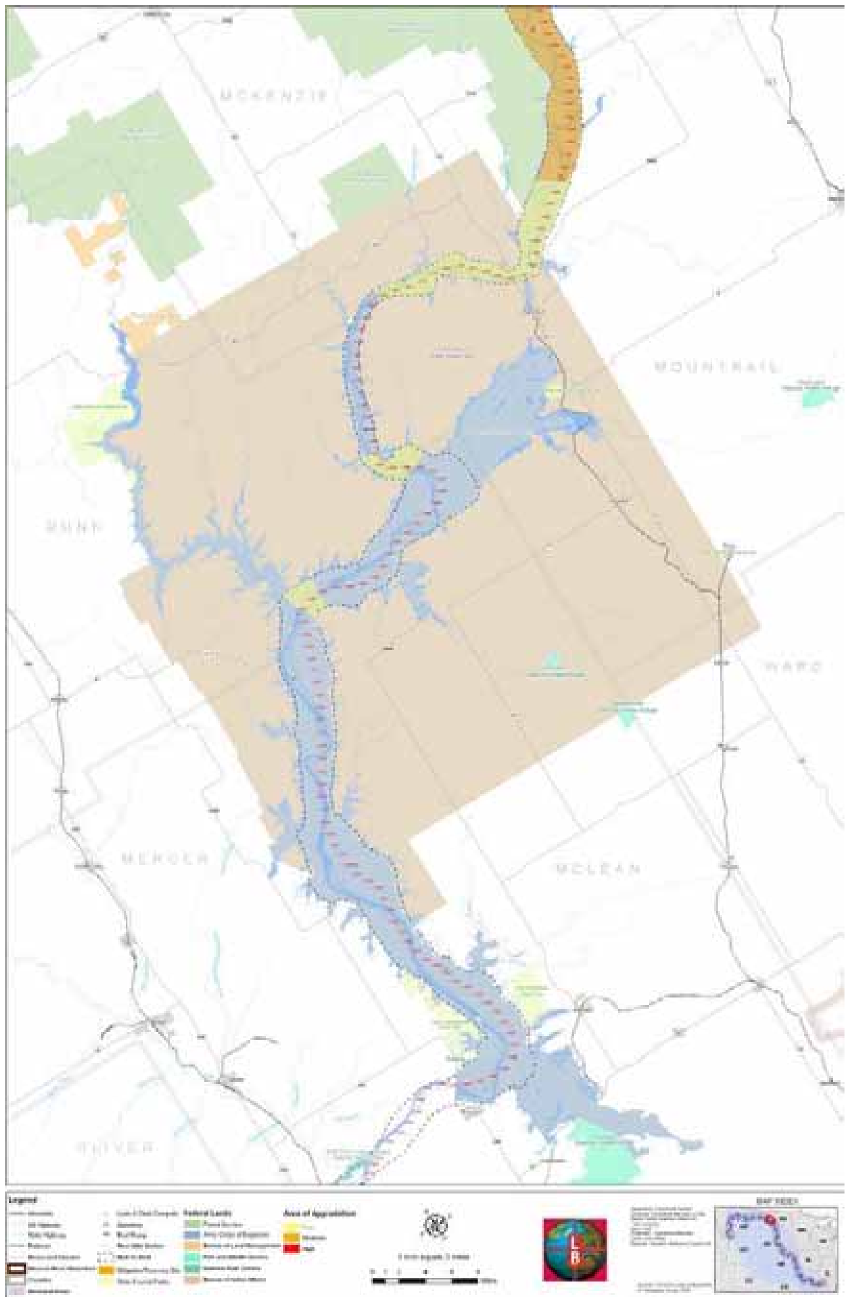


FIGURE 4–2.—*Aggradations Area Map—Lake Sakakawea upstream from Garrison Dam through Ft. Berthold Indian Reservation*

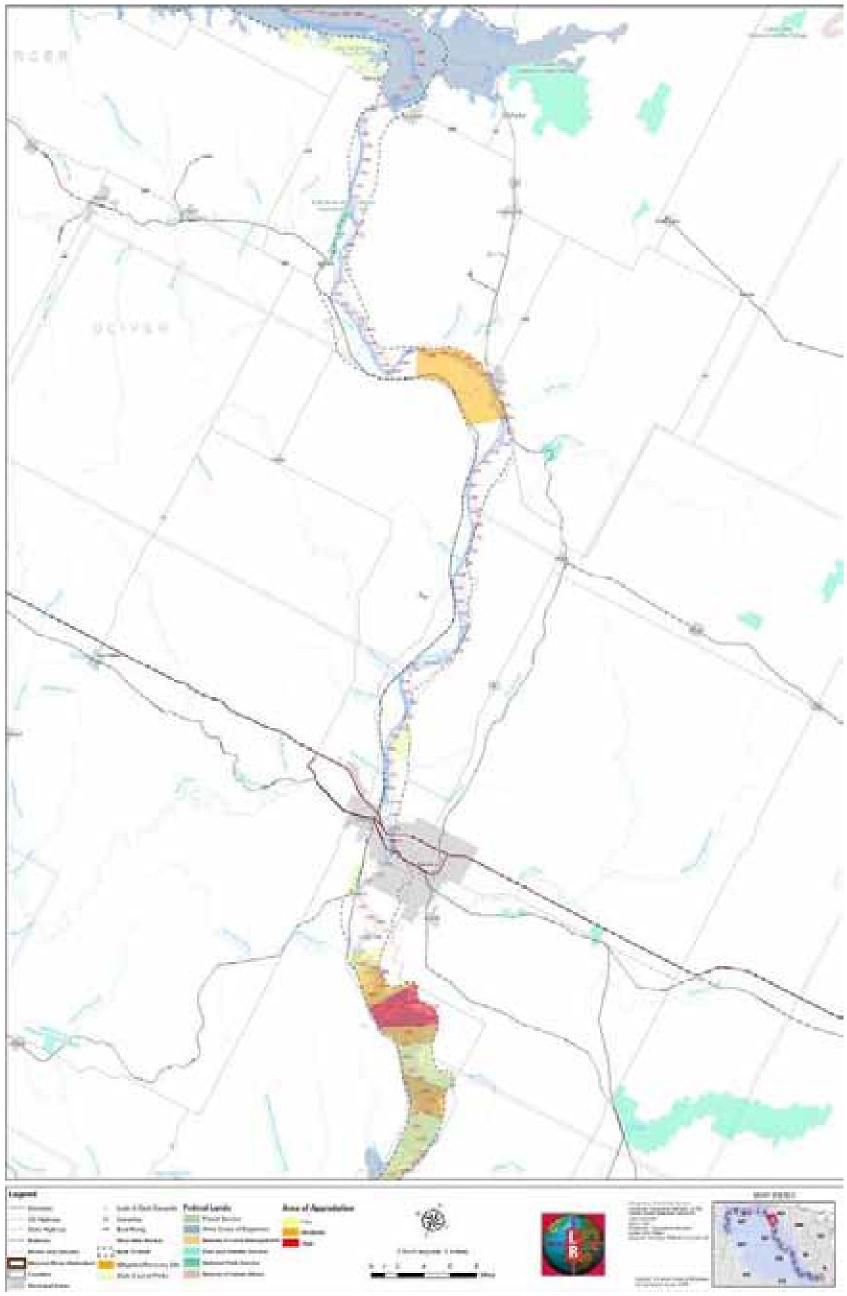


FIGURE 4–3.—*Aggradations Area Map—Mainstem between Garrison Dam and RM 1279*

FIGURE 4–4.—*Aggradations Area Map—Mainstem between RM 1279 and 1180*

5.0 SEDIMENT SOURCE ASSESSMENT

Berger conducted an assessment of potential sediment sources for the mainstem Missouri River in North Dakota. The purpose of this assessment is to estimate approximate sediment loads of each potential source delivered to the mainstem Missouri River in North Dakota and approximate sediment loads produced within the mainstem Missouri River in North Dakota (instream erosion loads from bed and banks). Potential sediment sources are delivered from Missouri River in Montana, the Yellowstone River watershed (largest watershed draining into the Missouri River within North Dakota), from the remaining watersheds in North Dakota draining into the Missouri River, and produced within the area between Garrison Dam and the city of Bismarck of the Missouri River. The delivered sediment loads from Montana and from the Yellowstone River were obtained from sediment load estimates by USACE. The delivered sediment loads from the remaining watersheds within North Dakota were estimated using the planning-level tool Generalized Watershed Loadings Functions (GWLF). The instream erosion loads were estimated using USGS gaging data and the estimates from GWLF.

5.1 Delivered Sediment Load From Montana and the Yellowstone River

Based on Wuebben and Gagnon (1995), the USACE in 1978 estimated an annual long-term sediment load for Missouri River at Culbertson, Montana (USGS gage number 06185500, located approximately 20 miles upstream from the Montana—North Dakota border) of approximately 13.5 million tons and for the Yellowstone River at Sidney, Montana (USGS gage number 06329500, located approximately 20 miles upstream from the confluence with the Missouri River) of approximately 41.5 million tons. Both sediment loads are delivered into Lake Sakakawea. However, as mentioned in Wueben and Gagnon (1995), based on a preliminary study by the USGS, these loads may have been overestimated by 30-percent. The USACE (1993a) estimated that the gross storage loss for all of Lake Sakakawea since closure of the dam in 1953 and the survey date in 1988 was 907,000 acre-feet or 25,900 acre-feet/year. Using a bulk density of 1.4 g/cm3, based on values provided by Geiger (1963) for sand and silt, this volume translates into a sediment supply of 45 million tons/year. This volume is similar to the volume discussed above in Wuebben and Gagnon (1995), after allowing for a 30 percent reduction as suggested. Therefore, using this 30-percent reduction, the approximate annual delivered sediment load from the Missouri River at Culbertson, Montana, is 9.5 million tons and from the Yellowstone River at Sidney, Montana, 29.1 million tons.

5.2 Delivered Sediments From the Remaining Watersheds Within the Study Area

Berger evaluated sediment sources for the remaining watersheds draining into the Missouri River in North Dakota using a planning level tool. The remaining watersheds included the HUC–8 watersheds Lake Sakakawea, Little Muddy River, Upper Little Missouri River, Boxelder Creek, Middle Little Missouri River, Beaver Creek, Lower Little Missouri River, Painted Woods-Square Butte, Upper Lake Oahe, Apple Creek, Beaver Creek Oahe, Knife River, Upper Heart, Lower Heart River, Upper Cannonball River, Cedar Creek, and Lower Cannonball River. The planning-level tool is the Generalized Watershed Loadings Functions (GWLF). It is a time-variable simulation model that simulates hydrology and land-based sediment loadings on a watershed basis. The objective was to combine the data collected for these watersheds and to assess and rank the land-based loads of sediments.

The following outlines the overall procedure used to assess the sources of erosion in the remaining watersheds within the study area:

—The watershed was divided into HUC–10 segments (Figure 3–1). These sub-watersheds served as the basis for developing the erosion sources thematic map which shows the land-based sediment loads for each sub-watershed.

—The planning tool was applied to the Knife River watershed to estimate the delivered land based sediment unit-loads (tons per hectare) to the Missouri River. The Knife River watershed served as a prototype to verify the hydrology and generate the reference land-based sediment loads by land use category. As a result, the planning tool was validated for hydrology and sediment loads.

—The reference land-based delivered sediment unit-loads, specific to the Knife River; serve as a basis to develop the unit-loads in each of the sub-watersheds. The Knife River unit-loads were adjusted using the following HUC10 specific factors:

—Land use distribution in each of the HUC10 watersheds (Exhibit A)
—Soil erodibility (K factor)
—Field slope length and steepness (LS factor)
—Land cover management factor (C factor)
—Conservation practice factor (P factor)
—Sediment delivery ratios based on drainage area and total delivered sediment load

5.2.1 Description of the Planning Tool—GWLF

The GWLF planning tool is a time variable model that simulates hydrology and sediment loadings on a watershed basis. Observed daily precipitation data is required in GWLF as the basis for water budget calculations. Surface runoff, evapotranspiration and groundwater flows are calculated based on user specified parameters. Stream flow is the sum of surface runoff and groundwater discharge and was computed using the Soil Conservation Service's Curve Number Equation. Curve numbers are a function of soils and land use type. Evapotranspiration is computed based on the method described by Hamon (1961) and is dependent upon temperature, daylight hours, saturated water vapor pressure, and a cover coefficient. Groundwater discharge to the stream was calculated using a lumped parameter for unsaturated and shallow saturated water zones. Infiltration to the unsaturated zone occurs when precipitation exceeds surface runoff and evapotranspiration. Percolation to the shallow saturated zone occurs when the unsaturated zone capacity is exceeded. The shallow saturated zone is modeled as a linear reservoir to calculate groundwater discharge. In addition, the model allows for seepage to a deep saturated zone.

Erosion and sediment loading is a function of the land source areas present in the watershed. Multiple source areas may be defined based on land use type, the underlying soils type, and the management practices applied to the lands. Sediment loads from each source area are summed to obtain a watershed total. The Universal Soil Loss Equation (USLE) is used to compute erosion for each source area and a sediment delivery ratio is applied to determine the sediment loadings to the stream (Wischmeier and Smith, 1978), and is expressed as:

$$A = R*K*LS*C*P$$

Where:
A = Average annual soil loss in tons per hectare per year
R = Rainfall/runoff erosivity
K = Soil erodibility
LS = Field slope length and steepness
C = Cover/management factor
P = Conservation practice factor.

The R factor is an expression of the erosivity of rainfall and runoff in the area of interest; the R factor increases as the amount and intensity of rainfall increases. The K factor represents the inherent erodibility of the soils in the area of interest under standard experimental conditions. The K factor is expressed as a function of the particle-size distribution, organic-matter content, structure, and permeability of the soils. The LS factor represents the effect of topography, specifically field slope length and steepness, on rates of soil loss at a particular site. The LS factor increases with field slope length and steepness due to the resulting accumulation and acceleration of surface runoff as it flows down slope. The C factor represents the effects of surface cover and roughness, soil biomass, and soil-disturbing activities on rates of soil loss at the area of interest. The C factor decreases as surface cover and soil biomass increase. The P factor represents the effects of supporting conservation practices, such as contouring, buffer strips, and terracing, on soil loss at the area of interest.

5.2.2 Application of the Planning Tool to the Knife River

This section presents and describes the setup and calibration of the GWLF planning tool and the sediment loading estimates generated for the Knife River. The tool was set up and validated for hydrology and sediment by comparing model output to observed stream flow data and published sediment loading data.

5.2.2.1 Model Set-Up

The GWLF planning tool requires two input files: a weather input file (Weather.dat) and a transport input file (Transport.dat). The weather input file requires daily precipitation data expressed in centimeters and daily temperature data expressed in degrees Celsius. The transport input file requires specification of input parameters relating to hydrology, erosion, and sediment yield. Runoff curve numbers and USLE erosion factors are specified as an average value for a given source area. The existing and projected land cover classifications present in the study area (Section 4) were used to define model source areas. A total of 16 source areas were defined in modeling the land cover conditions in the study area. As necessary, GIS analyses were employed to obtain area-weighted parameter values for each given source area.

Runoff curve numbers were developed for each model source area in the study area based on values published in the NRCS Technical Release 55 (NRCS, 1986). STATSGO soils GIS coverages were analyzed to determine the dominant soil hydrologic groups for each model source area. Evapotranspiration cover coefficients were developed based on values provided in the GWLF manual (Haith et al., 1992) for each model source area. Average watershed monthly evapotranspiration cover coefficients were computed based on an area-weighted method. Initialization of groundwater hydrology and other parameters were set to default values recommended in the GWLF manual.

USLE factors for soil erodibility (K), length-slope (LS), cover and management (C), and supporting practice (P) were derived from multiple sources based on data availability. KLSCP factors were obtained from the revised 1997 National Resources Inventory (NRI) database provided by the NRCS. Otherwise, average K, LS, C, and P values for model source areas were determined based on GIS analysis of soils and topographic coverages, and literature review. The rainfall erosivity coefficient was determined from values given in the GWLF manual. The sediment delivery ratio was computed directly in the GWLF model interface.

Developed lands include impervious surfaces that are not subject to soil erosion. Therefore, sediment loads from developed lands were not modeled using the USLE. Instead, sediment loads from developed lands were computed based on typical loading rates from developed lands (Horner et al., 1994).

5.2.2.2 Hydrology Calibration in the Knife River Watershed

GWLF was originally developed as a planning tool for estimating nutrient and sediment loadings on a watershed basis. Designers of the model intended for it to be implemented without calibration. Nonetheless, comparisons were made between predicted and observed stream flow collected in the study area to ensure the general validity of the model.

Daily stream flow data were available at one USGS station (06340500) located in the study area (Figure 3–1). The groundwater seepage coefficient, base flow recession coefficient, and unsaturated zone available water capacity were adjusted using an iterative approach in order to obtain a best fit with observed data.

Results of the hydrology verification are presented in Figures 5–1 and 5–2. Figure 5–1 depicts the monthly observed and simulated flows and Figure 5–2 shows the stream flow verification statistics. Total flow volume was under-predicted by approximately 13 percent. The GWLF model predicted fairly well the observed flow in the Knife River indicated by the robustness of the regression with an R-square of 0.87.

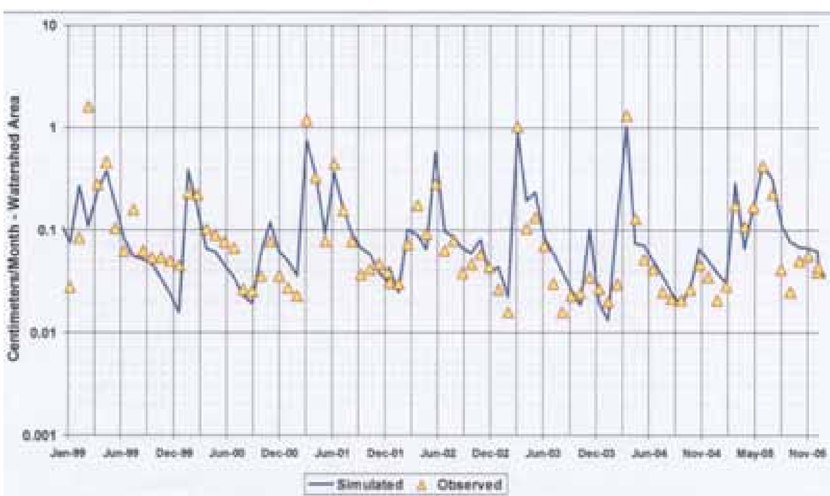


FIGURE 5–1.—*Hydrology Verification for the Knife River—Observed and Simulated Flow*

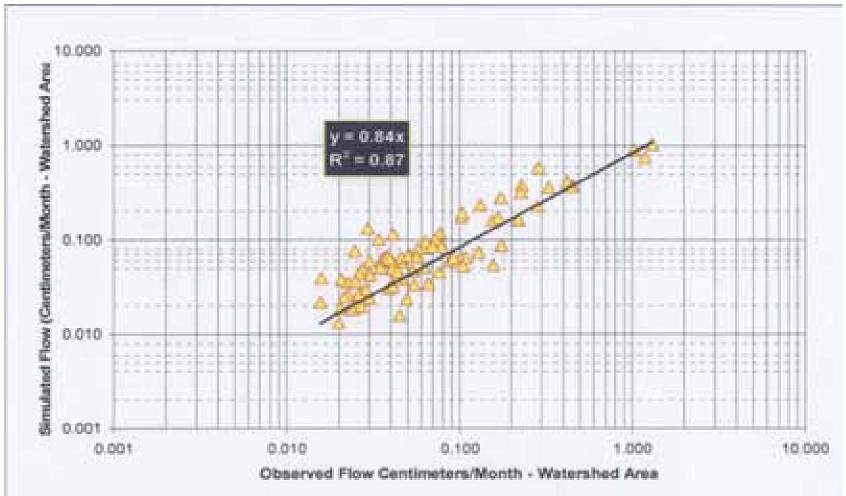


FIGURE 5–2.—*Hydrology Verification for the Knife River—Regression between Observed and Simulated Flows*

5.2.2.3 Sediment Loads Verification in the Knife River Watershed

The objective of the sediment verification was to insure that the sediment loads (erosion rates or edge of stream loads) were within acceptable published values. As a guideline, published literature values of expected erosion rates (Donigian, 2003) were used. Table 5–1 depicts the results of the simulated erosion rates in the Knife River watershed as they compared to the published values.

TABLE 5–1.—SIMULATED EROSION RATES BY LAND COVER TYPE IN THE KNIFE RIVER WATERSHED

Land Use Type	Published Values (tons/ha)	Simulated Erosion Rates (tons/ha)			
		MEAN	STDEV	MIN	MAX
Mixed Forest	0.1–0.9	0.29	0.16	0.11	0.51
Grassland/Herbaceous	0.35–1.9	0.82	0.46	0.33	1.47
Pasture/Hay	0.7–3.8	1.53	0.86	0.61	2.73
Cultivated Crop [1]	1.6–12.3	3.67	2.07	1.45	6.55
Barren Land	> 15.0	5.05	2.85	2.00	9.00
Developed, Low intensity	0.4–2.2	0.27	0.15	0.11	0.49
Developed, Med Intensity	0.4–2.2	0.32	0.18	0.13	0.57
Developed, High Intensity	0.4–2.2	0.38	0.22	0.15	0.68
Developed, Open Space	0.4–2.2	0.40	0.22	0.16	0.71

[1] Average sediment loads from conventional and low-till land uses.

The typical erosion rates presented in Table 5–1 were used as verification guidelines to insure that the simulated erosion rates were within acceptable published values. These sediment loads from the Knife River serve as the basis to estimate the sediment loads from the remaining watersheds.

5.2.3 Sediment Load Assessment for the Remaining Sub-Watersheds

The reference land-based delivered sediment unit-loads presented in the previous section served as a basis to develop the unit-loads in each of the sub-watersheds. In the first step, the sediment unit-loads were applied to the land use distribution in each of the sub-watersheds. Then the estimated sediment loads were adjusted using the specific K, LS, C, and P factors of the prototype watershed (Knife River) and each sub-watershed. This initial adjustment accounted for the differences between the Knife River watershed and each sub-watershed in terms of the USLE factors including: soil erodibility (K factor), field slope length and steepness (LS factor), land cover management factor (C factor), and the conservation practice factor (P factor) The USLE factors were obtained from the revised 1997 NRI database.

The derived sediment loads from each sub-watershed were then adjusted to derive the sediment loads delivered to the Missouri River. Sediment delivery ratios were estimated for each sub-watershed based on the size of the drainage area using a method published by McCuen (1998) for Midwestern watersheds:

$$SDL = 64.6 * A^{-0.2775} (100 \leq A \leq 1000 mi^2)$$

$$SDL = \text{Sediment Delivery ratio (\%)}$$

$$A = \text{Drainage Area } (mi^2)$$

The estimated land-based sediment loads delivered to the Missouri River in North Dakota from each of the sub-watersheds were used to develop a thematic map using GIS. Figure 5–3 shows the thematic map of the land-based delivered sediments to the main stem of the Missouri River from each sub-watershed. The results revealed that the largest portion of the delivered sediment loads originated from the northern and center sections of the study area. These areas also contained the largest percentage of land cover devoted to cultivated crops in the study area that is prone to soil erosion (Figure 3–2). The calculated total delivered sediment load was then used to rank each of the sub-watersheds (HUC08) based on loads (Table 5–2). As a result of this analysis, the highest delivered sediment load to the Missouri River originated from the Lake Sakakawea watershed that accounts for approximately 29-percent of the total delivered land based sediment load.

TABLE 5–2.—DELIVERED SEDIMENT LOAD TO THE MISSOURI RIVER FROM EACH WATERSHED (HUC08)

Watershed	HUC08	Sediment Load delivered to the Missouri River	
		metric tons/year	Fraction of the total delivered load (percent)
Lake Sakakawea	10110101	496,447	28.7
Painted Woods—Square Butte	10130101	159,527	9.2
Knife River	10130201	150,124	8.7
Upper Cannonball River	10130204	126,027	7.3
Upper Heart	10130202	105,946	6.1
Lower Heart River	10130203	102,731	5.90
Upper Lake Oahe	10130102	94,924	5.5
Little Muddy River	10110102	91,445	5.3
Middle Little Missouri River	10110203	88,971	5.1
Cedar Creek	10130205	74,852	4.3
Apple Creek	10130103	53,657	3.1
Upper Little Missouri River	10110201	49,194	2.8
Beaver Creek	10110204	38,660	2.2
Upper Cannonball River	10130204	33,356	1.9
Beaver Oahe Creek	10130104	32,153	1.9
Boxelder Creek	10110202	25,350	1.5
Lower Little Missouri River	10110205	7,280	0.4
Total delivered land based load		1,730,644	100.0

5.3 Produced Instream Erosion in the Mainstem of the Missouri River Between Garrison Dam and the City of Bismarck

Based on the analysis in section 4 of this report and additional studies by USACE (2008) and USGS (1995), the mainstem reach between Garrison Dam and the city of Bismarck is the only segment in the mainstem of the Missouri River of North Dakota in which instream erosion dominates. The total instream erosion load for this reach was estimated by subtracting the total annual sediment load at the USGS Bismarck gaging station (USGS 06342500) from the sediment load delivered by sub-watersheds that drain into the Missouri River between Garrison Dam and the city of Bismarck; the sediment load delivered from Garrison Dam was deemed to be insignificant. The total annual sediment load was estimated using all available flow and TSS measurements (1971–1981) at USGS 06342500 (Table 3–6) and a 10 percent adjustment to account for bedload (USGS, 1995). The total sediment load delivered from the sub-watersheds draining into the Missouri River between Garrison Dam and the city of Bismarck was estimated based on estimates provided in Table 5–2. This analysis resulted in a total instream erosion load of 4.7 million tons/year and accounts for 90 percent of the total sediment load produced between Garrison Dam and the City of Bismarck.

5.4 Summary of Sediment Loads in the Missouri River Within North Dakota

Based on the sediment load assessment conducted in Section 5.1, 5.2, and 5.3, the Yellowstone River and the Missouri River in Montana delivered the largest fraction of sediment loads to the main stem Missouri River in North Dakota. The Yellowstone River and the Missouri River in Montana accounted for more than 86 percent of the total delivered load whereas the watersheds within the study area (not including the Yellowstone River watershed) accounted only for approximately 4 percent of the total delivered load in North Dakota. Sediment load from instream erosion within the Missouri River accounted for more than 10 percent. Table 5–3 summarizes the sediment loads and their fractions.

TABLE 5–3.—SEDIMENT LOADS AND THEIR FRACTIONS IN THE MISSOURI RIVER, ND

Source	Estimated Sediment Load of the mainstem of the Missouri River within North Dakota (million tons/year)	Fraction of Total Delivered Sediment Load (percent)
Yellowstone River [1]	29.1	64.7
Missouri River from Montana [2]	9.5	21.1
Watersheds within the Study Area [3]	1.7	3.8
Instream Erosion within the Garrison Reach [4]	4.7	10.4
Total [5]	45.0	100.0

[1] Based on estimated sediment loads by USACE at USGS station 06185500 (Missouri River at Culbertson, Montana) and reduction of 30 percent.

[2] Based on estimated sediment loads by USACE at USGS station 06329500 (Yellowstone River at Sidney, Montana) and reduction of 30 percent.

[3] Based on 5 year average sediment load using GWLF; Includes all watersheds draining into the Missouri River in North Dakota except for the Yellowstone River.

[4] Based on the difference between the total annual sediment load at USGS 06342500 and the total delivered sediment load of the four sub-watersheds draining between Garrison Dam and the city of Bismarck.

[5] Sum of delivered sediment load to the mainstem of the Missouri River within North Dakota and produced sediment within the Garrison Reach (Missouri River mainstem between Garrison Dam and the City of Bismarck).

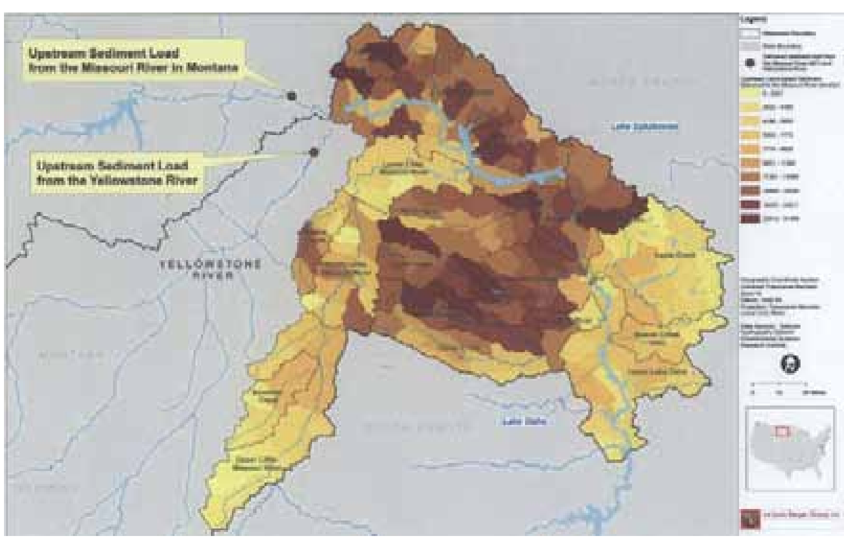


FIGURE 5–3.—*Thematic Map of the Sediments Delivered to the Missouri River*

6.0 LINKAGE BETWEEN AGGRADATION AREAS AND SEDIMENT SOURCES

The main stem of Missouri River located between the North Dakota—Montana state line and Lake Oahe was analyzed to determine whether the identified aggradation areas presented in Section 4 could be linked to sediment sources delivered from Montana and from 201 sub-watersheds in North Dakota presented in Section 5. Figure 6–1 shows the identified aggradation areas and delivered sediment to the main stem of the Missouri River from Montana and from each sub-watershed within the study area. The following conclusions can be drawn from this analysis.

—The majority of the identified aggradation areas were located upstream of Lake Sakakawea in the close vicinity to the Montana/North Dakota border and in the vicinity of watersheds that showed large amounts of delivered land-based sediments. It appears that the aggradation areas were predominantly caused by the delivered sediment loads from the Yellowstone River and the Missouri River in Montana when the proportions of estimated delivered sediment load are compared to each other (Table 5–3).

—The area between the city of Bismarck and Lake Oahe showed several aggradation areas with mostly low and moderate aggradation. Potential sources for sediment deposition were sediment erosion from instream erosion caused by hydropower at Garrison Dam and delivered land-based sediments from the Painted Woods Square Butts, Knife River, Heart River, and Cannonball River watersheds. The largest source of these aggradation areas are likely sediment deposits from eroded riverbed and riverbank sediments due to the impact of hydropower use at Garrison Dam.

—Areas that showed little or no aggradation were generally located within the center of the lakes (Lake Sakakawea and Lake Oahe) and in the stream reach between Garrison Dam and the city of Bismarck in which instream erosion dominates (90 percent of the total sediment load originates from instream erosion).

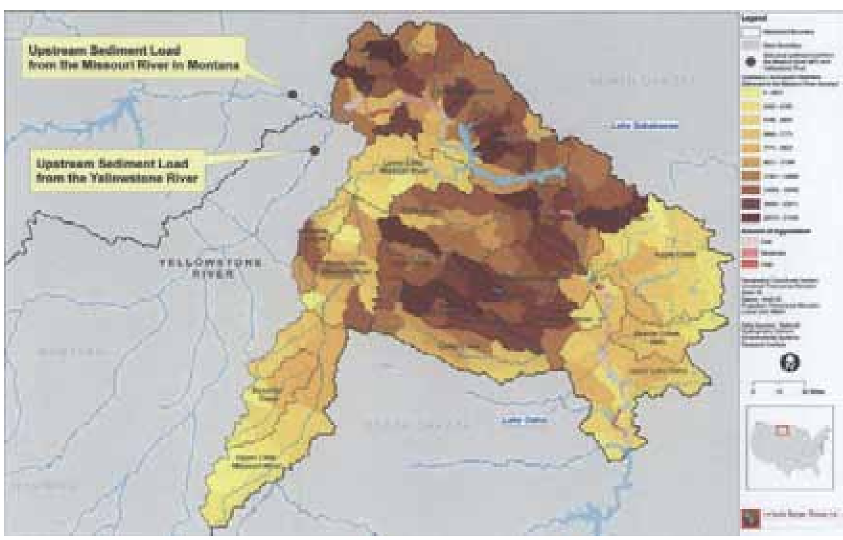


FIGURE 6–1.—*Sediment Aggradation Areas and Amount of Delivered Sediment from each Sub-watershed*

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EXHIBIT A

Table A–1 through A–18: Land Use Distribution for the Yellowstone River Watershed and each HUC8 Watersheds within the Study Area.

TABLE A–1.—LAND USE DISTRIBUTION OF THE YELLOWSTONE RIVER WATERSHED

NLCD Land Use Type	Hectare	Percent
Open Water	68,614	0.84
Developed, Open Space	49,780	0.61
Developed, Low Intensity	18,155	0.22
Developed, Medium Intensity	2,958	0.04
Developed, High Intensity	433	0.01
Barren Land (Rock/Sand/Clay)	127,428	1.56
Deciduous Forest	17,209	0.21
Evergreen Forest	1,323,268	16.17
Mixed Forest	4,332	0.05
Shrub	3,367,598	41.15
Grassland/Herbaceous	2,578,292	31.50
Pasture/Hay	211,442	2.58
Cultivated Crops	264,217	3.23
Woody Wetlands	84,425	1.03
Emergent Herbaceous Wetlands	57,212	0.70
Perennial Ice/Snow	8,417	0.10
Total	8,175,362	100.00

TABLE A–2.—LAND USE DISTRIBUTION OF THE LAKE SAKAKAWEA WATERSHED (HUC 10110101)

NLCD Land Use Type	Hectare	Percent
Open Water	151,781	8.90
Developed, Open Space	52,092	3.06
Developed, Low Intensity	5,018	0.29
Developed, Medium Intensity	591	0.03
Developed, High Intensity	107	0.010
Barren Land (Rock/Sand/Clay)	7,611	0.45
Deciduous Forest	37,138	2.18
Evergreen Forest	1,207	0.07
Mixed Forest	2,968	0.17

TABLE A–2.—LAND USE DISTRIBUTION OF THE LAKE SAKAKAWEA WATERSHED (HUC 10110101)—Continued

NLCD Land Use Type	Hectare	Percent
Shrub	23,126	1.36
Grassland/Herbaceous	639,752	37.52
Pasture/Hay	24,466	1.43
Cultivated Crops	705,176	41.36
Woody Wetlands	11,687	0.69
Emergent Herbaceous Wetlands	42,270	2.48
Total	1,704,993	100.00

TABLE A–3.—LAND USE DISTRIBUTION OF THE LITTLE MUDDY RIVER WATERSHED (HUC 10110102)

NLCD Land Use Type	Hectare	Percent
Open Water	3,452	1.46
Developed, Open Space	9,512	4.03
Developed, Low Intensity	377	0.16
Developed, Medium Intensity	29	0.01
Developed, High Intensity	3	....
Barren Land (Rock/Sand/Clay)	46	0.02
Deciduous Forest	232	0.10
Evergreen Forest	16	0.01
Mixed Forest	31	0.01
Shrub	3,303	1.40
Grassland/Herbaceous	51,703	21.89
Pasture/Hay	740	0.31
Cultivated Crops	161,623	68.44
Woody Wetlands	670	0.28
Emergent Herbaceous Wetlands	4,412	1.87
Total	236,148	100.00

TABLE A–4.—LAND USE DISTRIBUTION OF THE UPPER LITTLE MISSOURI RIVER WATERSHED (HUC 10110201)

NLCD Land Use Type	Hectare	Percent
Open Water	566	0.06
Developed, Open Space	3,960	0.45
Developed, Low Intensity	483	0.05
Developed, Medium Intensity	14	....
Developed, High Intensity	1	....
Barren Land (Rock/Sand/Clay)	1,729	0.19
Deciduous Forest	686	0.08
Evergreen Forest	30,083	3.39
Mixed Forest	1	....
Shrub	284,486	32.02
Grassland/Herbaceous	514,185	57.88
Pasture/Hay	1,710	0.19
Cultivated Crops	40,017	4.50
Woody Wetlands	4,165	0.47
Emergent Herbaceous Wetlands	6,316	0.71
Total	888,402	100.00

TABLE A–5.—LAND USE DISTRIBUTION OF THE BOXELDER CREEK WATERSHED (HUC 10110202)

NLCD Land Use Type	Hectare	Percent
Open Water	219	0.07

TABLE A–5.—LAND USE DISTRIBUTION OF THE BOXELDER CREEK WATERSHED (HUC 10110202)—Continued

NLCD Land Use Type	Hectare	Percent
Developed, Open Space	563	0.18
Developed, Low Intensity	130	0.04
Developed, Medium Intensity	....	....
Developed, High Intensity	....	....
Barren Land (Rock/Sand/Clay)	324	0.11
Deciduous Forest	218	0.07
Evergreen Forest	8,069	2.62
Mixed Forest	....	....
Shrub	82,732	26.84
Grassland/Herbaceous	197,962	64.21
Pasture/Hay	116	0.04
Cultivated Crops	14,232	4.62
Woody Wetlands	2,246	0.73
Emergent Herbaceous Wetlands	1,484	0.48
Total	308,294	100.00

TABLE A–6.—LAND USE DISTRIBUTION OF THE MIDDLE LITTLE MISSOURI RIVER WATERSHED (HUC 10110203)

NLCD Land Use Type	Hectare	Percent
Open Water	3,410	0.61
Developed, Open Space	7,332	1.30
Developed, Low Intensity	777	0.14
Developed, Medium Intensity	15	....
Developed, High Intensity	0.4	....
Barren Land (Rock/Sand/Clay)	7,542	1.34
Deciduous Forest	16,637	2.95
Evergreen Forest	8,621	1.53
Mixed Forest	2,288	0.41
Shrub	61,781	10.96
Grassland/Herbaceous	354,883	62.98
Pasture/Hay	13,986	2.48
Cultivated Crops	81,856	14.53
Woody Wetlands	3,475	0.62
Emergent Herbaceous Wetlands	921	0.16
Total	563,524	100.00

TABLE A–7.—LAND USE DISTRIBUTION OF THE BEAVER CREEK WATERSHED (HUC 10110204)

NLCD Land Use Type	Hectare	Percent
Open Water	278	0.12
Developed, Open Space	5,040	2.23
Developed, Low Intensity	675	0.30
Developed, Medium Intensity	73	0.03
Developed, High Intensity	4	....
Barren Land (Rock/Sand/Clay)	1,796	0.79
Deciduous Forest	2,926	1.29
Evergreen Forest	1,591	0.70
Mixed Forest	418	0.18
Shrub	14,944	6.60
Grassland/Herbaceous	112,922	49.87
Pasture/Hay	11,595	5.12
Cultivated Crops	71,494	31.58
Woody Wetlands	2,155	0.95
Emergent Herbaceous Wetlands	508	0.22
Total	226,420	100.00

TABLE A–8.—LAND USE DISTRIBUTION OF THE LOWER LITTLE MISSOURI RIVER WATERSHED (HUC 10110205)

NLCD Land Use Type	Hectare	Percent
Open Water	7,970	1.70
Developed, Open Space	3,635	0.78
Developed, Low Intensity	710	0.15
Developed, Medium Intensity	38	0.01
Developed, High Intensity	4	....
Barren Land (Rock/Sand/Clay)	15,876	3.39
Deciduous Forest	58,399	12.48
Evergreen Forest	9,763	2.09
Mixed Forest	5,671	1.21
Shrub	38,440	8.21
Grassland/Herbaceous	260,691	55.71
Pasture/Hay	9,011	1.93
Cultivated Crops	49,411	10.56
Woody Wetlands	4,990	1.07
Emergent Herbaceous Wetlands	3,330	0.71
Total	467,939	100.00

TABLE A–9.—LAND USE DISTRIBUTION OF THE PAINTED WOODS-SQUARE BUTTE WATERSHED (HUC 10130101)

NLCD Land Use Type	Hectare	Percent
Open Water	29,657	4.62
Developed, Open Space	24,365	3.79
Developed, Low Intensity	1,899	0.30
Developed, Medium Intensity	307	0.05
Developed, High Intensity	21	....
Barren Land (Rock/Sand/Clay)	813	0.13
Deciduous Forest	8,259	1.29
Evergreen Forest	52	0.01
Mixed Forest	53	0.01
Shrub	324	0.05
Grassland/Herbaceous	267,816	41.71
Pasture/Hay	58,377	9.09
Cultivated Crops	204,979	31.92
Woody Wetlands	17,615	2.74
Emergent Herbaceous Wetlands	27,564	4.29
Total	642,103	100.00

TABLE A–10.—LAND USE DISTRIBUTION OF THE UPPER LAKE OAHE WATERSHED (HUC 10130102)

NLCD Land Use Type	Hectare	Percent
Open Water	59,833	6.55
Developed, Open Space	19,825	2.17
Developed, Low Intensity	3,306	0.36
Developed, Medium Intensity	740	0.08
Developed, High Intensity	262	0.03
Barren Land (Rock/Sand/Clay)	2,429	0.27
Deciduous Forest	6,871	0.75
Evergreen Forest	125	0.01
Mixed Forest	82	0.01
Shrub	1,420	0.16
Grassland/Herbaceous	606,052	66.34
Pasture/Hay	38,323	4.19
Cultivated Crops	152,196	16.66
Woody Wetlands	9,059	0.99
Emergent Herbaceous Wetlands	13,036	1.43

TABLE A–10.—LAND USE DISTRIBUTION OF THE UPPER LAKE OAHE WATERSHED (HUC 10130102)—Continued

NLCD Land Use Type	Hectare	Percent
Total	913,559	100.00

TABLE A–11.—LAND USE DISTRIBUTION OF THE APPLE CREEK WATERSHED (HUC 10130103)

NLCD Land Use Type	Hectare	Percent
Open Water	71,174	7.95
Developed, Open Space	28,751	3.21
Developed, Low Intensity	2,643	0.30
Developed, Medium Intensity	706	0.08
Developed, High Intensity	189	0.02
Barren Land (Rock/Sand/Clay)	323	0.04
Deciduous Forest	344	0.04
Evergreen Forest	18	
Mixed Forest	23	
Shrub	523	0.060
Grassland/Herbaceous	509,259	56.87
Pasture/Hay	71,997	8.04
Cultivated Crops	172,864	19.30
Woody Wetlands	527	0.06
Emergent Herbaceous Wetlands	36,198	4.04
Total	895,537	100.00

TABLE A–12.—LAND USE DISTRIBUTION OF THE BEAVER OAHE WATERSHED (HUC 10130104)

NLCD Land Use Type	Hectare	Percent
Open Water	7,883	2.98
Developed, Open Space	8,631	3.26
Developed, Low Intensity	1,049	0.40
Developed, Medium Intensity	159	0.06
Developed, High Intensity	40	0.02
Barren Land (Rock/Sand/Clay)	270	0.10
Deciduous Forest	208	0.08
Evergreen Forest	2	
Mixed Forest		
Shrub	2,005	0.76
Grassland/Herbaceous	151,276	57.16
Pasture/Hay	27,906	10.54
Cultivated Crops	64,086	24.21
Woody Wetlands	225	0.08
Emergent Herbaceous Wetlands	933	0.35
Total	264,671	100.00

TABLE A–13.—LAND USE DISTRIBUTION OF THE KNIFE RIVER WATERSHED (HUC 10130201)

NLCD Land Use Type	Hectare	Percent
Open Water	1,827	0.28
Developed, Open Space	17,360	2.68
Developed, Low Intensity	1,578	0.24
Developed, Medium Intensity	199	0.03
Developed, High Intensity	44	0.01
Barren Land (Rock/Sand/Clay)	607	0.09
Deciduous Forest	8,573	1.32
Evergreen Forest	315	0.05
Mixed Forest	176	0.03
Shrub	5,291	0.82
Grassland/Herbaceous	371,983	57.34

TABLE A–13.—LAND USE DISTRIBUTION OF THE KNIFE RIVER WATERSHED (HUC 10130201)—Continued

NLCD Land Use Type	Hectare	Percent
Pasture/Hay	51,626	7.96
Cultivated Crops	181,352	27.95
Woody Wetlands	6,354	0.98
Emergent Herbaceous Wetlands	1,484	0.23
Total	648,771	100.00

TABLE A–14.—LAND USE DISTRIBUTION OF THE UPPER HEART WATERSHED (HUC 10130202)

NLCD Land Use Type	Hectare	Percent
Open Water	2,667	0.60
Developed, Open Space	16,584	3.73
Developed, Low Intensity	3,026	0.68
Developed, Medium Intensity	567	0.13
Developed, High Intensity	60	0.01
Barren Land (Rock/Sand/Clay)	1,095	0.25
Deciduous Forest	1,200	0.27
Evergreen Forest	56	0.01
Mixed Forest	45	0.01
Shrub	2,354	0.53
Grassland/Herbaceous	178,175	40.08
Pasture/Hay	45,944	10.33
Cultivated Crops	187,860	42.26
Woody Wetlands	4,584	1.03
Emergent Herbaceous Wetlands	349	0.08
Total	444,566	100.00

TABLE A–15.—LAND USE DISTRIBUTION OF THE LOWER HEART RIVER WATERSHED (HUC 10130203)

NLCD Land Use Type	Hectare	Percent
Open Water	2,296	0.54
Developed, Open Space	14,194	3.36
Developed, Low Intensity	1,538	0.36
Developed, Medium Intensity	271	0.06
Developed, High Intensity	31	0.01
Barren Land (Rock/Sand/Clay)	605	0.14
Deciduous Forest	6,180	1.46
Evergreen Forest	61	0.01
Mixed Forest	56	0.01
Shrub	915	0.22
Grassland/Herbaceous	217,000	51.30
Pasture/Hay	29,785	7.04
Cultivated Crops	141,800	33.52
Woody Wetlands	7,183	1.70
Emergent Herbaceous Wetlands	1,113	0.26
Total	423,027	100.00

TABLE A–16.—LAND USE DISTRIBUTION OF THE UPPER CANNONBALL RIVER WATERSHED (HUC 10130204)

NLCD Land Use Type	Hectare	Percent
Open Water	1,324	0.31
Developed, Open Space	14,097	3.33
Developed, Low Intensity	860	0.20

TABLE A–16.—LAND USE DISTRIBUTION OF THE UPPER CANNONBALL RIVER WATERSHED (HUC 10130204)—Continued

NLCD Land Use Type	Hectare	Percent
Developed, Medium Intensity	31	0.01
Developed, High Intensity	4	....
Barren Land (Rock/Sand/Clay)	332	0.08
Deciduous Forest	997	0.24
Evergreen Forest	108	0.03
Mixed Forest	17	....
Shrub	1,037	0.24
Grassland/Herbaceous	139,550	32.93
Pasture/Hay	57,497	13.57
Cultivated Crops	204,153	48.17
Woody Wetlands	3,103	0.73
Emergent Herbaceous Wetlands	718	0.17
Total	423,827	100.00

TABLE A–17.—LAND USE DISTRIBUTION OF THE CEDAR CREEK WATERSHED (HUC 10130205)

NLCD Land Use Type	Hectare	Percent
Open Water	1,453	0.32
Developed, Open Space	12,952	2.82
Developed, Low Intensity	564	0.12
Developed, Medium Intensity	8	....
Developed, High Intensity	2	....
Barren Land (Rock/Sand/Clay)	219	0.05
Deciduous Forest	662	0.14
Evergreen Forest	80	0.02
Mixed Forest	24	0.01
Shrub	891	0.19
Grassland/Herbaceous	194,924	42.49
Pasture/Hay	68,676	14.97
Cultivated Crops	174,620	38.07
Woody Wetlands	3,304	0.72
Emergent Herbaceous Wetlands	361	0.08
Total	458,741	100.00

TABLE A–18.—LAND USE DISTRIBUTION OF THE LOWER CANNONBALL RIVER WATERSHED (HUC 10130206)

NLCD Land Use Type	Hectare	Percent
Open Water	1,125	0.49
Developed, Open Space	3,709	1.60
Developed, Low Intensity	90	0.04
Developed, Medium Intensity	8	....
Developed, High Intensity	....	....
Barren Land (Rock/Sand/Clay)	240	0.10
Deciduous Forest	1,362	0.59
Evergreen Forest	42	0.02
Mixed Forest	23	0.01
Shrub	265	0.11
Grassland/Herbaceous	178,363	77.01
Pasture/Hay	8,062	3.48
Cultivated Crops	35,417	15.29
Woody Wetlands	2,186	0.94
Emergent Herbaceous Wetlands	707	0.31
Total	231,600	100.00

EXHIBIT B

Figure B–1 through B–7: Time Series of TSS and Flow at USGS Monitoring Stations at Boundary Stations and within the Missouri River in North Dakota.

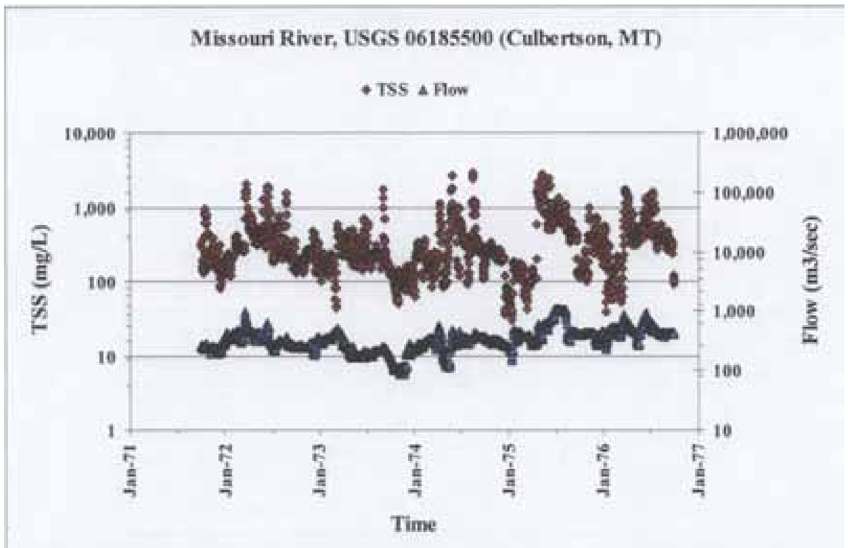

FIGURE B–1.—*TSS and Flow Measurements at USGS 06185500, Missouri River (Culbertson, MT)*

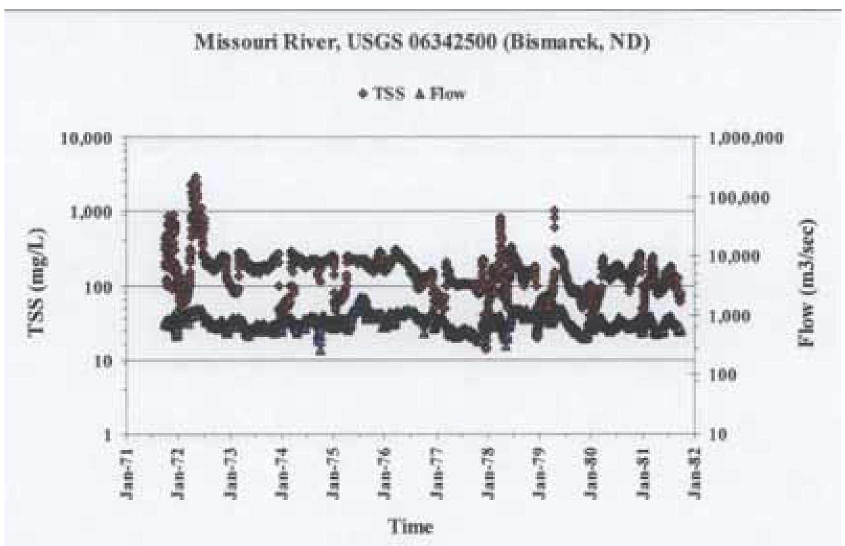

FIGURE B–2.—*TSS and Flow Measurements at USGS 06342500, Missouri River (Bismarck, ND)*

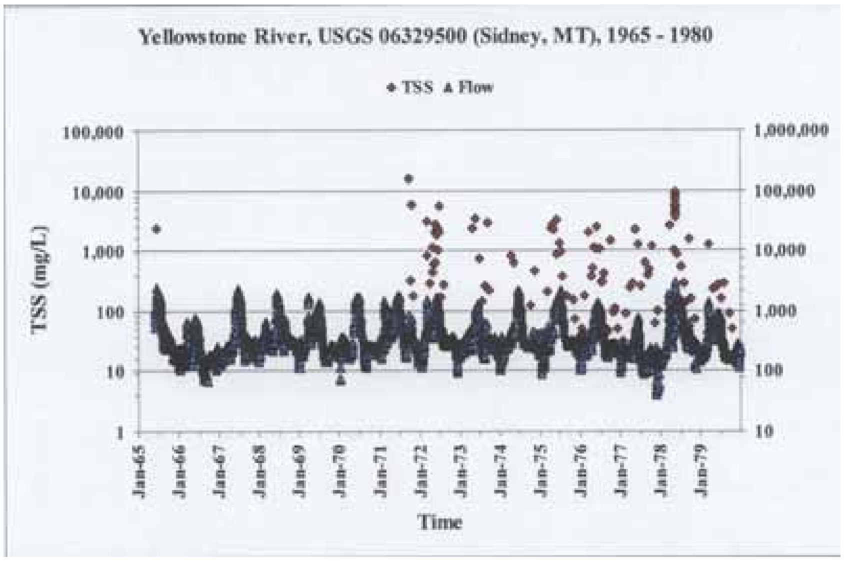

FIGURE B–3.—*TSS and Flow Meas. at USGS 06329500, Yellowstone River (Sidney, MT), 1965–1980*

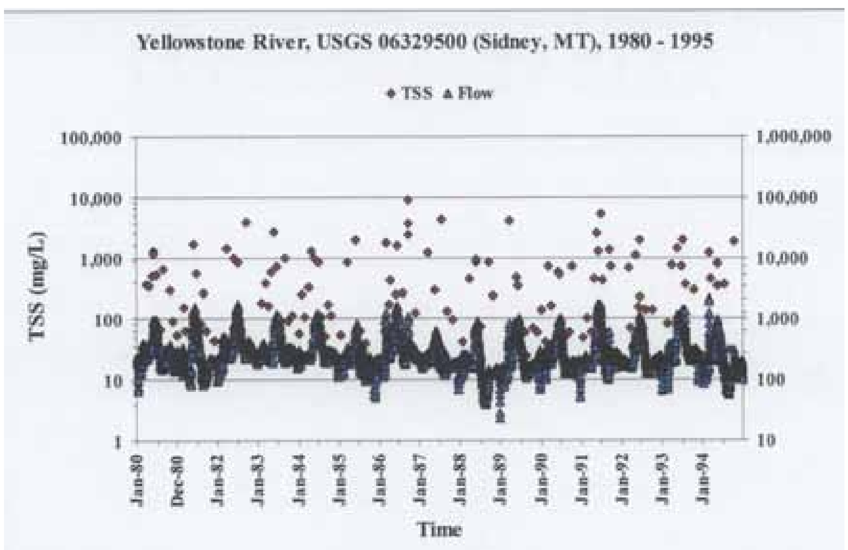

FIGURE B–4.—*TSS and Flow Meas. at USGS 06329500, Yellowstone River (Sidney, MT), 1980–1995*

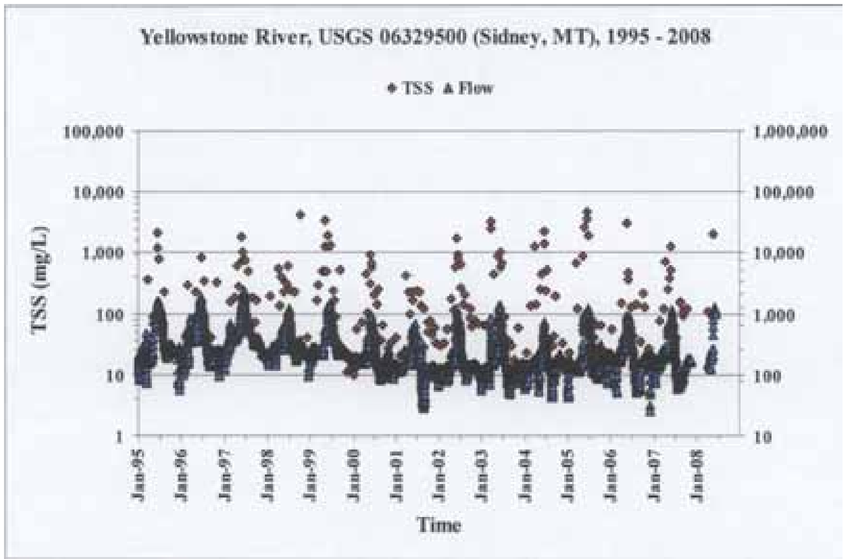

FIGURE B–5.—*TSS and Flow Measurements at USGS 06329500, Yellowstone River (Sidney, MT),1995–2008*

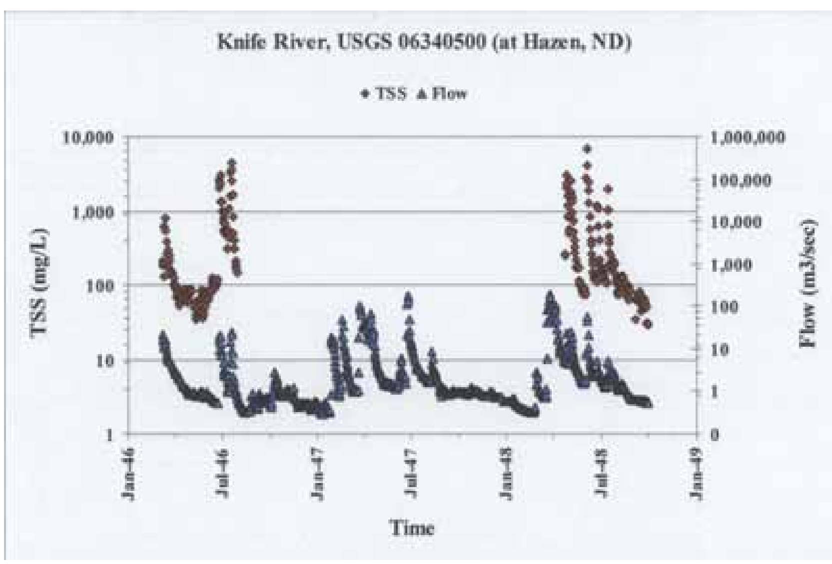

FIGURE B–6.—*TSS and Flow Measurements at USGS 06340500, Knife River (at Hazen, ND)*

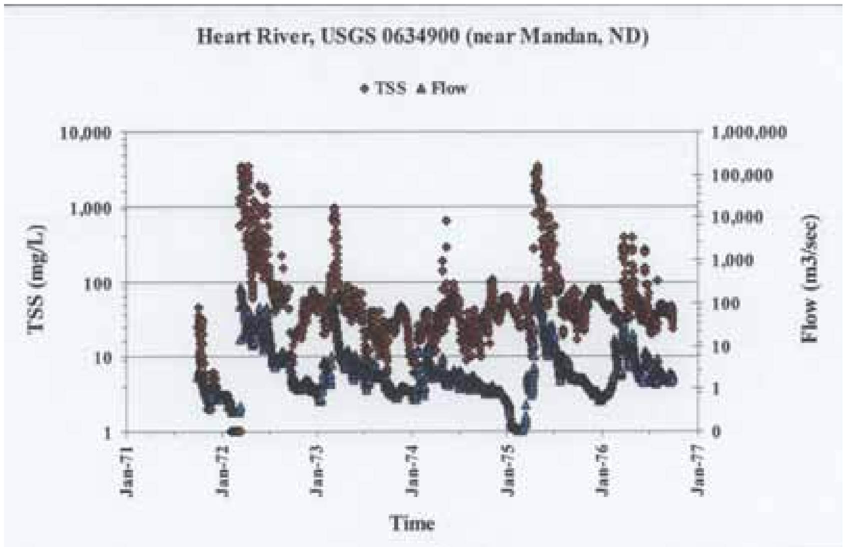

FIGURE B–7.—*TSS and Flow Measurements at USGS 0634900, Heart River (near Mandan, ND)*

APPENDIX B—ECONOMIC IMPACT OF SEDIMENTATION AND EROSION ALONG THE MISSOURI RIVER, NORTH DAKOTA

1.0 INTRODUCTION

The Louis Berger Group Inc. (Berger) was tasked by the U.S. Army Corps of Engineers (USACE) to assess impacts of sedimentation in the Missouri River Basin within the State of North Dakota. This assessment is intended to meet the level of effort defined in the Missouri River Protection and Improvement Act. The assessment has two objectives. First, Berger identified sources and deposit locations of sediment within the Missouri River Basin in the State of North Dakota, utilizing existing data and information. This task was completed in August (2008). Next, the team analyzed the potential impacts of sedimentation, using the results of Task 5A on important issues and resources including:

—Federal, tribal, State and Regional Economies;
—Recreation;
—Hydropower Generation;
—Fish and Wildlife;
—Flood Control; and
—Indian and Non-Indian Historical and Cultural sites.

Under this subtask the direct economic impacts associated with increased sedimentation and erosion along the Missouri River in the State of North Dakota were evaluated. The evaluation includes a qualitative discussion on whether or not the direct economic impacts are relevant in scale and location to Federal, tribal, State, and Regional economies. For instance, certain impacts may be very relevant to tribal or regional economies due to the location of impacts but may not be relevant at the State or national levels due to the size of the impact. Where possible, these distinctions will be made with direct economic impacts identified in this report.

Berger utilized an integrated approach to evaluate the economic impacts using the results of other tasks that evaluated the resources listed above. As such, results of other subtasks were important to the economic evaluation such as flood control, recreation, and hydroelectric generation. Thus the task leads worked closely together to properly identify and quantify, where possible, the potential impacts in a way that can be used to evaluate economic implications.

Louis Berger has identified potential impacts from erosion and sedimentation that may have economic impacts to Federal, tribal, State and Regional economies. These potential impacts were identified in the results of other subtasks as well as additional literature searches and interviews with subject matter experts. The potential impacts would be associated with the following resources or activities including:

—Land Use
—Coal-Fired Power Production
—Hydropower Production
—Recreation
—Water Supply Intakes
Each of these potential impacts is discussed below.

2.0 LAND USE

The initial assumption used for this analysis is that local land use near or adjacent to the Missouri River can be impacted by fluvial geomorphic changes, including rapid aggregation and erosion of riparian lands, and that these changes would lead to complications for landowners. The evaluations to date show that land uses most likely to be impacted by erosion and sedimentation include agricultural uses (grasslands and pasture, cultivated crops) and small areas of development. The developed areas are near the cities of Williston and Bismarck.

2.1 Agriculture

To evaluate sedimentation impacts to agricultural lands, Berger first evaluated the land uses within the aggradation areas identified in Task 5A. The GIS layers for the aggradation areas were over laid on agricultural acreage published by the U.S. Department of Agriculture.[1] The land use categories were sorted to include only those uses that were thought to be in agriculture production. Thus, areas identified as "wetlands" were removed from the analysis. The results provided a summary of potential agricultural land uses that may be impacted by sedimentation along the Missouri River. Table 2–1 summarizes the acreage by county and level of impact and shows that in total approximated 43,000 agricultural acres fall within the aggradations areas. This total distribution of acreage includes 37 percent in low impact areas (16,000), 59 percent in medium impact areas (25,600) and 4 percent (1,600) in high impact areas.

TABLE 2–1.—ESTIMATED AGRICULTURAL ACREAGE WITHIN THE AGGRADATION AREAS ALONG THE MISSOURI RIVER IN NORTH DAKOTA

County	Level of Impact			Total
	Low	Medium	High	
Williams	3,560	11,947	211	15,717
McKenzie	3,162	1,066	182	4,411
Mountrail	902	294	....	1,196
Dunn	6	....	....	6
Oliver	....	7,172	....	7,172
Morton	376	663	508	1,547
Sioux	5,539	1,020	....	6,558
McLean	73	264	....	337
Burleigh	373	751	717	1,841
Emmons	2,135	2,420	....	4,555
Total	16,126	25,596	1,618	43,339

Table 2–2 through Table 2–11 shows a further breakdown of agricultural land use types impacted within each county.

TABLE 2–2.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—WILLIAMS COUNTY

Crop Type	Level of Impact Area			Total
	Low	Medium	High	
Alfalfa	680	331	5	1,016
Barley	128	976	....	1,104
Canola	4	58	1	62
Corn	8	757	....	764
Clover/Wildflowers	1	2	....	3
Durum Wheat	74	1,609	5	1,688
Fallow/Idle Cropland	32	255	1	288

[1] USDA National Agricultural Statistics Service (NASS) Cropland Data Layer for Midwestern/Prairie States, 2007.

TABLE 2–2.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—WILLIAMS COUNTY—Continued

Crop Type	Level of Impact Area			Total
	Low	Medium	High	
Flaxseed	....	30	....	30
Herbaceous Grassland	2,301	4,831	190	7,322
Lentils	1	561	4	566
Misc. Vegs. And Fruits	....	7	....	7
Oats	4	13	1	18
Peas	8	475	4	486
Potatoes	....	215	....	215
Safflower	3	3	1	7
Soybeans	....	6	....	6
Spring Wheat	124	1,187	1	1,311
Sugar beets	164	406	....	570
Sunflowers	2	152	....	153
Winter Wheat	26	73	....	100
Total	3,560	11,947	211	15,717

TABLE 2–3.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—MCKENZIE COUNTY

Crop Type	Level of Impact			Total
	Low	Medium	High	
Alfalfa	335	2	....	337
Barley	25	4	1	29
Canola	7	2	....	9
Corn	11	17	4	32
Clover/Wildflowers	2	....	....	2
Dry Beans	....	1	....	1
Durum Wheat	84	17	....	101
Fallow/Idle Cropland	102	3	....	105
Flaxseed	2	1	....	2
Herbaceous Grassland	2,428	993	174	3,595
Lentils	2	....	....	2
Millet	1	1	....	2
Misc. Vegs. And Fruits	1	....	....	1
Oats	6	....	....	6
Peas	26	....	....	26
Safflower	5	1	....	6
Sunflowers	4	....	....	4
Spring Wheat	118	20	3	141
Sugar beets	2	3	....	4
Winter Wheat	2	2	1	5
Total	3,162	1,066	182	4,411

TABLE 2–4.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—MOUNTRAIL COUNTY

Crop Type	Level of Impact			Total
	Low	Medium	High	
Barley	17	....	....	17
Canola	1	1	....	3
Durum Wheat	10	....	....	10
Fallow/Idle Cropland	1	....	....	1
Herbaceous Grassland	772	290	....	1,062
Flaxseed	1	....	....	1
Oats	1	....	....	1
Peas	5	1	....	6
Spring Wheat	14	1	....	15
Sunflowers	1	....	....	1

TABLE 2–4.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—MOUNTRAIL COUNTY—Continued

Crop Type	Level of Impact			Total
	Low	Medium	High	
Winter Wheat	81	....	....	81
Total	902	294	....	1,196

TABLE 2–5.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—DUNN COUNTY

Crop Type	Level of Impact			Total
	Low	Medium	High	
Herbaceous Grassland	6	....	....	6
Total	6	....	....	6

TABLE 2–6.—AGRICULTURAL LAND WITHIN THE AGGRADATION AREAS—MCLEAN COUNTY

Crop Type	Level of Impact			Total
	Low	Medium	High	
Alfalfa	....	9	....	9
Barley	1	1	....	2
Canola	....	1	....	1
Corn	....	7	....	7
Dry Beans	....	21	....	21
Durum Wheat	....	1	....	1
Herbaceous Grassland	71	220	....	291
Other Small Grains	....	2	....	2
Safflower	....	1	....	1
Spring Wheat	1	2	....	4
Total	73	264	....	337

TABLE 2–7.—AGRICULTURAL LAND WITHIN THE AGGRADATION AREAS—OLIVER COUNTY

Crop Type	Level of Impact			Total
	Low	Medium	High	
Alfalfa	....	444	....	444
Barley	....	73	....	73
Canola	....	23	....	23
Corn	....	2,141	....	2,141
Dry Beans	....	61	....	61
Durum Wheat	....	16	....	16
Fallow/Idle Cropland	....	11	....	11
Flaxseed	....	32	....	32
Herbaceous Grassland	....	2,450	....	2,450
Millet	....	1	....	1
Oats	....	19	....	19
Peas	....	33	....	33
Safflower	....	1	....	1
Sorghum	....	4	....	4
Soybeans	....	19	....	19
Spring Wheat	....	1,644	....	1,644
Sugar beets	....	1	....	1
Sunflowers	....	196	....	196
Winter Wheat	....	3	....	3
Total	....	7,172	....	7,172

TABLE 2–8.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—MORTON COUNTY

Crop Type	Level of Impact			Total
	Low	Medium	High	
Alfalfa	15	26	31	73
Barley	1	2	27	31
Corn	26	8	45	80
Fallow/Idle Cropland	6	....	1	7
Herbaceous Grassland	312	617	355	1,284
Oats	....	....	1	1
Spring Wheat	12	8	12	32
Sunflowers	4	....	2	5
Winter Wheat	....	....	34	34
Total	376	663	508	1,547

TABLE 2–9.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—BURLEIGH COUNTY

Crop Type	Level of Impact			Total
	Low	Medium	High	
Alfalfa	2	2	2	6
Barley	2	3	1	5
Canola	....	....	1	1
Corn	....	4	4	8
Dry Beans	....	....	....	....
Fallow/Idle Cropland	....	....	3	3
Herbaceous Grassland	369	671	694	1,735
Oats	....	5	....	5
Peas	....	1	2	2
Soybeans	....	....	....	....
Spring Wheat	....	64	11	75
Winter Wheat	....	1	....	1
Total	373	751	717	1,841

TABLE 2–10.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—EMMONS COUNTY

Crop Type	Level of Impact			Total
	Low	Medium	High	
Alfalfa	7	1	....	8
Barley	7	3	....	10
Canola	1	1	....	2
Corn	8	....	....	8
Dry Beans	5	....	....	5
Fallow/Idle Cropland	5	5	....	10
Herbaceous Grassland	2,013	2,377	....	4,390
Oats	1	2	....	2
Potatoes	27	....	....	27
Soybeans	1	....	....	1
Spring Wheat	48	23	....	71
Sunflowers	12	....	....	12
Winter Wheat	1	8	....	9
Total	2,135	2,420	....	4,555

TABLE 2–11.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—SIOUX COUNTY

Crop Type	Level of Impact			Total
	Low	Medium	High	
Alfalfa	177	87	....	264

TABLE 2–11.—AGRICULTURAL LAND USES WITHIN THE AGGRADATION AREAS—SIOUX COUNTY—Continued

Crop Type	Level of Impact			Total
	Low	Medium	High	
Barley	57	26	....	83
Canola	2	4	....	6
Corn	721	6	....	727
Durum Wheat	....	....	....	....
Fallow/Idle Cropland	7	....	....	7
Flaxseed	1	....	....	1
Herbaceous Grassland	4,234	853	....	5,087
Millet	....	1	....	1
Oats	49	....	....	49
Peas	....	1	....	1
Soybeans	4	3	....	7
Spring Wheat	223	29	....	252
Sunflowers	43	10	....	54
Winter Wheat	20	....	....	20
Total	5,539	1,020	....	6,558

While the total acreage within each impact magnitude category and land use was identified, it is uncertain how these different areas would be impacted by sedimentation on an annual basis. For instance, it is possible that acreage within a low impact area would only be impacted during an extreme flood event. It is likely that acreage within medium and high impact areas would be impacted more often than acreage in low impact areas. Because of this uncertainty, it is impossible to estimate the economic impact on agricultural production from sedimentation. However, data was collected on the productivity, prices and returns by land use to gain an understanding of the importance of these areas to Federal, tribal, State and regional agricultural industries and economies.

To estimate average economic returns from acreage within sedimentation impact areas, certain assumptions were needed regarding agricultural operations. For instance, herbaceous grasslands were assumed to be used for cattle operations (e.g. cow/calf). Cultivated crop production was assumed to follow the lands uses identified in the GIS layer. Berger then collected average productivity, crop and livestock prices, and average returns on labor and management from the National Agricultural Statistical Agency and the North Dakota Agricultural Extension Agency.[2] These values were used in combination with acreage estimates to estimate annual revenues and returns.

Table 2–12 shows the estimates of average total annual revenue and returns for acreage within each county that may be impacted by sedimentation. For all 43,300 acres, average annual revenue was estimated to be $13.5 million and annual returns were estimated to $970,000.

TABLE 2–12.—ESTIMATED ANNUAL REVENUES AND RETURNS TO AREAS POTENTIALLY IMPACTED BY SEDIMENTATION

County	Total Impacted Acreage	Total Revenue	Total Returns
Williams	15,717	$5,071,164	$501,793
McKenzie	4,411	1,358,325	132,906
Mountrail	1,196	395,671	25,236
Dunn	6	2,018	([1])
Oliver	7,172	1,724,668	112,531
Morton	1,547	493,904	3,546
Sioux	6,558	2,080,086	98,887
McLean	337	113,187	1,736
Burleigh	1,841	626,123	−77

[2] Where possible, 2009 Projected Crop Budgets published by the North Dakota Extension Agency were used to estimate average revenue per acre and returns per acre. For crops that did not have a projected budget (e.g. sugar beets, potatoes) data on average productivity and prices were obtained for the National Agricultural Statistical Service for North Dakota.

TABLE 2–12.—ESTIMATED ANNUAL REVENUES AND RETURNS TO AREAS POTENTIALLY IMPACTED BY SEDIMENTATION—Continued

County	Total Impacted Acreage	Total Revenue	Total Returns
Emmons	4,555	1,609,779	102,561
Total	43,339	13,474,924	979,119

[1] NA.

According to the U.S. Bureau of Economic Analysis, value added produced by Agriculture, Forestry, Fishing and Hunting in 2007 was $2.1 billion for North Dakota. Comparing the estimated revenue from the potential impacted areas with the value added for the entire State from these industries, indicates the areas are a relatively small contributor to the industry and the State economy (less than 1 percent) as a whole. However, if increased sedimentation were to cause these areas to be removed from production, it would likely have a measurable impact on local communities, tribes and counties. This is especially true for counties with the large percentage of potentially impacted acreage (Williams, Sioux, Oliver and Emmons).

It is noted here that the impacts discussed above are not related to lands already part of the flowage easements that have been purchased by the USACE. In 1996, Congress passed Public Law 104–303, which required the Federal Government to purchase flowage and saturation easements from willing sellers within the Buford-Trenton Irrigation District located on the headwaters of the Garrison Dam/Lake Sakakawea project and southwest of Williston, North Dakota. According to the Garrison Dam/Lake Sakakawea Master Plan, published in December 2007, acquisition of flowage easements in the Buford-Trenton Irrigation District is nearly complete. The total flowage easement acreage was approximately 11,750.[3] While individual owners were compensated for these easements, the State of North Dakota, county and local governments will continue to be impacted by the loss in tax base into the future due to the Federal acquisition of these easements.

The analysis discussed above was only able to examine areas that may be impacted by increased sedimentation. There are other agricultural areas along the river that will also be affected by erosion. Stream bank erosion results in the permanent loss of flood plain land, leading to a loss of production for individual land owners. Louis Berger was unable to quantify the magnitude of this impact at this time given the availability of information and data.

2.1.1. High Water Tables

Berger has discovered that sedimentation may be impacting agricultural lands near Williston due higher water tables. These impacts may be causing additional acreage to go out of production. While there is antidotal evidence of this impact, no studies were located which evaluate the issue in detail.

2.1.2. Potential Increased Flooding in Developed Areas

Berger completed an evaluation of the potential impacts of sedimentation on flood control associated with the Missouri River in North Dakota. The analysis only included a review of Flood Insurance Studies (FIS) prepared by the Federal Emergency Management Agency (FEMA) for the Bismarck, North Dakota area to analyze changes in water surface elevation and its affects on flooding. At this time, new flood data has not been generated for significant portion of the Missouri River. The exception is Williams County near the city of Williston which is now being developed. Due to the lack of new flood data all along the Missouri River, the analysis was limited to the areas where historic and current flood data were available, particularly the areas surrounding the city of Bismarck.

Sedimentation in the reach between the Garrison Dam and Lake Oahe has resulted in increased risk of flooding in the downstream reach between the dam and the headwater of Lake Oahe. Because of this sediment aggradation, the impact of ice dams on seasonal flooding is increasing. As a means to counter this impact, careful sequenced water releases during the winter months are made to decrease the potential for flooding caused by ice effects. Water releases from the Garrison Dam are also used to provide flood control during other seasons as well.

[3] USACE, Omaha District, Garrison Dam/Lake Sakakawea Master Plan with Integrated Programmatic Environmental Assessment, Missouri River, North Dakota, Update of Design Memorandum MGR–107D, December 14, 2007.

Analysis of floodplain maps for the 1985 and 2005 Flood Insurance Study (FIS) for the city of Bismarck and parts of Burleigh County indicated that the area of the 100-year floodplain has increased by nearly 28.6 percent within Burleigh County (Table 2–13). This may be attributed to areas with high aggradation and/or the natural morphology of the river changing and/or restricting the channel's ability to convey the flow associated with a particular storm event.

TABLE 2–13.—FLOODPLAIN AREA COMPARISON

Burleigh County	Bismarck City Limits
1985 100-year Floodplain—28 mi^2	1985 100-year Floodplain—2.7 mi^2
2005 100-year Floodplain—36 mi^2	2005 100-year Floodplain—3.6 mi^2

mi^2 = square miles

In urban areas such as Bismarck and Mandan, flood plain development restricts the Missouri River's ability to accommodate increases flows during certain storm events (e.g. river channel has no room to widen without affecting properties). Aggradation in this area of the river compounds the problem resulting in an increase risk of flooding and the loss of property. Potential buyouts due to flooding concerns in the Bismarck-Mandan area are estimated at over $100 million.[4] The impact of flooding is estimated to be greatest between RM 1300 and 1316, i.e., in downtown Bismarck and Mandan.[5] Flooding also occurs outside of urbanized areas, affecting cropland and causing soil erosion.

Property owners whose property now lies within the expanded flood plain may also be impacted by a decline property values and increased insurance cost. Homes, businesses, and agricultural land are among the types of properties most heavily affected by an increase in the 100-year flood plain.

FEMA manages the National Flood Insurance Program (NFIP) which insures buildings and structures against flood damage. As a result of changes in the Flood Insurance Rate Map, all entities requiring a mortgage for structures on property within the 100-year floodplain will be required to purchase insurance under the NFIP. Owners of buildings must purchase insurance against damages to the structure of the building itself and also against damages to the contents of any floors below flood level that would be inundated in the event of a 100-year flood. Owners may purchase a basic level of coverage or increase coverage for an additional cost. The cost of the insurance is based on the area of the building (square feet). The insurance rate per square foot is dependent on the building's characteristics, on the date of construction of the building, and on the "flood zone" that the building is located in.

There are four different types of buildings covered under NFIP:

—Non-residential
—Single-family dwellings
—Condominiums
—2–4 family dwellings

Each building type has a different flood insurance rate depending on the zone where it is located as delineated in FEMA's Flood Insurance Rate Map (FIRM). It appears that areas impacted by the new delineation will be designated as either in FEMA's Zone B or Zone C.

Table 2–15 summarizes the insurance costs per square foot for buildings of various types located within FEMA's Zone C. This table is based on the FEMA's Flood Insurance Manual.[6] At this time, it is unknown the exact number, type or square footage of structures that may be required to purchase flood insurance. However, an evaluation of GIS data[7] provided by the city of Bismarck associated with the 1985 and 2005 Flood Insurance Study indicates that the number of structures within the floodplain has declined (Table 2–14). This indicates that the number of individuals or entities that would be subject to flood insurance may have actually declined in this area even with an increase in the size of the 100-year floodplain.

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[4] Remus, John, Personal Communication, November, 2008.

[5] FEMA. *Flood Insurance Study—Burleigh County, North Dakota and Incorporated Areas.* FIS Number 3801 5CV000A. Federal Emergency Management Agency, July 2005.

[6] FEMA. National Flood Insurance Program, Flood Insurance Manual, May 2008, Revised October 2008. Accessed at http://www.fema.gov/pdf/nfip/manual200810/cover__102008.pdf.

[7] The city of Bismarck provided GIS layers showing building foot prints, the 1985 flood plain and the 2005 flood plain that was used for this analysis.

TABLE 2–14.—BUILDINGS WITHIN FLOOD PLAIN AREAS IN 1985 AND 2005 IN BISMARCK

1985 Flood Plain	2005 Flood Plain
1341 buildings (86 acres)	1332 buildings (78 acres)

To gain an understanding of how individual property owners may be impacted by flood insurance, a simple example was developed to demonstrate the magnitude of flood insurance costs. Assume a single family unit of 1,500 square feet in size without a basement is located within the floodplain. Basic coverage would cost $1,170 for building coverage and $1,800 for contents on an annual basis.

As mentioned earlier, properties within the expanded flood plain are also likely to realize a decline in property value. At this time, it is not possible to quantify the potential decline in property values that may occur under this scenario.

TABLE 2–15.—ANNUAL INSURANCE RATES PER SQUARE FOOT FOR $100 IN COVERAGE FOR BUILDINGS IN ZONE C (BASIC/ADDITIONAL)

Occupancy	Single Family		2–4 Family		Other Residential		Non-Residential	
	Building	Contents	Building	Contents	Building	Contents	Building	Contents
Building Type:								
No Basement/Enclosure	.78/.21	1.20/.37	0.78/0.21		0.74/0.21		0.74/0.21	
With Basement	.89/.30	1.36/.43	0.89/0.30		0.95/0.30		0.95/0.30	
With Enclosure	.89/.34	1.36/.49	0.89/0.34		0.95/0.34		0.95/0.34	
Manufactured (Mobile) Home	.78/.38	1.20/.37					0.95/0.39	
Contents Location:								
Basement & Above				1.53/0.56		1.53/0.56		1.58/0.61
Enclosure & Above				1.53/0.65		1.53/0.65		1.58/0.73
Lowest Floor Only—Above Ground Level				1.20/0.59		1.20/0.59		0.97/0.43
Lowest Floor Above Ground Level and Higher Floors				1.20/0.37		1.20/0.37		0.97/0.31
Above Ground Level—More than One Full Floor				0.35/0.12		0.35/0.12		0.22/0.12
Manufactured (Mobile) Home								0.85/0.53

Source: FEMA, 2008.

3.0 COAL-FIRED POWER GENERATION FACILITIES

Berger has identified seven coal-fired power generation facilities in North Dakota that may be impacted by sedimentation or erosion along the Missouri River. Figure 3–1 shows the location of these facilities relative to the sediment load map produced in the Sedimentation Report. Berger completed a series of interviews with managers at some of the facilities to gain knowledge on the potential impacts to their operations from sedimentation or erosion. Table 3–1 provides a summary of the plants, location, generation capacity, operator and a summary of impacts identified in the interviews.

From these interviews, Berger learned the following regarding potential impacts. Thermoelectric power plants have two dominate uses for water to conduct basic operations: steam creation for driving turbines and water for condensing steam back to water, with the latter constituting the highest volume of water use. Problems incurred at facilities with once through cooling[8] from high sedimentation levels include degradation and plugging of the tubes and tube sheets in condensers, degradation of mechanical pumps and decreasing thermal efficiency. Associated impacts include having to reduce power production and more frequent maintenance. This can reduce the life span of mechanical pumps from 10 years to 7 years due to sedimentation requiring plants to obtain new, more expensive equipment increasing their costs. Many of those interviewed believe that larger costs are associated with the loss in capacity to generate electricity. This can lead to a reduction in revenue in the millions over the lifetime of the facility. In addition, sediment issues can necessitate additional maintenance over the life of the plant.

To gain an understanding of the cost of lost energy production from thermal electric plants due to sedimentation issues, Berger was able to obtain some actual data from one of the facilities over the course of 8 months. The operator provided data on the reductions in capacity due to issues related to condensers. Reductions in capacity were due to the following:

—Debris in the condenser causing a decline in efficiency;

—Large ice dams during the winter months at the intake reducing inlet flows to the pumps;

—Low river levels; and

—River temperatures (Upper Thermal Discharge limitations).

[8] Thermal electric plants may either have a once through or closed loop cooling system. Once through systems can realize a reduction in thermal efficiencies from sedimentation. Closed cooling processes have potential withdrawal impacts as well as higher costs associated with water treatment.

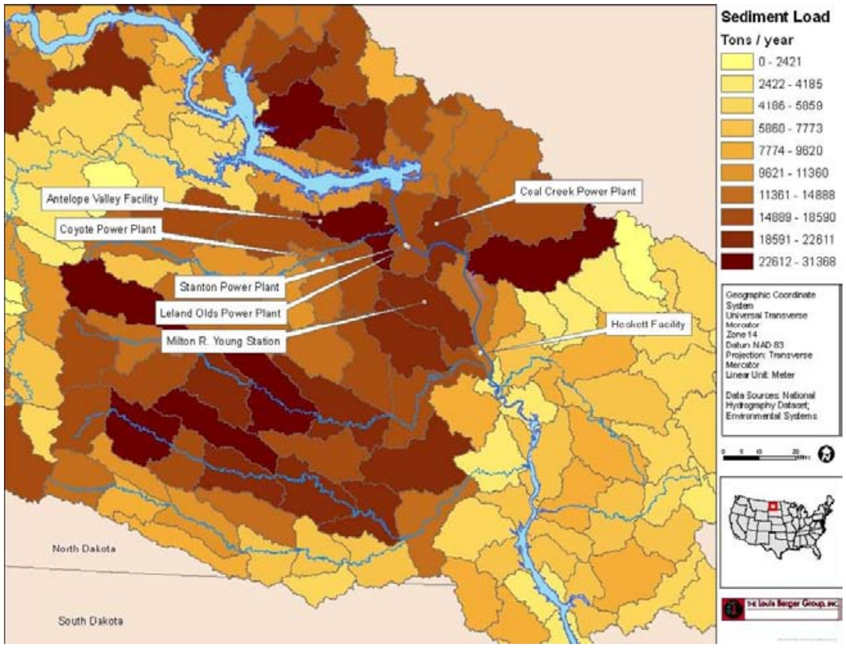

FIGURE 3–1.—*Location of Coal Fired Power Plants in North Dakota*

TABLE 3–1.—IMPACTS OF SEDIMENTATION AND EROSION TO COAL-FIRED POWER PLANTS NEAR THE MISSOURI RIVER IN NORTH DAKOTA

Power Plant	Location	Electric Generation Capacity	Operator	Issues Related to Sedimentation
Antelope Valley	Beulah	Unit 1: 43 8mw; Unit 2: 438mw	Basin Electric Power Co-op	Water withdrawals come from Sakakawea Reservoir (150 feet deep). No direct sedimentation impacts. Higher turbidity in the reservoir lead to higher water treatment costs because of a closed cooling process is employed. Potential sedimentation impacts to water withdrawals but no impact to plant efficiencies.
Coal Creek	Underwood	Unit 1: 550mw; Unit 2: 550mw	Great River Energy Co-op	Higher turbidity in water source will cause an increase in water treatment costs because of a closed cooling process is employed. Potential sedimentation impacts to water withdrawals but no impact to plant efficiencies.
Leland Olds	Stanton	Unit 1: 216mw; Unit 2: 440mw	Basin Electric Power Co-op	Missouri River provides once through cooling. The performance of the condensers can be adversely affected by the build-up of sediment, scale, corrosion or biological growth inside the tubes. Erosion can affect mechanical pumps. etc. Impacts can lead to a decrease in thermal efficiency and requires a reduction in electrical generation.
Coyote	Beulah	Unit 1: 4 14mw	Otter Tail Corp	Coyote is not a once through system; pump to secondary pond then from pond to plant. Siltation affects condensers, pumps and pipelines that bring water to the plant. Sedimentation impacts on condensers can cause millions of dollars in maintenance and replacement costs. For a 50 year plant, sediment issues can necessitate maintenance to occur once or twice over the 50 year lifetime. Sediment can also plug the river intake itself, which is an issue at this plant from time to time. If output from dam falls below 11,000 cfs, intakes will silt in.
Milton R. Young	Center	Unit 1: 257mw; Unit 2: 454mw	Minnkota Power Co-op	Missouri River is the main source of surface water. Water removed from river is diverted to stand-alone man-made lake for once through cooling.
Stanton	Stanton	Unit 1: 170mw	Great River Energy Co-op	Missouri River provides once through cooling.
Heskett Station	Mandan	Unit 1: 25mw; Unit 2: 75mw	Montana Dakota Utilities Co	Missouri River provides once through cooling.

Berger evaluated the data and selected occurrences that were most likely tied to increases in sedimentation. The results are summarized in Figure 3–2. Over the 8 month period, this facility lost over 13,000 MWh in electricity generation due to sedimentation issues. To evaluate the value of this reduction in capacity, Berger utilized wholesale electricity rates published by the Energy Information Agency for the Cinergy Hub during 2008 (EIA, 2008).

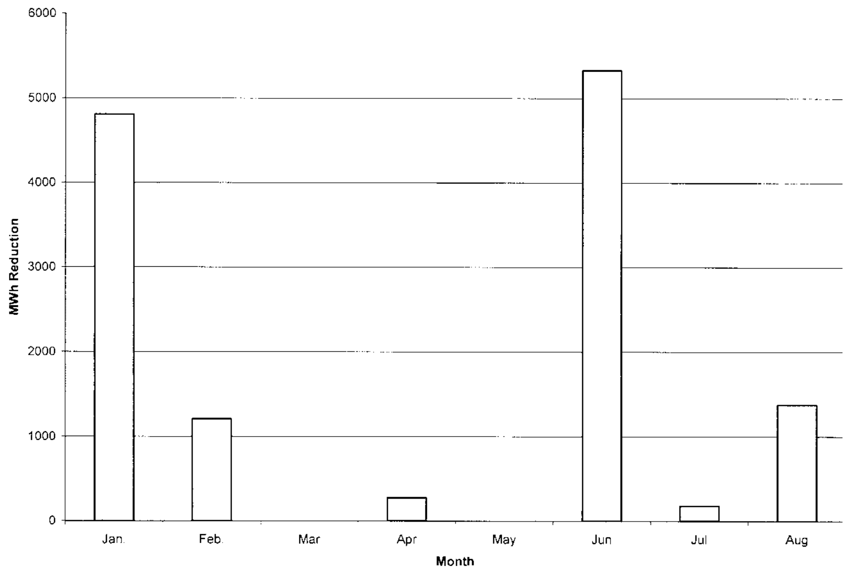

FIGURE 3–2.—*Loss in Capacity (MWh) due to Sedimentation*

Weekly weighted average wholesale prices were used to estimate an average monthly price used in the analysis as summarized in column three of Table 3–2. The average monthly price was applied to the decrease in capacity that may be due to increased sedimentation for this particular facility. It is assumed that this facility would either experience a reduction in revenue with a decrease in capacity or would need to purchase electricity from the wholesale market to meet contract obligations. This would likely either result in a loss in sales or an increase in cost to the operator. Table 3–2 represents an estimated value in the loss of this capacity based on the assumptions listed above over an 8 month period.

TABLE 3–2.—ESTIMATED VALUE OF LOST POWER PRODUCTION CAPACITY DUE TO SEDIMENTATION

Month	MWh Reduction	Wholesale Price Per MWh	Energy Value
Jan	4,808	$45.17	$217,139
Feb	1,207	78.00	94,120
Mar		67.67	
Apr	274	73.06	20,018
May		61.50	
Jun	5,333	53.70	286,400
Jul	181	93.42	16,862
Aug	1,374	64.00	87,931
Total	13,176		722,470

4.0 HYDROPOWER

Hydropower facilities along the Missouri River in North Dakota consist of the Garrison Dam and its reservoir, Lake Sakakawea. In addition, hydropower operations in North Dakota are affected by the operation of Oahe Dam in South Dakota because Lake Oahe extends into southern North Dakota up to just south of the city of Bismarck when the pool is full. Louis Berger completed an evaluation of the potential impacts to hydropower generation at the Garrison facility. The results indicate the only measurable impact of sedimentation on hydropower generation at this time is a loss in power production during the colder months of the year due to increased flooding risks. This section will evaluate the economic implications of this loss in power production.

Outflows from Lake Sakakawea at Garrison Dam are commonly through the power facilities. The power facilities have a normal capacity of 38,000 cfs and a maximum capacity of 41,000 cfs.[9] The average outflow is 22,800 cfs, resulting in an annual plant factor of approximately 60 percent. The Garrison Dam has a five unit power plant with a generating capacity 583.3 MW. This reflects a recent upgrade from previously 518 MW (USACE, 2006).

The benefits of the hydropower facilities along the Missouri River consist of providing dependable energy to meet annual peak power demands of the region. Energy generated by these facilities have valuable characteristics that improve the reliability and efficiency of the electric power supply system, such as efficient peaking, a rapid rate of unit unloading, and rapid power availability for emergencies in the power grid (USACE, 2006). Further, the facilities generate clean energy with a minimal carbon-footprint.

Annual gross power generation at Garrison Dam was on average 2.29 million MWh from 1967 (2 years after Lake Sakakawea was filled) through 2007 (Table 4–1). During this time, the annual power generation at the dam has ranged from 1.31 million MWh in 2007 to 3.35 million MWh in 1975. Hydropower generation is highest during the winter heating season (December to mid-February) and in the summer when air-conditioning systems are used (mid-June to early September).

In general, power generation has decreased over time, largely as a function of decreased runoff in the watershed caused by drought. The exception occurred during the mid-1990s when spring snow melt and high rainfall in the Upper Missouri River watershed resulted in high power generation rates. In addition, some generation capacity, especially during the winter months, has been lost and sedimentation is playing an unquantifiable part.

To get an understanding to the impacts that may occur with a reduction in hydropower capacity at the Garrison facility during the winter, an analysis was conducted on average power production as follows. Water release rates at Garrison Dam for ice-in vary from year to year depending on the specific conditions and needs of other users. Under “normal conditions”, the USACE would release from “the top of the maintenance zone” and gradually release the water over the winter. However, reduced runoff in the watershed has resulted in a decline in power generation between 1967 and 2008 by almost a factor of two. Louis Berger used linear regression to estimate the decline as approximately 8 percent greater during the 5-month-long colder period (December to April) than during the other months of the year. Although there are other potential causes for a relatively greater decline during the winter months (such as the statistical effect of the floods in the mid-1990s), aggradation in the Missouri River in the headwater of Lake Oahe have likely contributed to this decline but at an unquantifiable level.

[9] USACE, Northwest Division. Missouri River Mainstem Reservoir System, Master Water Control Manual, Missouri River Basin. 2006.

TABLE 4–1.—GROSS ENERGY PRODUCTION IN GARRISON RESERVOIR, JUNE 1967 TO SEPTEMBER 2008 (IN MWH)

YEAR	MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1967	....	....	....	....	....	232,818	295,092	336,767	237,050	275,633	237,942	241,156
1968	252,539	250,001	172,681	196,858	181,466	149,118	156,431	189,139	212,389	290,561	220,158	234,317
1969	270,694	273,173	274,214	226,709	220,131	163,022	257,475	282,114	238,412	234,153	234,215	270,807
1970	238,768	229,732	184,253	216,135	249,277	249,694	253,971	260,164	202,972	254,324	255,847	226,249
1971	278,471	237,686	261,810	310,917	344,378	316,965	332,812	252,987	219,089	227,357	231,432	227,571
1972	264,805	246,236	251,070	339,180	355,277	337,281	259,622	223,343	193,055	207,270	207,332	216,580
1973	252,601	214,626	235,511	184,710	162,558	175,566	195,675	200,477	182,992	184,094	183,062	216,226
1974	239,337	220,615	229,313	173,132	193,606	216,058	250,441	265,274	217,902	274,602	224,294	229,846
1975	202,670	228,625	228,566	159,040	300,368	344,928	327,106	346,401	344,051	307,207	301,414	259,895
1976	238,366	267,342	241,560	280,298	293,607	337,657	347,855	297,624	241,298	240,857	267,802	222,627
1977	261,495	226,827	187,604	145,158	146,577	140,361	161,710	149,503	130,351	116,836	144,514	188,750
1978	238,901	223,758	170,809	152,426	147,911	282,902	365,976	359,461	297,607	294,386	288,538	216,800
1979	273,286	242,247	243,472	247,986	337,281	326,261	248,273	200,522	161,316	143,923	131,469	185,069
1980	211,978	250,217	244,215	180,241	171,693	187,355	242,163	220,382	195,389	205,592	215,010	192,581
1981	223,298	221,708	201,301	144,434	157,530	220,945	258,497	211,709	169,211	137,018	134,494	174,483
1982	229,612	246,046	230,513	150,534	220,269	205,686	241,775	196,792	165,964	182,936	273,082	214,505
1983	195,282	252,410	265,769	202,091	158,451	166,381	171,991	255,878	213,868	133,385	156,472	209,450
1984	255,688	234,352	177,212	149,491	133,458	133,898	219,728	268,821	241,132	229,359	235,378	208,485
1985	252,369	240,712	177,209	160,436	177,001	188,864	185,625	173,756	156,144	127,688	139,786	199,184
1986	235,321	212,537	229,322	170,761	99,653	141,125	188,609	235,182	184,242	214,922	226,168	193,816
1987	226,673	231,899	158,323	97,604	148,884	169,561	180,083	178,711	154,063	127,735	122,734	191,642
1988	198,547	223,301	175,902	159,051	168,085	166,187	172,799	160,599	117,128	95,739	94,058	159,654
1989	163,976	170,372	137,847	130,908	182,384	192,195	198,356	190,547	108,517	95,189	158,685	170,366
1990	206,707	148,555	128,636	146,336	164,180	168,175	172,163	158,428	92,532	88,832	96,474	148,656
1991	173,156	159,305	103,663	140,304	163,980	161,695	174,731	173,966	118,687	116,791	122,517	166,840
1992	196,593	164,598	108,911	136,972	169,802	164,615	172,671	160,192	115,239	86,884	84,653	156,621
1993	159,708	104,673	89,163	85,072	134,907	138,487	137,753	149,864	104,769	96,345	102,339	130,855
1994	136,453	117,532	115,117	111,526	231,975	216,358	190,774	184,486	150,159	112,592	128,289	180,847
1995	199,766	175,462	134,753	111,981	119,587	105,419	137,043	300,487	347,671	353,293	294,565	197,713
1996	221,226	191,266	182,434	250,196	290,399	335,550	367,096	359,879	331,570	261,562	197,127	185,159
1997	218,714	183,318	153,772	154,629	297,147	360,731	377,870	362,492	359,527	356,377	316,385	199,143
1998	197,614	198,563	173,961	170,373	214,778	223,976	219,973	220,021	185,343	146,834	175,793	190,242
1999	221,959	217,155	212,825	235,541	236,204	265,232	267,076	260,022	210,046	171,329	154,754	177,371
2000	187,146	200,649	163,472	167,992	197,165	209,323	210,979	204,901	151,966	122,592	174,651	153,161
2001	159,385	129,011	113,542	103,331	105,408	116,976	121,032	122,385	94,213	85,351	85,865	111,259

TABLE 4–1.—GROSS ENERGY PRODUCTION IN GARRISON RESERVOIR, JUNE 1967 TO SEPTEMBER 2008 (IN MWH)—Continued

YEAR	MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2002	111,452	100,760	99,396	86,132	106,810	172,552	179,593	180,714	144,581	118,357	146,246	162,429
2003	150,925	164,934	142,549	150,091	155,550	174,755	183,761	177,311	135,844	86,510	93,167	130,288
2004	156,136	171,953	132,585	130,906	126,761	140,007	145,470	138,970	116,618	92,022	97,700	119,484
2005	118,210	90,236	93,733	129,719	125,240	115,245	125,521	127,459	110,058	100,814	103,473	122,061
2006	140,181	109,310	114,305	104,814	122,996	158,479	169,765	176,082	135,781	94,534	99,072	117,784
2007	121,942	108,113	112,359	100,052	104,596	125,814	130,747	129,425	90,900	85,512	82,820	117,329
2008	117,115	110,226	97,062	92,767	98,124	110,098	114,729	119,052	104,899	....	....	....

TABLE 4–1 (CONTINUED).—GROSS ENERGY PRODUCTION IN GARRISON RESERVOIR, JUNE 1967 TO SEPTEMBER 2008 (IN MWH)

Year	FULL YEAR (Jan–Dec)				Colder Months (Dec–Apr)		
	MIN	MAX	TOTAL	MEAN	MIN	MAX	Mean
1967	232,818	336,767	....	....	172,681	252,539	222,647
1968	149,118	290,561	2,505,658	208,805	226,709	274,214	255,821
1969	163,022	282,114	2,945,119	245,427	184,253	270,807	227,939
1970	184,253	260,164	2,821,386	235,116	226,249	310,917	263,027
1971	219,089	344,378	3,241,475	270,123	227,571	339,180	265,772
1972	193,055	355,277	3,101,051	258,421	184,710	252,601	220,806
1973	162,558	252,601	2,388,098	199,008	173,132	239,337	215,725
1974	173,132	274,602	2,734,420	227,868	159,040	229,846	209,749
1975	159,040	346,401	3,350,271	279,189	238,366	280,298	257,492
1976	222,627	347,855	3,276,893	273,074	145,158	261,495	208,742
1977	116,836	261,495	1,999,686	166,641	152,426	238,901	194,929
1978	147,911	365,976	3,039,475	253,290	216,800	273,286	244,758
1979	131,469	337,281	2,741,105	228,425	180,241	250,217	214,344
1980	171,693	250,217	2,516,816	209,735	144,434	223,298	196,664
1981	134,494	258,497	2,254,628	187,886	150,534	246,046	206,238
1982	150,534	273,082	2,557,714	213,143	195,282	265,769	226,011
1983	133,385	265,769	2,381,428	198,452	149,491	255,688	205,239
1984	133,458	268,821	2,487,002	207,250	160,436	252,369	207,842
1985	127,688	252,369	2,178,774	181,565	170,761	235,321	209,425
1986	99,653	235,321	2,331,658	194,305	97,604	231,899	181,663

1987	97,604	231,899	1,987,912	165,659	159,051	223,301	189,689
1988	94,058	223,301	1,891,050	157,588	130,908	170,372	152,551
1989	95,189	198,356	1,899,342	158,279	128,636	206,707	160,120
1990	88,832	206,707	1,719,674	143,306	103,663	173,156	145,017
1991	103,663	174,731	1,775,635	147,970	108,911	196,593	154,783
1992	84,653	196,593	1,717,751	143,146	85,072	159,708	119,047
1993	85,072	159,708	1,433,935	119,495	111,526	136,453	122,297
1994	111,526	231,975	1,876,108	156,342	111,981	199,766	160,562
1995	105,419	353,293	2,477,740	206,478	182,434	250,196	208,567
1996	182,434	367,096	3,173,464	264,455	153,772	218,714	179,118
1997	153,772	377,870	3,340,105	278,342	170,373	199,143	187,931
1998	146,834	223,976	2,317,471	193,123	190,242	235,541	215,544
1999	154,754	267,076	2,629,514	219,126	163,472	200,649	179,326
2000	122,592	210,979	2,143,997	178,666	103,331	159,385	131,686
2001	85,351	159,385	1,347,758	112,313	86,132	111,452	101,800
2002	86,132	180,714	1,609,022	134,085	142,549	164,934	154,186
2003	86,510	183,761	1,745,685	145,474	130,288	171,953	144,374
2004	92,022	171,953	1,568,612	130,718	90,236	129,719	110,276
2005	90,236	129,719	1,361,769	113,481	104,814	140,181	118,134
2006	94,534	176,082	1,543,103	128,592	100,052	121,942	112,050
2007	82,820	130,747	1,309,609	109,134	92,767	117,329	106,900
2008	92,767	119,052	....	....	....	....	....

The value of lost power production was estimated as follows. Table 4–2 shows the monthly average hydropower production during the cold months during two points in time. This includes 1968 and 1972 after the dam was operational and 2003 and 2007, the last years that data are available. The average for the cold months for each of these periods is shown in the last row of the table and indicates that production has declined by nearly 50 percent.

TABLE 4–2.—MONTHLY MEAN HYDROPOWER PRODUCTION FROM THE GARRISON DAM

Year	Cold Month (Dec.–April) Mean Hydropower Production		
	Mean Monthly Production	Year	Mean Monthly Production
1968	225,821	2003	144,374
1969	227,939	2004	110,276
1970	263,027	2005	118,134
1971	265,772	2006	112,050
1972	184,710	2007	106,900
5-yr Average (MWh)	233,454		118,347

Table 4–3 shows the reduction in mean power production between the two time periods. These differences were extrapolated to calculate a loss in power production over the 5 month cold period as shown in column 3. In other words, on average power production has declined be over 570,000 MWh during the cold months between the late 1960s and the present.

TABLE 4–3.—DIFFERENCE IN HYDROPOWER PRODUCTION

	Mean Cold Month Generation (MWh)	Total Average Production During Cold Months (MWh)
1968–1972	233,454	1,167,269
2003–2007	118,347	591,734
Difference	115,107	575,535

Because it is uncertain how much aggradation in downstream reaches is contributing to flooding and reduced flows from the Garrison Dam during colder months, several scenarios were developed to provide some insight on the potential economic impacts to hydropower production. The results are shown in Table 4–4. The top of the table shows electricity generation reduction scenarios which range from 10 to 100 percent.

As mentioned earlier, Western markets and transmits the power generated at the dam at cost to non-profit preference power entities. While the cost of hydropower production does not change over the year, the value of the power produced varies due to changes in demand with the highest demand occurring in the summer and winter. Therefore, the impacts of a reduction in electricity generation would not occur to Western but to its customers if it is unable to meet power demands. This issue has been raised most recently in relation to Western's inability to meet power commitments due to drought conditions. For instance, between 2004 and 2007, rates to wholesale customers increased by 37.3 percent to cover cost of power purchased off the open market due, in part, to reduced reservoir levels.[10]

To value of the loss in electricity generation at the Garrison Dam, a price differential was applied to the capacity losses as discussion above. The price differential represents the difference in cost of production to Western and the average weighted monthly wholesale prices for winter months discussed in Section 3.0. The difference thus represents a higher cost alternative for power reduction than hydropower.

The results are summarized in Table 4–4. Under a low impact scenario, electricity generation capacity would decline by 10 percent or 57,000 MWh. Assuming a price differential of $27/MWh, the cost to replace this capacity with an alternative is $1.5 million per year. Under a high impact scenario, with the greatest reduction in hydropower capacity due to various factors and the highest price differential, losses could reach as much as $34.5 million per year.

[10] "The Missouri River: A View from Upstream", Prairie Fire Newspaper, December 2007, http://www.prairiefirenewspaper.com/print/178.

TABLE 4–4.—ESTIMATED VALUE OF POWER PRODUCTION SCENARIOS

	Percentage Reduction in Hydropower (MWh)				
	10 percent (57,554)	25 percent (143,884)	50 percent (287,768)	75 percent (431,651)	100 percent (575,535)
Value of Lost Production (Sales)—$27/MWh	$1,553,945	$3,884,861	$7,769,723	$11,654,584	$15,539,445
Value of Lost Production (Sales)—$42/MWh	2,417,247	6,043,118	12,086,235	18,129,353	24,172,470
Value of Loss Production (Sales)—$60/MWh	3,453,210	8,633,025	17,266,050	25,899,075	34,532,100

5.0 RECREATION

Water based recreation, especially sport fishing, has a very important role in North Dakota's economy. A recent study by North Dakota State University estimated that the total gross business volume generated by fishing on Lake Sakakawea alone was as high as $89 million per year. Thus, changes in the reservoirs or river reaches due to sedimentation and erosion have potential significant economic implications. The economic evaluation will utilize the results of subtask 5C which evaluated the impacts of siltation on recreation in North Dakota.

Under Task 5A, Berger identified areas of the river impacted most by the accumulation of sediments and occur approximately 10 to 15 miles downstream from the upstream end of the lake zones (Lake Sakakawea and Lake Oahe) created by the Garrison and Oahe Dams. Most of the sediment accumulation is concentrated within a 30-mile reach of these points. Under Task 5C, Berger identified recreational sites that are located within the areas impacted by sedimentation as summarized in Figure 5–1. According to the sediment aggradation maps, nearly all of the intensive use recreation sites on Lake Sakakawea are in areas of low to moderate sedimentation levels. On Lake Oahe, Graner Park Recreation Area and Kimball Bottom Recreation Area are areas of intense recreational use that are affected by high levels of sedimentation. MacLean Bottom Recreation Area is also identified as an area with high sedimentation levels but the site is considered a low density recreation area. In all, 1.1 million visitors recreated at sites within areas identified as either "low" or "moderate" areas of sediment aggradation on Lake Sakakawea and an additional 2.3 million visitors recreated at similarly identified sites in Lake Oahe according to the aggradation maps.

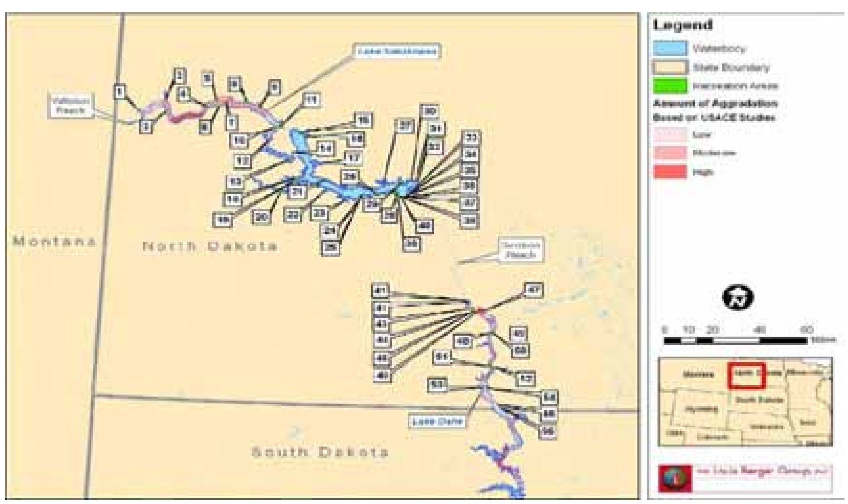

FIGURE 5–1.—*Developed Recreational Sites within Aggradation Areas*

Sedimentation can negatively affect recreation resources in two ways:

—*Direct.*—Affecting access or pathways within the reservoirs which impact visitors ability to access or utilize the water, compromising their safety, or affecting the aesthetic environment, or

—*Indirect.*—Affecting physical properties within the reservoirs which in turn affect aspects of the recreationists overall trip (e.g., important fish habitat which would affect the recreational fishery).

Loss of either access or declines in sport fishing would have negative consequences on recreators coming to the area for these activities. This can lead to economic impacts but will depend on how recreators react to changing conditions. For instance, if sedimentation reduces access to certain boat ramps at the river or reservoirs but recreators can utilize alternative sites for access the number of visitor days may or may not decline. Recreators may need to incur higher costs to recreate in the area due to traveling farther to gain access to the site. However, this reaction will not have a negative impact on the regional or State economy though it may have some negative impacts to local areas where high sedimentation is occurring. Louis Berger was unable to find any studies that have evaluated how recreators would change their behaviors in reaction to sedimentation levels. Thus, it is unknown how sedimentation may cause economic impacts to the recreation industry.

5.1 Impacts to Boat Ramps

Erosion and transport of silts and sediments into Lakes Sakakawea and Oahe can result in the aggradation near boat ramps posing problems to users and rendering them unusable. Dredging the ramps is currently performed when access is blocked by sediment build up on and around ramps; however this poses an ongoing maintenance cost to monitor and remove the sediments to keep ramps open. Complicating the management of sediment bound boat ramps are the lake levels. Severe drought in the recent past has resulted in very low lake levels which leaves some ramps out of the water or the ends of the ramps a long distance from the parking area. Sediment aggradation and boat ramp closures in areas with few points of access would cause additional strain as the cost to remove the sediment may outweigh the benefit of clearing the ramp resulting in ramp closures. Ramp closures in remote locations around the study area would force visitors to drive further to launch a boat. In some areas, building a new ramp nearby is more cost effective than dredging existing ramps.

The USACE provides high, mid, and low water ramps at many of the access areas to accommodate changes in reservoir levels which also provide alternative access during periods when ramps are covered with sediment. Most recently Fort Stevenson State Park, Government Bay, and Sanish Bay were locations within the reservoir that required dredging to provide boater access. The Fort Stevenson West Ramp was closed because it is entirely silted in and a brand new marina ramp is being constructed on the northwest side of the bay. Fort Stevens State Park is approximately 3 miles south of the town of Garrison; however it is not known if sediment is being loaded into the arm from tributary or in-reservoir sources. The Government Bay low water ramp was completely reconstructed within the last year because of siltation problems as the bay is filling up with silt and there is no longer a good location for moving the boat ramp. Complicating matters, the ramp cannot be extended because of a lack of room. In general, USACE's recent solution has been to move or extend ramps rather than continue to dredge out areas, because it is less expensive. These areas are within bays or smaller arms that are subject to local sedimentation processes and were not identified as areas of aggradation by Berger under Task 5A that focused on changes in the elevations within the main channel and thalweg.

6.0 WATER SUPPLY AND IRRIGATION INTAKES

Review of documents and studies has revealed that an increase in sedimentation along the river is impacting water intakes for municipalities, irrigation, commercial and industrial customers. According to the Missouri River Master Manual [11] there are over 500 water intakes along Lake Sakakawea and the Garrison Reach of the Missouri River in North Dakota. Table 6–1 summarizes the number and type of intakes by location.

TABLE 6–1.—WATER INTAKE LOCATIONS ALONG THE MISSOURI RIVER IN NORTH DAKOTA

Location	Power	Municipal	Industrial	Irrigation	Domestic	Public	Total
Lake Sakakawea	1	10 (5)	6 (1)	44 (10)	228 (63)	11	300 (79)

[11] USACE, Missouri River Master Water Control Manual, Final Environmental Impact Statement, March 2004.

TABLE 6–1.—WATER INTAKE LOCATIONS ALONG THE MISSOURI RIVER IN NORTH DAKOTA—Continued

Location	Power	Municipal	Industrial	Irrigation	Domestic	Public	Total
Garrison Reach	6	3	6	77	28	3	123

Source.—USACE, Missouri River Master Water Control Manual, Final Environmental Impact Statement, Table 3.10.1, p. 3–112, March 2004.

( ) Denotes intakes on Reservation Lands.

Berger further evaluated potential impacts to water intakes from sedimentation. Given that 77 percent of total water use in North Dakota is for power generation, impacts to these facilities are addressed separately in Section 3.0. In addition, Berger conducted interviews with the city of Mandan Water Department and the Public Works Director of the city of Williston to learn about potential impacts to municipal water intakes from sedimentation. Both entities indicated that they have been impacted by increased sedimentation. The city of Mandan's water intake has been impacted by both increases in sedimentation and vegetation. The city shares the intake with the Tesoro Refinery. Both parties have spent several thousands of dollars keeping the intake free of debris. This includes $150,000 to dredge one-half mile of the river 5 years ago and $20,000 to hire a diver to remove silt from the intake in April 2007. They are expecting that additional maintenance will be needed in another 2 years.

The city of Williston originally operated three water intakes from the Missouri River as the city's sole source of water. Two of these intakes became completely covered with silt and in 2003 the city received $2.0 million from the EPA to develop an alternative water line.

The interviewees indicated that Trenton Indian Service Area, which is controlled by Turtle Mountain, and the Heskett Plant are also experiencing impacts to intakes due to sedimentation or increased vegetation. However, Berger was unable to reach any representatives from these entities to confirm these statements.

In addition to these uses, 121 intakes are used for agricultural irrigation which helps to increase crop yields or grow crops that could not be grown in this region. Most of these irrigation intakes are portable and placed to access water at a low cost. However, operators may be impacted by higher operating costs, loss in efficiency or increases in maintenance related to sedimentation issues.

To get an understanding of how many irrigation intakes may be affected by sedimentation along the Missouri River in North Dakota, Berger obtained location data of all the irrigation intakes from the USACE and plotted these locations on the aggradation maps created under Task 5A. Each intake located within one-half mile of the aggradation areas was identified as being potentially impacted by sedimentation. The analysis showed that 100 intakes were located within defined aggradation areas. Of these 100 intakes, most were located in either "low" or medium aggradation areas while five were located in a "high" aggradation area (Table 6–2). It is not known at this time how intakes within the different aggradation areas may be impacted by sedimentation though it is likely that operators in areas of high aggradation will be impacted more severally than those in moderate or low areas.

TABLE 6–2.—INTAKES WITHIN INDENTIFIED AREAS OF AGGRADATION

Level of Aggradation	Number of Intakes
Low	48
Moderate	47
High	5

7.0 CONCLUSIONS

Under this Task, Berger evaluated the potential impacts to different resources and activities from sedimentation and what consequences these impacts would have to Federal, tribal, State, regional economies. It appears that the most significant impact is from increased flooding in and around Bismarck and Mandan especially in the winter. Other resources and activities are also experiencing impacts such as electric power production (hydro and thermal), recreation, water supply and land use. However none of these impacts appear as significant as flood control. The report was unable to quantify impacts to recreation and agricultural use and would suggest these resources be studied further. In addition, data and costs may become available associated with operational and maintenance impacts for infrastructure impacted by sedimentation.

The results of the analysis are summarized in Table 7–1.

TABLE 7–1.—POTENTIAL ECONOMIC IMPACTS OF SEDIMENTATION ALONG THE MISSOURI RIVER IN NORTH DAKOTA

Resource	Potential Impact	Impact to Economy				Timeframe	Comments
		Federal	State	Local	Tribal		
Agricultural Land Use	Loss of Productivity of Ag Lands	....	....	X	X	Short Term	
Flood Control	Increased Flooding	....	X	X	....	Long-term	Increased flooding potential can lead to costly buy outs, increased insurance costs and reduction in property values.
Coal-Fired Power Plants	Reduction in generation capacity	....	....	X	....	Long-term	Loss in revenue or increase in costs to meet contract demands.
Hydropower	Reduction in generation capacity	....	X	X	X	Long-term	Increased flooding potential can reduce hydropower production; especially during colder months.
Recreation	Increased maintenance costs for recreational facilities.	....	X	X	X	Long-term	Increased cost to dredge and maintain facilities affected by sedimentation. Impacts to visitor behavior are unknown.
Water Supply	Increase operation and maintenance costs	....	....	X	X	Long-term	Small number of intakes are impacted by sedimentation causing an increase in operation and maintenance costs.

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APPENDIX C—IMPACTS OF SILTATION OF THE MISSOURI RIVER ON RECREATION IN NORTH DAKOTA

1.0 INTRODUCTION

The Missouri River flows for approximately 410 miles through North Dakota providing a multitude of recreation opportunities for residents and visitors alike. Lakes Sakakawea and the upper 70 miles of Lake Oahe supply approximately 430,000 acres of flat water boating opportunities between these two reservoirs. The study area includes an area of the Missouri River from the Montana border to the upstream end of Lake Sakakawea, which can extend past Williston to just south of Bismarck at full pool, and also approximately 80 miles of riverine conditions from Garrison Dam to the upstream end of Lake Oahe (Garrison reach). In the summer, recreational opportunities in the area consist of boating, fishing, hunting, camping, hiking, horseback riding, wildlife viewing, swimming, and sunbathing. In the winter, activities such as snowmobiling and ice fishing are common in this area.

North Dakota contains one dam, Garrison Dam, and its associated reservoir, Lake Sakakawea. The reservoir known as Lake Oahe, formed by the Oahe Dam in South Dakota, also extends into North Dakota from the south. Therefore, from a recreation perspective the Missouri River in North Dakota may be thought of as having four parts:

—*The Williston Reach.*—The riverine segment close to the Montana border, into which the Yellowstone River flows, and which flows into Lake Sakakawea. This reach can become inundated by Lake Sakakawea at full pool;

—*Lake Sakakawea.*—The reservoir formed by Garrison Dam (finished in 1953), whose entire surface is within the State of North Dakota;

—*The Garrison Reach.*—The riverine segment from Garrison Dam to the headwaters of Lake Oahe; and

—*Lake Oahe.*—The reservoir formed by Oahe Dam in South Dakota (closed in 1958), and which is in both North Dakota and South Dakota.

These four separate regions will be used to describe impacts to recreation from siltation of the Missouri River in North Dakota.

2.0 LITERATURE AND DATA COLLECTION METHODOLOGY

Several types of information were used to meet study objectives, including (1) interviews with experienced recreation managers and (2) a review of existing documents. Key recreation personnel were contacted from the following institutions:

—North Dakota Game and Fish

—North Dakota Park and Recreation Department

—North Dakota Water Commission

—North Dakota State University

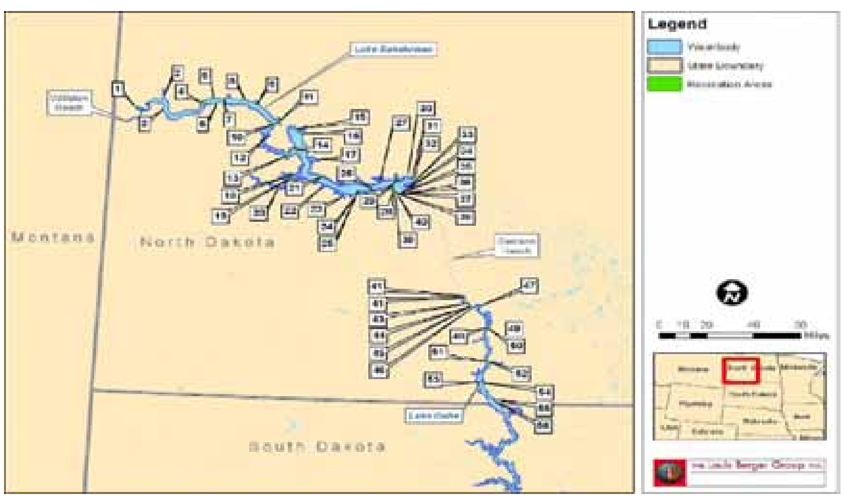
—City of Williston
—Bismarck Parks and Recreation District
—Ford Abraham Lincoln State Park
—United States Army Corps of Engineers, Omaha District

A list of recreation issues, sites, and documents were derived from the interviews and incorporated into the evaluation. In addition, Federal, State, and local agencies in the recreation resources arena were contacted for literature detailing recreation opportunities, policies, planning efforts, use levels, and attitudes related to recreation on the Missouri River. The following reports, documents, and Web sites were reviewed for information related to recreation, erosion, and siltation related to the study objectives:

—Quarterly Drought Reports from the, (USACE—Omaha District, 2008).
—North Dakota State Comprehensive Outdoor Recreation Plan 2008–2012, (DH Research, the North Dakota Recreation and Parks Association and the North Dakota Parks and Recreation Department).
—Missouri River Mainstem Reservoir System Master Water Control Manual Missouri River Basin (Reservoir Control Center, USACE—Northwestern Division, 2006).
—A Reference Guide to Water in North Dakota (North Dakota Water Commission, 2005) The Valley Outdoors: Lake Sakakawea in Peril [1] (Leier, 2004).
—Minnesota Public Radio, Water Wars: Recreation on the Missouri River (Gunderson, July 2, 2003).[2]

3.0 RECREATION OPPORTUNITIES

The Missouri River accounts for 80 percent of the total streamflow in the State (USGS 2008) and also provides significant water based recreation opportunities. Recreation facilities along the river vary from game lands, State parks, municipal parks, Native American owned and operated facilities, and private access, to primitive dispersed areas. Figure 3–1 shows the location of the 56 formal recreation areas along the river in the study area, while Table 3–1 contains the names of the access points on the figure and summarizes the amenities at the site and the agency/entity responsible for managing the site.



(Source: USACE 2008a, as modified by staff)

FIGURE 3–1.—*Developed Recreation Facilities Along the Missouri River in North Dakota*

[1] http://www.nodakoutdoors.com/valleyoutdoors5.php.
[2] http://news.minnesota.publicradio.org/features/2003/07/03__gundersond__riverrecreation/.

TABLE 3–1.—AMENITIES AT EACH DEVELOPED RECREATION FACILITY ALONG THE MISSOURI RIVER IN NORTH DAKOTA

Location/Manager	ID	Amenities at Each Recreation Facility																	
		Boat Ramp	Boat Dock	Boat Rental	Boat Storage	Camping	Cabin Rental	Electric Hookup	Drinking Water	Showers	Restrooms	Picnic Shelter	Picnic Tables	Swim Beach	Playground	Restaurant/ Concession	Boat Fuel	Dump Station	Fishing Cleaning Station
Lake Trenton/WCWRD	1	X	X			X		X	X	X	X	X	X	X	X	X		X	X
Little Muddy/WCWRD	2	X									X	X	X						
American Legion Park/American Legion	3	X				X		X	X		X	X	X						
Lewis and Clark State Park/State of ND	4	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
White Tail Bay (Lund's Landing)/ WCWRD	5	X	X			X	X		X	X	X	X	X			X			
Tobacco Gardens/McKenzie Co. Park Board	6	X	X			X	X	X	X	X	X	X	X		X	X	X	X	X
Little Egypt/WCWRD	7					X					X	X	X						
Little Beaver Bay/Williams County Water Resource District (WCWRD)	8	X	X			X					X	X	X						
White Earth Bay/Mountrail County Park Board	9	X	X			X			X	X	X	X	X			X		X	X
Four Bears/Three Affiliated Tribes	10	X	X			X			X		X	X				X	X	X	X
New Town/New Town Park Board	11	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X
Reunion Bay (Sanish Bay)/New Town Park Board	12	X	X																
Skunk Creek/Three Affiliated Tribes	13	X				X	X				X								
Pouch Point/Three Affiliated Tribes	14	X	X			X		X	X	X	X	X	X			X			
Van Hook/Mountrail County Park Board	15	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X
Parshall Bay/Mountrail County Park Board	16	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X
Deepwater Creek/USACE	17	X	X			X			X		X	X	X						
McKenzie Bay/Watford City Park Board	18	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X

Charging Eagle/Three Affiliated Tribes	19	X									X								
Little Missouri Bay (now closed)/ USACE	20	X									X								
Indian Hills/State of ND & Three Affiliated Tribes	21	X	X	X	X	X	X	X	X	X	X		X			X	X	X	X
Twin Buttes/Three Affiliated Tribes	22					X		X			X	X	X	X					
Beaver Creek Bay/Zap Park Board	23	X	X			X					X	X	X						
Lake Shore Park (DakotaWaters)/ Beulah Park Board	24	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X
Beulah Bay/Beulah Park Board	25	X	X			X	X	X	X	X	X	X	X					X	X
Hazen Bay (Walleye Bay)/Hazen Park Board	26	X	X			X	X	X	X	X	X	X	X					X	X
Douglas Creek/USACE	27	X	X			X			X		X		X						
Lake Sakakawea State Park/State of ND	28	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ft. Stevenson State Park/State of ND	29	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sportsmen's Centennial Park/ McLean County	30	X	X			X		X	X	X	X	X	X	X	X	X			X
West Totten Trail/McLean County	31	X	X								X								
East Totten Trail/USACE	32	X	X			X		X	X		X		X					X	X
Wolf Creek/USACE	33	X	X			X			X		X	X	X		X			X	X
Government Bay/USACE	34	X	X								X								X
Riverdale Overlook/USACE	35											X	X						
Spillway Overlook/USACE	36										X	X	X						
Tailrace (Missouri River Ramp)/ USACE	37	X	X								X								X
Tailrace West/USACE	38										X								
Downstream Campground/USACE	39					X		X	X	X	X		X		X			X	
Spillway Pond/USACE	40	X							X		X	X	X	X	X				
General Sibley Park/city of Bismarck	41	X				X		X	X	X	X	X	X		X				
Sibley Nature Park (Trail)/city of Bismarck	42																		
Little Heart/Morton County	43	X				X					X								
Kimball Bottom/Burleigh County	44	X				X					X								

TABLE 3–1.—AMENITIES AT EACH DEVELOPED RECREATION FACILITY ALONG THE MISSOURI RIVER IN NORTH DAKOTA—Continued

Location/Manager	ID	Amenities at Each Recreation Facility																	
		Boat Ramp	Boat Dock	Boat Rental	Boat Storage	Camping	Cabin Rental	Electric Hookup	Drinking Water	Showers	Restrooms	Picnic Shelter	Picnic Tables	Swim Beach	Playground	Restaurant/ Concession	Boat Fuel	Dump Station	Fishing Cleaning Station
Kimball Bottom ORV/Burleigh County	45																		
Graner Park/Morton County	46	X				X					X		X		X				X
MacLean Bottom/State of ND	47	X				X					X								
Fort Rice/Morton County	48	X				X					X		X						X
Hazelton/USACE	49	X				X					X								X
Badger Bay/USACE	50					X					X								
Walker Bottom/Standing Rock Sioux Tribe	51					X					X								
Beaver Creek/USACE	52	X				X		X	X	X	X	X	X	X	X			X	X
Fort Yates/Standing Rock Sioux Tribe	53	X									X								
Cattail Bay/USACE	54	X				X					X								X
Langelier Bay/Emmons County	55	X				X					X								X
State Line/Emmons County	56	X																	

(Source: USACE 2005, USACE 2003, as modified by staff.)

In addition to traditional water based opportunities, recreation and visitors enjoy a number of other cultural and historical sites and wildlife areas which are located on the river. A list of these sites is provided in Appendix A.

3.1 Williston Reach

The Missouri River between the Montana border and the upstream end of Lake Sakakawea is generally referred to as the Williston reach. This approximately 60 mile section of the Missouri River is not inundated by a reservoir and the confluence with the Yellowstone River is within this reach. From a recreational perspective, the Williston reach is remote and access is limited to two boat ramps; one at the confluence with the Yellowstone River and the other about 25 miles down river at the Highway 85 bridge in Williston, North Dakota (not shown on the map). Boating and angling are common activities within this reach.

3.2 Lake Sakakawea

Lake Sakakawea is the largest reservoir in North Dakota and as such provides the greatest amount of flat water recreation opportunities in the State. There are forty formal public access areas adjacent to the reservoir of which 37 provide boater access (boat ramps). In addition to the public recreation facilities, access is provided from private lands, camps, commercial marinas, and other commercial recreational facilities (e.g., private campgrounds).

Lake Sakakawea is also North Dakota's largest recreational fishery, followed by Lake Oahe. Popular sport fish at these two reservoirs include walleye, salmon, northern pike, sauger, white bass, and channel catfish. Anglers also participate in ice fishing, shoreline fishing, boat fishing, and dark-house spearing and take advantage of the cold-water (salmon), cool-water (especially walleye), warm-water and riverine fishery opportunities (USACE 2007). Some of the boating is fishery-related; however, other reservoir activities include motorboating, sailboating, waterskiing, jetskiing, tubing, and wind surfing. Shoreline day uses and off road vehicle (OHV) use are popular at the reservoirs; however, high water levels can eliminate the conditions necessary to participate in these activities.

3.3 Garrison Reach

Aside from the Williston reach, the Garrison reach, is the only other section of the river in North Dakota that is not inundated by a reservoir. This approximately 80 mile reach is however controlled by releases from Garrison Dam. There are 11 boat ramps within this reach and although river levels do fluctuate, the river is rarely to low to canoe (USGS, 2008). The river provides water-based recreation including boating, boating-related activities, and swimming. However, sport fishing is a primary component of recreation along this section of the river. Swift currents along the Missouri River between Garrison Dam and Bismarck are popular with experienced canoeists; while nature lovers enjoy wildlife viewing for bald and golden eagles, osprey, beaver, and deer (USACE 2006).

3.4 Lake Oahe

Lake Oahe is the second largest reservoir in North Dakota and as such recreation is typically water based with boating and fishing the most popular activities. Recent drought conditions have changed the upstream reservoir sections from flat water (typically at elevations above 1,600–1,608 ft msl) to riverine characteristics which could affect the types of activities occurring within this section of the study area or leave boat ramps unusable altogether.

4.0 CURRENT RECREATIONAL USE

The USACE monitors recreation use activity throughout the study area. The amount of estimated use at formal and dispersed sites within the study area is summarized by general area below.

4.1 Lake Sakakawea

In 2008, the USACE found that recreation use levels, including dispersed recreation, at Lake Sakakawea consisted of over thirteen million visitor hours.[3] Of that total, dispersed recreation is estimated to account for over 2 million visitor hours on Lake Sakakawea. According to USACE data, recreation sites that received the most visitor hours include: Van Hook with over 1 million visitor hours, game man-

[3] Visitor hour is defined as the presence of one or more persons on an area of land or water for the purpose of engaging in one or more recreation activities during continuous, intermittent, or simultaneous periods of time aggregating to 60 minutes. Visitor-hour incorporates both the number of participants and duration of use and provides an estimate on the "amount" of use (USACE (Oahe Master Plan) 2007).

agement lands with nearly 1 million visitor hours, Fort Stevenson State Park accounting for about 950,000 visitor hours, Lake Sakakawea State Park with approximately 720,000 visitor hours, East Totten Trail with nearly 700,000 visitor hours, and Lake Shore Park with over 575,000 visitor hours. Table 4–1 shows USACE visitor use estimates (actual users) for 40 formal and combined dispersed use areas around the lake for the years 2005 to 2008.

TABLE 4–1.—NUMBER OF RECREATIONAL USER ON LAKE SAKAKAWEA

Recreation Site	2005	2006	2007	2008
Fort Stevenson State Park	948,435	1,208,383	975,556	952,910
Lake Sakakawea State Park	1,084,604	1,006,966	1,047,370	722,110
Downstream	895,659	872,760	763,113	995,582
Spillway Overlook	50,711	52,410	51,451	53,272
Wolf Creek	215,953	225,762	169,548	131,894
East Totten Trail	774,454	789,407	811,685	696,755
Douglas Creek	138,018	158,493	107,236	246,966
Deep Water Creek	205,276	211,304	204,431	139,767
Lewis and Clark State Park	204,023	120,676	127,957	128,222
Tobacco Garden	215,990	75,669	65,245	108,825
McKenzie Bay	313,674	364,795	249,653	306,695
Little Missouri [1]	....	....	....	....
Charging Eagle	336,151	332,481	304,942	276,837
Beulah Bay	512,623	540,316	391,570	450,855
Missouri River Ramp	297,261	310,459	310,276	328,106
Riverdale Overlook	11,870	13,245	9,827	14,665
Parshall Bay	579,234	618,510	416,201	465,110
Van Hook Area	811,438	1,023,799	1,024,974	1,199,300
New Town	257,215	279,656	262,736	184,036
Twin Buttes	28,117	16,857	32,401	16,678
Hazen Bay	229,406	249,017	302,255	277,534
American Legion Park	33,854	30,622	19,854	71,493
Lake Trenton	263,887	207,277	230,401	253,550
Little Beaver	8,246	12,195	9,714	14,540
Power Plant	2,723	1,138	1,823	1,878
Game Management	1,176,316	1,176,715	1,175,256	1,145,243
Sportsmen's Centennial (Benedict)	157,194	153,958	115,942	139,123
White Earth Bay	75,431	96,543	107,446	75,389
Beaver Creek	98,128	143,699	128,816	144,564
Pouch Point Bay	229,132	147,288	103,956	172,127
White Tail Bay	31,348	37,203	30,460	122,301
Indian Hills	229,736	227,217	226,759	205,751
West Totten Trail	14,771	18,170	14,441	15,397
Lake Shore Park	562,616	548,735	582,109	576,504
Government Bay	80,191	77,659	77,187	78,525
Spillway Pond	24,239	15,702	16,171	22,855
Little Muddy	34,001	27,320	18,883	26,619
Little Egypt	11,517	13,303	11,777	10,229
West Trail Race	37,594	38,728	34,070	41,480
Reunion Bay	39,009	42,929	28,667	32,184
Skunk Creek Bay	230,234	230,053	79,931	96,770
Dispersed Use	1,706,500	1,706,092	1,913,077	2,268,823

[1] Drought conditions rendered the site unusable.

(Source: USACE, 2008)

Angling is the most popular recreation activity on Lake Sakakawea. Boating and sightseeing are also popular activities as they are often occurring within the same party on the same day. Table 4–2 summarizes the mix of activities and the primary purpose of trips taken by visitors to Lake Sakakawea.

TABLE 4–2.—RECREATIONAL ACTIVITY MIX AT LAKE SAKAKAWEA

Recreation Activity	Percent of All Activities	Percent of Visits
Fishing	41.7	23.1
Boating	39.7	22.0

TABLE 4–2.—RECREATIONAL ACTIVITY MIX AT LAKE SAKAKAWEA—Continued

Recreation Activity	Percent of All Activities	Percent of Visits
Sightseeing	31.1	17.2
Other (jetskiing, hiking, playground, bird watching, pow-wows etc.)	22.1	12.2
Camping	19.5	10.8
Picnicking	11.7	6.5
Swimming	8.7	4.8
Hunting	3.5	1.9
Waterskiing	2.4	1.3
Winter Activities	< 1	< 1
Total Percent2	180.5	100
Activities Per Visit	1.8	....

(Source: USACE 2007, modified by staff)

4.2 Garrison Reach

Visitor use estimates for the Garrison reach are more difficult to calculate. North Dakota Game and Fish Department (NDGFD) most recent creel surveys estimated 95,322 angler days during 2007 (NDGFD 2007b) which amounted to over 338,000 angler hours along this reach. Boat anglers accounted for over 80 percent of the estimate (NDGFD 2007b). Overall, visitation is likely much higher when considering the canoe trips and land based opportunities within the reach.

4.3 Lake Oahe

The USACE estimated recreational use of Lake Oahe sites within North Dakota totaled approximately 3.8 million visitor hours in 2008 (USACE 2008). Recreation sites that received the most visitor hours included: General Sibley Park with approximately 1.4 million visitor hours, Kimball Bottom with over 850,000 visitor hours, Beaver Creek with over 300,000 visitor hours, Graner Bottom with approximately 280,000 visitor hours, and Hazelton with nearly 272,000 visitor hours.[4] Table 4093 shows the USACE visitor use estimates (actual users) for 15 formal and combined dispersed use areas around the lake for the years 2005 to 2008.

TABLE 4–3.—NUMBER OF RECREATIONAL USERS ON LAKE OAHE

Recreation Site	2005	2006	2007	2008
Fort Yates	122,523	96,178	53,727	60,646
Cattail Bay	85,903	86,504	70,461	76,428
Beaver Creek	276,485	234,492	277,777	329,614
Badger Bay	5,538	4,587	3,416	4,670
Hazelton	104,741	150,906	173,419	271,992
Fort Rice	24,731	30,908	38,769	43,140
Graner Bottom	235,735	150,473	265,718	280,006
Little Heart (NDG&F Managed)	148,686	163,741	168,123	115,290
East Sibley Park (Nature Trail)	2,913	3,611	5,378	6,560
General Sibley Park	702,388	995,321	1,343,763	1,439,609
Kimball Bottom	838,378	656,671	620,293	856,412
Langelier	5,760	6,044	3,452	13,407
Kimball Bottom ORV	257,240	214,088	1,999,598	137,449
Maclean Bottom	134,692	187,071	208,501	146,657
Prairie Knights Marina (Walker Bottom)	29,120	29,337	19,758	26,571

Note.—This area of Oahe in North Dakota generally consisted of ''river'' conditions rather than ''Lake'' conditions during these years.

(Source: USACE, 2008)

Fishing, boating, and sightseeing are the most popular activities on Lake Oahe. According to the USACE, hunting accounts for 60 to 80 percent of total visitor hours in the fall, but may be misrepresented because of a lack of traffic counters on hunting related roads. Table 4–4 summarizes activity participation rates for visitors to Lake Oahe.

[4] The total percent of activities is greater than 100 percent because many people participated in more than one activity at a given recreation area.

TABLE 4–4.—ACTIVITY MIX FOR LAKE OAHE

Recreation Activity	Activity Partici-pation Rate (percent)
Fishing	43.9
Boating	30.0
Sightseeing	22.0
Other	16.1
Camping	7.0
Swimming	5.6
Hunting	4.9
Picnicking	3.6
Waterskiing	0.6
Total [1]	133.7

[1] Totals more than 100 percent as users typically participate in more than one activity.

(Source: USACE 2007, modified by staff)

5.0 RECREATIONAL NEEDS

USACE Lake Sakakawea Master Plan (2007) and Lake Oahe Draft Master Plan (2007) estimate that recreation use levels at both reservoirs are expected to grow in the coming years causing increasing demand for recreational facilities throughout the study area. Facility needs were identified by the North Dakota Parks and Recreation Department (NDPRD) in the North Dakota 2003–2008 State Comprehensive Outdoor Recreation Plan (SCORP) through the use of eight public forums (one for each SPR) that included recreation agency representatives and members of the general public. The top six recreational priorities of the planning districts adjacent to the study area were the same as those identified in the State and included: (1) Trails, (2) golf courses, (3) sports courts, (4) pools/beaches, (5) playgrounds/picnic areas, and (6) sports fields. Activities occurring in the study area but not in the top six were: water access (ranked 7th by adjacent planning districts), historic sites (ranked 8th by adjacent planning districts), and campgrounds (ranked 14th by adjacent planning districts). Because the study area offers the majority of flat water and a substantial amount of river based recreation opportunities in the State, the recreation sites within the study area will have to keep up with the demand for water access.

6.0 EFFECTS OF SILTATION ON RECREATION RESOURCES

Lake Sakakawea receives approximately 1,642 acre-feet of sediment as estimated at the Montana/North Dakota border (The Louis Berger Group [Berger], 2008). Sedimentation presents hazards to boaters, impairs fisheries, creates marshy areas, and jeopardizes recreation facilities (USACE, 2007). Siltation can negatively affect recreation resources in two ways:

—*Direct.*—Affecting access or pathways within the reservoirs affecting visitors ability to access or utilize the water, compromising their safety, or affecting the aesthetic environment, or

—*Indirect.*—Affecting physical properties within the reservoirs which in turn affect aspects of the recreationists overall trip (e.g., important fish habitat which would affect the recreational fishery).

Loss of either access or declines in sport fish would have negative consequences on the amount of recreation visits to the study area which would have negative effects on the local economies that depend on recreation. Economic effects of sedimentation will be evaluated under a separate task for this project.

Erosion and transport of silts and sediments into Lakes Sakakawea and Oahe can result in the aggradation near boat ramps posing problems to users and rendering them unusable. Dredging the ramps is currently performed when access is blocked by sediment build up on and around ramps; however this poses an ongoing maintenance cost to monitor and remove the sediments to keep ramps open. Complicating the management of sediment bound boat ramps are the lake levels. Severe drought in the recent past has resulted in very low lake levels which leaves some ramps out of the water or the ends of the ramps a long distance from the parking area. Sediment aggradation and boat ramp closures in areas with few points of access would cause additional strain as the cost to remove the sediment may outweigh the benefit of clearing the ramp resulting in ramp closures. Ramp closures in remote locations around the study area would force visitors to drive further to launch a boat. In some areas, building a new ramp nearby is more cost effective than dredging existing ramps.

In addition to compromising access to the water, siltation can compromise boater safety by filling in the historic river channel. When river channels are filled in the resulting shallower reservoir can cause unsuspecting boaters to hit bottom possibly injuring the boaters or causing damage to the boat motors.

Sedimentation can also have negative effects on biological resources. Silt entering the study area settles to the bottom altering the bottoms of the river and reservoirs potentially negatively affecting spawning habitat. Walleye are the most sought after fish in the study area and the area has a productive walleye fishery. Walleye spawn on gravel and siltation greatly reduces the quantity and quality of walleye spawning habitat (Garrison Master Plan, 2007).

Over time, sediment accumulations could fill in the deeper areas of the reservoirs potentially affecting fish habitat by altering water depth and ultimately the volume of cold water habitat necessary for some sport fish. The effects of such a situation would be exacerbated by drought conditions similar to the one experienced in recent years. Steps to preserve cold water habitat within Lake Sakakawea were undertaken by the Corps in 2005 and 2006 by (1) modifying the trash racks on 2 of the 5 penstocks, (2) closing 2 of the 10 passage gates to restrict the opening to the dam's power tunnels, and (3) altering the release schedule. The effects of sedimentation on the aquatic resources including the fisheries are discussed in greater detail under a separate task.

Other effects of siltation occurring in areas other than boat ramps include modified stream channels and bathymetry which can have negative effects on water quality (shallow water equals warmer water which in turn could affect the fishery). Additionally, as sedimentation accumulates and point bars rise, and as water levels decline with the recent drought conditions, the area of land susceptible to overgrowth by invasive species increases, which can cause more problems (USACE 2007).

In reviewing existing USACE reports on sedimentation in the Missouri River, the areas of the river impacted most by the accumulation of sediments occur approximately 10 to 15 miles downstream from the upstream end of the lake zones (Lake Sakakawea and Lake Oahe) created by the Garrison and Oahe Dams. Most of the sediment accumulation is concentrated within a 30-mile reach of these points (Berger, 2008). A tremendous amount of sediment, including sediment from all upstream tributaries has accumulated in the headwaters of Lake Sakakawea (estimated annual deposit rate of 26,000 acre-feet annually) and has buried the old river channel downstream (NDGF 2002). Lower elevations in Lake Sakakawea do not provide additional riverine habitat but rather exposes vast expanses of accumulated sediments (NDGF 2002).

Figure 6–1. shows the locations of formal recreation access sites with the sediment aggradation areas. According to the sediment aggradation maps, nearly all of the intensive use recreation sites on Lake Sakakawea are in areas of the lake with low to moderate sedimentation levels. On Lake Oahe, Graner Park Recreation Area and Kimball Bottom Recreation Area are areas of intense recreational use that are affected by high levels of sedimentation. MacLean Bottom Recreation Area is also identified as an area with high sedimentation levels but the site is considered a low density recreation area. In all, 1.1 million visitors recreated at sites within areas identified as either "low" or "moderate" areas of sediment aggradation on Lake Sakakawea and an additional 2.3 million visitors recreated at similarly identified sites in Lake Oahe according to the aggradation maps (Berger, 2008).

The USACE provides high, mid, and low water ramps at many of the access areas to accommodate changes in reservoir levels which also provides alternative access during periods when ramps are covered with sediment. Most recently Fort Stevenson State Park, Government Bay, and Sanish Bay were locations within the reservoir impacted by sediment on the boat ramps affecting boater access. The Fort Stevenson West Ramp (low water ramp) was closed because it was entirely silted in, however a brand new marina ramp is being constructed on the northwest side of the park. Fort Stevens State Park is approximately 3 miles south of the town of Garrison; however it is not known if sediment is being loaded into the arm from tributary or in-reservoir sources. Government Bay and Sanish Bay were locations within the reservoir that required dredging to provide boater access. The Government Bay low water ramp was completely reconstructed within the last year because of siltation problems as the bay is filling up with silt and there is no longer a good location for moving the boat ramp. Complicating matters, the ramp cannot be extended because of a lack of room. In general, USACE's recent solution has been to move or extend ramps rather than continue to dredge out areas, because it is less expensive (Linda Phelps, USACE personal communication). These areas are within bays or smaller arms that are subject to local sedimentation processes and were not identified as areas of aggradation by the earlier Berger (2008) report that focused on changes in the elevations within the main channel and thalweg.

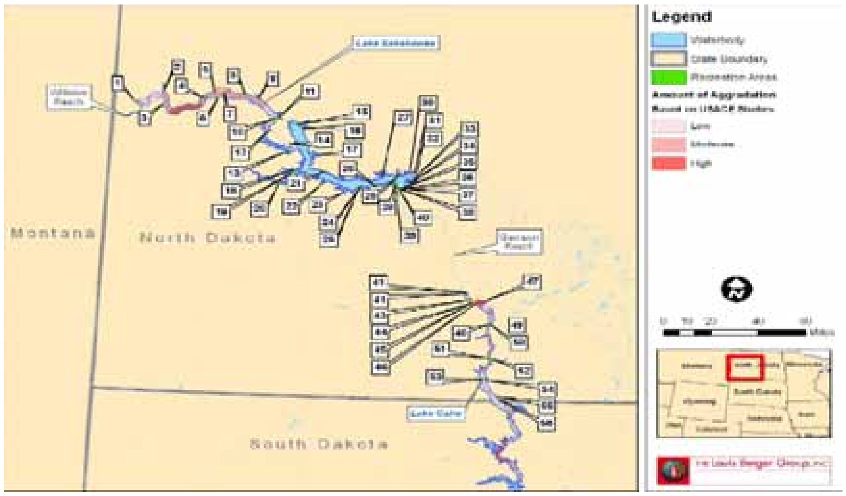


FIGURE 6–1.—*Developed Recreational Sites within Aggragation Areas*

Recent drought conditions have resulted in lower than normal lake levels in Lake Oahe changing the upstream character of the reservoir from a reservoir to that of riverine character. According to the USACE, channel shifting and erosion is occurring at Kimball Bottoms Recreation Area and MacLean Bottoms Recreation Area, limiting recreation access by undercutting the boat ramps or leaving them out of the water as the channel migrates away from the access area. Boat ramps and land based amenities need some level of protection and support from erosion processes. Rip rap has been installed over the years along the east side of Lake Oahe to protect the recreation sites from erosive processes; however this can be challenging in light of large fluctuations in reservoir elevations.

7.0 SUMMARY AND RECOMMENDATIONS

Erosion of the Missouri River above Lake Sakakawea and below Garrison dam poses the same problems in that sediment is moved in the channel and deposited in areas of calm water. When the reservoir is full, sediment is typically deposited further up the river but when the reservoir is down the channel is eroded and those sediments are moved within the channel downstream.

Drought conditions and sedimentation/siltation processes can result in park or access closures preventing recreational access to areas within the reservoirs, directly impacting the recreation resources. The loss of boater access results in longer drives to launch boats, trip cancellation, poor aesthetics, and safety hazards to those using the Missouri River. Boat access site managers are forced to spend an increasing amount of time and resources to operate and maintain the boat ramps free of sediments to maintain boater access. Bays or arms just off the main channel have historically been the primary location of boater access; however these areas are susceptible to sediment aggradation as reported in interviews conducted for this research. It is important to note that these areas were not identified by the sediment aggradation modeling tool so the number of visitors affected by siltation is likely much higher. It is also important to remember that siltation can be a nuisance at boat ramps; however the reservoirs still provide greatest amount of flat water recreation opportunities in the state of North Dakota so that once on the water, recreationists may still report satisfactory trips.

Successfully addressing sedimentation issues within the Missouri River will likely require a holistic approach and recommendations pertaining to the recreation resources would be a part of that solution. Lake Sakakawea and Lake Oahe are relatively young reservoirs and areas identified upon their creation as good or suitable recreation sites (e.g., within bays or off channel arms) have subsequently filled in with sediments. This process is likely to continue into the future until sediment sources and in-reservoir sediment processes like shoreline erosion stabilize. Until then, identifying alternative boat ramp areas within existing parks may alleviate some maintenance of dredging ramps open and should be pursued when long term planning is initiated for the access sites. For example rebuilding boat ramps in areas less susceptible to sediment aggradation may have expensive up front costs; however the overall costs may be lower if there is no need for additional dredging of the ramps on a regular basis. As such, we recommend that strategic planning efforts identify and target areas that are currently susceptible to sediment aggradation, are close to population centers (e.g. Fort Stevens State Park) and have alternative ramp sites that would result in less sediment aggradation on the ramps. Permanent ramp closures is a viable option for access sites that do not have viable alternative locations for new ramps and have regular dredging needs.

USACE maintains a Web site for the boat ramps on Lake Sakakawea and Lake Oahe that informs visitors of the reservoir depth and whether or not ramps are available for use. This is beneficial for visitors because it provides a method to check accessibility and plan trips in advance. We recommend that USACE continue to utilize the Web site planning tool. Although designed primarily for reservoir elevations, this trip planning tool possesses the ability to report closures due to sediment build up as well. Although not likely of interest to visitors, this could provide a way for the USACE to monitor sediment related closures.

Boat ramps have been extended or relocated to accommodate for low water levels. Extension or relocation would also accommodate for sedimentation build up at boat ramps within the study area. Siltation of boat ramps and erosion in other areas along the Missouri River is occurring in certain areas posing a nuisance to some of the open water areas; however, overall there are tremendous opportunities in the area for flat water recreation and access to the reservoirs and rivers. Table 7–1 summarizes the key findings related to the objectives of this task.

TABLE 7–1.—IMPACT OF SEDIMENTATION ON RECREATION RESOURCES

Direct Impact	Significance	Timeline	Recommendations
Ramp or Access Closure	The lack of boater access results in longer drives to launch boats, trip cancellation, poor aesthetics, and safety hazards to those using the Missouri River. Boat access site managers are forced to spend an increasing amount of time and resources to operate and maintain the boat ramps free of sediments to maintain boater access.	Parks and access areas are predominantly used in the summer therefore summer time would have the greatest level of impact, however because sedimentation processes occur throughout the year, impacts to access areas would be on-going.	(1) Identify and prioritize areas, for long term planning purposes, that are currently susceptible to sediment aggradation and are close to population centers (e.g. Fort Stevens State Park) and identify alternative ramp sites that would result in less aggradation on the ramps. (2) Additional study of visitor's willingness to travel in the event that popular boat ramps are closed and the proximity to nearby alternatives. (3) Evaluate extending or relocate boat ramps depending on the first parts above. (4) Evaluate closing ramps at sites that do not have viable alternative locations for new ramps and have regular dredging needs.
Underwater hazards	Shallow water due to sediment deposition pose a risk to boaters and boating equipment.	Dynamic and dependent on reservoir elevations. Summer peak boating season with low lake levels pose the greatest risk.	Evaluate options of educating the boating public, signage and updating bathymetric mapping efforts.

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APPENDIX D—IMPACT OF SILTATION ON HYDROPOWER GENERATION, MISSOURI RIVER, NORTH DAKOTA

EXECUTIVE SUMMARY

This report assesses the impacts of siltation in the Missouri River Basin within the State of North Dakota on hydropower facilities and operations. Hydropower facilities along the Missouri River in North Dakota consist of the Garrison Dam and its reservoir, Lake Sakakawea. In addition, hydropower operations in North Dakota are affected by the operation of Oahe Dam in South Dakota because Lake Oahe extends into southern North Dakota up to just south of the city of Bismarck when the pool is full.

Hydropower Facilities

The two reservoirs are part of the Missouri River Mainstem System (System) consisting of six dams in total. Construction of the System started in the 1930s with the Fort Peck Dam. Garrison Dam was closed in 1953; Oahe Dam was closed in 1958. The Flood Control Act (Pick-Sloan Act) from 1944 specifies that the reservoirs were to be operated as an integrated system. Aside from hydropower, other uses are relevant in the operation of the System: flood control, navigation, irrigation, recreation, water supply, and fish and wildlife.

The hydropower facilities of the System provide dependable energy to meet annual peak power demands of the region. Annual gross power production at the Garrison Dam was on average 2.29 million MWh from 1967 (2 years after Lake Sakakawea was filled) through 2007. However, hydropower operations at Garrison Dam have generally decreased over time to 1.31 MWh in 2007 due to drought. The main exception was a period in the mid-1990s with high precipitation in the upper Missouri River watershed. Peak months of outflow and thus energy generation are December, July, and August due to high power demand.

Power release rates are commonly adjusted on a daily basis to support a variety of uses. The generated electricity is marketed by the Western Area Power Administration (WAPA) which is an agency of the Department of Energy (Western). Revenues are highest during the peak generation months in the winter and summer. The total revenues from energy generated at Garrison Dam in the last 5 years (2003 to 2007) ranged from $15 million to $22 million. Highest annual revenues were generated during the wet year 1996 with $43 million.

Impacts

Potential impacts from siltation in the Missouri River on hydropower operations in North Dakota consist of the following:

—*Loss of Storage in Lake Sakakawea.*—Lake Sakakawea traps nearly 100 percent of the sediment that enters the reservoir. Most of the sediment originates from the Missouri River and the Yellowstone River, a tributary to the Missouri River. This includes sediment that is eroded from the bank and bottom of the Missouri River, downstream of the Fort Peck dam. The USACE estimated a storage loss rate of 25,900 acre-feet/year (or 0.11 percent per year). At this rate, the life expectancy of Lake Sakakawea is approximately 900 years before it is completely filled. This value is a first-order estimate only, as the life expectancy depends on a number of variables such as sediment trapping efficiency (which decreases over time), climate variability over time, and sediment contributions from the watershed of Fort Peck Dam (sediment from its watershed is currently trapped in its reservoir).

—*Entrainment of Sediment Into the Turbines at Garrison Dam.*—With an annual loss of storage capacity by 0.11 percent, and most of the deposition occurring in the upper reaches of the reservoir, impacts to the intakes to the hydropower facility are not expected for a long time. As a result, the USACE does not have any specific sediment management methods or sediment control facilities at their hydroelectric facilities at this time.

—*Reduced Releases at Garrison Dam in Winter Due to Flooding Risk From Sediment Aggradation.*—Siltation in the reach between Garrison Dam and Lake Oahe has resulted in increased risk of flooding in the downstream reach between the dam and the headwater of Oahe Lake. The Missouri River typically freezes in December, remains frozen in January and February, and starts to thaw in March and April. A large consideration in flow releases are the potential formation of ice dams. Aggradation of the river channel in the headwaters of Lake Oahe has resulted in a slightly greater decrease in energy production in the colder months of the years than during the warmer months of the year.

Recommendations

Releases from Garrison Dam by the USACE for various uses already aim to minimize flooding. Detailed monitoring data should continue to be collected to allow for effective adaptive management measures of the operations of Garrison Dam to maximize the benefit of the dam and the overall System, while minimizing impacts. This is particularly important in light of the fact that there are a number of natural variables that change regularly (daily, as well as longterm), such as rainfall, temperature, flow, erosion and deposition patterns, etc. In addition, the river serves multiple uses that also need to be balanced.

Dredging could be considered on a temporary and localized basis for flood control, but a larger-scale dredging operation would most likely be cost-prohibitive.

The risk of flooding will increase once the current drought has passed, and Lake Oahe again has full pool elevations. Higher pool elevations imply that sediment carried by the Missouri River will be settling out closer to the city of Bismarck than at present which will result in further aggradation. A higher risk of flooding requires further reduction in hydropower generation at Garrison Dam. The existing flood plain and zoning should be reviewed in the cities of Bismarck and Mandan (as well as in non-urban areas in the Garrison Dam to Lake Oahe reach) to determine if additional steps should be undertaken to better accommodate high flows in the Missouri River. Developments close to the river edge should be avoided, or potentially even reversed if feasible. Further, appropriate bank stabilization measures should be considered in areas most heavily affected by flooding.

It is recommended to conduct a study that more quantitatively demonstrates that higher elevations in Lake Oahe will result in a decrease in flow velocities due to aggradation. This study would need to address the range of variables that affect the flow in order to extract the impact of lake elevations on outflow rates.

1.0 INTRODUCTION

The Louis Berger Group Inc. (Berger) was tasked by the U.S. Army Corps of Engineers (USACE) to assess impacts of sedimentation in the Missouri River Basin within the State of North Dakota. This assessment was intended to meet the level of effort defined in the Missouri River Protection and Improvement Act. The assessment had two objectives. First, Berger identified sources and deposit locations of sediment within the Missouri River Basin in the State of North Dakota, utilizing existing data and information. Next, the team analyzed the potential impacts of sedimentation on important issues and resources including: local, regional and national economies; recreation; hydropower generation; fish and wildlife; flood control and Indian and non-Indian historical and cultural sites.

The study area was defined by the USACE to include the watershed of the mainstem of the Missouri River from the North Dakota-South Dakota border on the downstream end to the Montana-North Dakota border on the upstream end (Figure 1–1). The study area was to include tributaries of the Missouri River, Lake Sakakawea and Lake Oahe.

This report presents the results of Task 5D—Impact of Siltation on Hydropower Generation. The assessment was based on review of relevant existing data and information. Further, individuals familiar with specific aspects of this task were contacted. The following sections address the results of the task. Section 2 describes the hydropower facilities in the study area. Section 3 address siltation impacts on hydropower operations. Section 4 provides some recommendations.

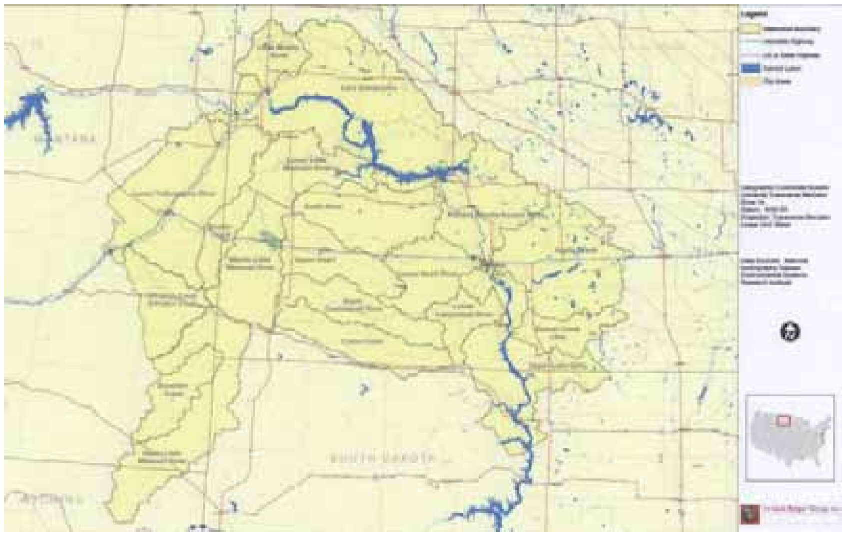

FIGURE 1–1.—*Location of the study area (Scale: 1 inch = 53 miles).*

2.0 HYDROPOWER FACILITIES

2.1 Overview

Hydropower facilities along the Missouri River in North Dakota consist of Garrison Dam and its reservoir, Lake Sakakawea (Figure 2–1). In addition, hydropower operations in North Dakota are affected by the operation of Oahe Dam in South Dakota. Lake Oahe extends into southern North Dakota, and can extend up to just south of the city of Bismarck when the pool is full. Oahe Dam is located just to the north of the city of Pierre in central South Dakota.

Garrison Dam and Oahe Dam and their respective reservoirs are part of the Missouri River Mainstem System (System) consisting of six dams in total (Figure 2–2). The other four dams are Fort Peck Dam, Big Bend Dam, Fort Randall Dam, and Gavins Point Dam. The total drainage area at Gavins Point Dam is 279,480 square miles (Figure 2–3).

Construction of the System started in the 1930s with the Fort Peck Dam. The other five dams were authorized in 1944 by the Flood Control Act (Pick-Sloan Act). This Act specified that the reservoirs were to be operated as an integrated system. Aside from hydropower, other uses are relevant in the operation of the System: flood control, navigation, irrigation, recreation, water supply, and fish and wildlife. In enacting this Act, Congress did not assign a priority to these operational purposes, as stated in the recent Record of Decision (ROD) for the Missouri River Master Control Manual Review and Update (USACE, 2004b). The ROD states further:

"Instead, it was contemplated that the Corps, in consultation with affected interests and other agencies, would consider all of the authorized purposes when making decisions to optimize development and utilization of the water resources of the Missouri River to best serve the needs of the people." (p.1)

The reservoirs in the System have defined zones to facilitate operations. These zones were developed for flood control, multiple uses, and the permanent pool (Figure 2–4). The six dams in the System are operated in an integrated manner to assure that the multi-use goals can be met. For example, Lake Sakakawea and Lake Oahe are significant for flood storage as they have the largest storage capacity of the six impoundments in the System (Figure 2–5).

The reservoir zones are defined as follows (USACE, 2004a):

—*Exclusive Flood Control Zone.*—This zone is the total upper volume of the mainstem lakes maintained exclusively for flood control. The System-wide capacity of this zone is 6 percent. Water is released from this zone as quickly as downstream channel conditions permit so that sufficient storage remains available for capturing future inflows.

—*Annual Flood Control and Multiple Use Zone.*—This zone is reserved for annual flood control and multiple uses. The System-wide capacity of this zone is 16 percent. This zone is used to store the high annual spring and summer inflows to the lakes in the System. Later in the year, water stored in this zone is released for riverine uses so that the zone is evacuated by the beginning of the next flood season on March 1. Evacuation is accomplished mainly during the summer and fall navigation season, because icing of the river may preclude high evacuation flows during the winter.

FIGURE 2–1.—*Aerial photograph of Garrison Dam (Source: Google Earth)*

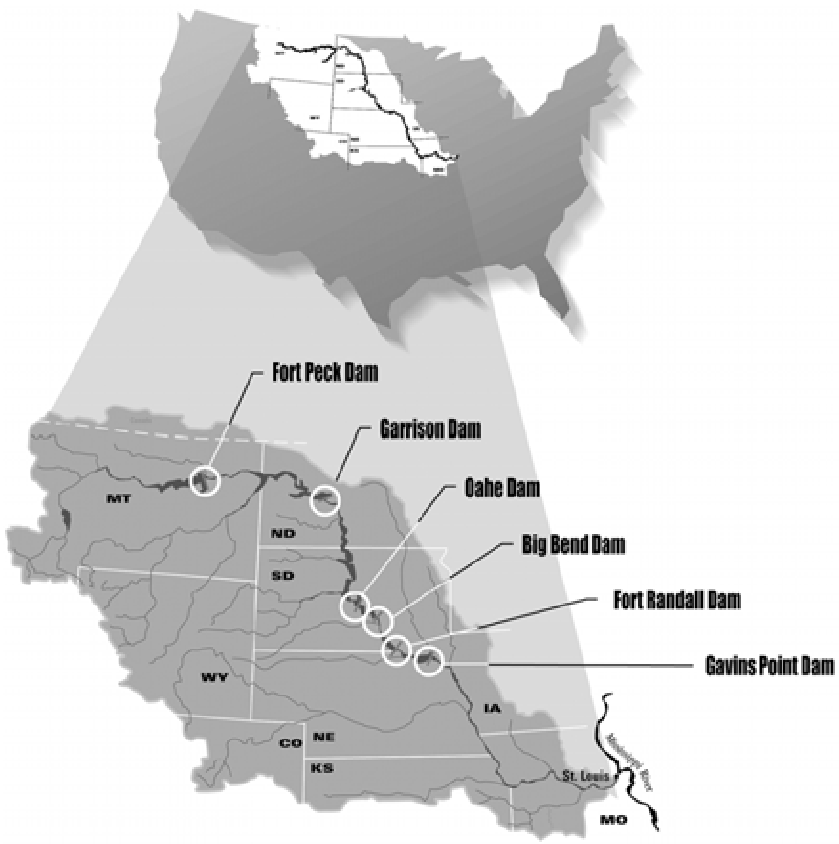

FIGURE 2–2.—*Location of Garrison Dam and Oahe Dam, as part of the Missouri River Mainstem Reservoir System (USACE, 2004a).*

Source: Missouri River Main Stem Reservoirs, Hydrologic Statistics, US Army Corps of Engineers, 1999

FIGURE 2–3.—*Total Drainage at Gavins Point Dam*

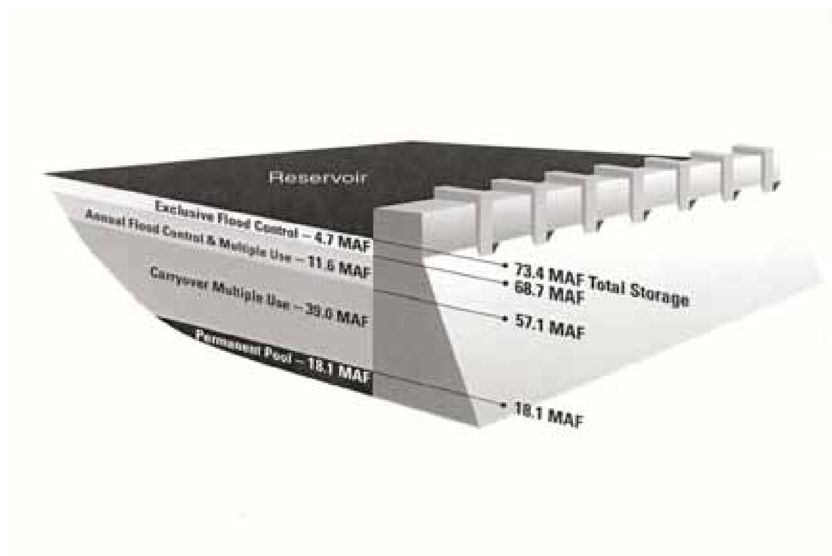

FIGURE 2–4.—*Reservoir zone locations of the system (schematic) (USACE, 2004a).*

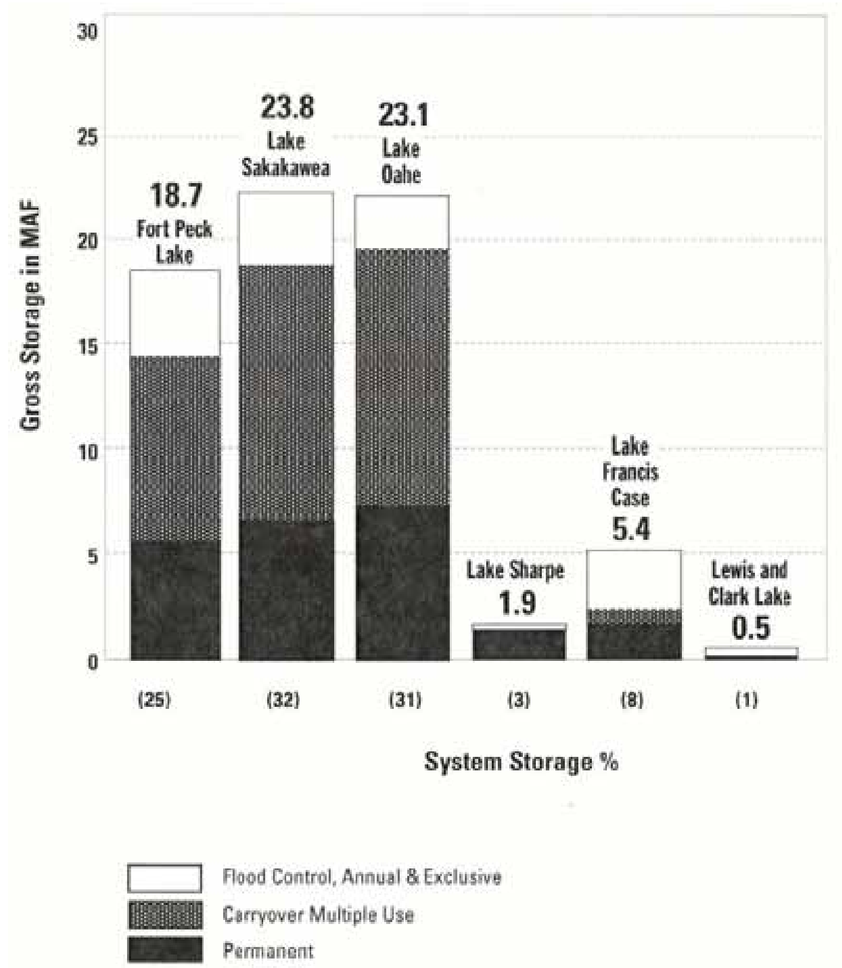

FIGURE 2–5.—*Missouri River mainstem system storage, by mainstem reservoir (USACE, 2004a).*

—*Carryover Multiple Use Zone.*—This zone is the largest portion of the System's upper storage capacity, designed to provide water for all uses during drought periods. This zone is confined to Fort Peck Lake, Lake Sakakawea, Lake Oahe, and Lake Francis Case. The System-wide capacity of this zone is 53 percent. The zone is operated so that it remains full during periods of normal inflow but is gradually drawn down during drought periods.

—*Permanent Pool.*—The remaining total storage capacity (25 percent System-wide) is reserved as the permanent pool. Total capacity allocated for the permanent pool is approximately 18 million acre-feet System-wide. The permanent pool provides the minimal water level necessary to allow the hydropower plants to operate and to provide reserved space for sediment storage. It also serves as a minimum pool for recreation and for fish and wildlife habitat and as an ensured minimum level for pump diversion of water from the lakes.

2.2 Physical Characteristics

2.2.1. Garrison Dam and Lake Sakakawea

Garrison Dam is located at river mile (RM) 1390 in central North Dakota near the Town of Riverdale, approximately 75 river miles northwest of the city of Bismarck. The dam is 180 feet high and one of the largest rolled earthfill dams in the world. Its gross storage capacity is 23.8 million acre-feet (USACE, 2004a). Construction of the Garrison Project started in 1946. Closure of the dam and thus filling of Lake Sakakawea occurred in April 1953. Operation of the powerplant began in 1955. The first three power-generating units were placed on line in 1956. Units 4 and 5 were placed into operation in October 1960.

Relevant physical characteristics of Garrison Dam, Lake Sakakawea, and the watershed for the lake are summarized below (USACE, 2000a; 2004a):

—Garrison Dam
  —Date of Closure—April 1953
  —Height—180 feet
  —Width—11,300 feet
—Lake Sakakawea
  —Pool Elevations (Figure 2–4):
    —Minimum Operating Pool (Top, Permanent Pool)—1,775.0 ft msl
    —Base Flood Control Level (Top, Carryover and Multiple Use Zone)—1,837.5 ft msl
    —Maximum Normal Pool (Top, Annual Flood Control and Multiple Use Zone)—1,850.0 ft msl
    —Maximum Operating Pool (Top, Exclusive Flood Control Reserve)—1,854.0 ft msl
  —Length of Reservoir (full)—178 valley miles
  —Maximum Depth (near dam)—180 feet
  —Shoreline Length (at 1,837.5 msl)—1,340 miles
  —Surface Area (at 1,837.5 msl)—380,000 acres
  —Surface Area (full)—593 sq.mi.
  —Gross Storage—23,821,000 acre-feet
  —Flood Storage—5,711,000 acre-feet
  —Carryover Storage—13,130,000 acre-feet
  —Mean Annual Outflow of Water
    —Rate—22,800 cfs
    —Volume—15.6 million acre-feet
—Watershed
  —Drainage Area for Lake Sakakawea (at Garrison Dam):
    —Including the drainage area of Fort Peck Dam—181,400 sq. mi.
    —Excluding the drainage area of Fort Peck Dam—123,900 sq. mi.

The Fort Peck Dam upstream of Lake Sakakawea was closed in 1937. Most of the sediment entering the Fort Peck Lake is captured by the reservoir, thus reducing the drainage area that supplies sediment to Lake Sakakawea by 32 percent.

2.2.2. Oahe Dam and Lake Oahe

Oahe Dam is located approximately 6 miles to the northwest of the city of Pierre, South Dakota, at RM 1072. It is 200 feet high and has a gross storage capacity is 23.1 million acre-feet (Figure 2–5). Construction of the Oahe Project started in 1948. Closure of the dam was completed in 1958. The pool was first filled in 1962 and the first power unit came on line. All power units were operational in July 1966.

Relevant physical characteristics of Lake Oahe are summarized below (USACE, 2000a; 2004a):

—Oahe Dam
  —Date of Closure—August 1958
  —Height—200 feet
  —Width—9,300 feet
—Lake Oahe
  —Pool Elevations (Figure 2–4):
    —Minimum Operating Pool (Top, Permanent Pool)—1,540.0 ft msl
    —Base Flood Control Level (Top, Carryover and Multiple Use Zone)—1,607.5 ft msl
    —Maximum Normal Pool (Top, Annual Flood Control and Multiple Use Zone)—1,617.0 ft msl
    —Maximum Operating Pool (Top, Exclusive Flood Control Reserve)—1,620.0 ft msl
  —Length of Reservoir (full)—231 valley miles
  —Gross Storage—23,137,000 acre-feet

—Flood Storage—4,303,000 acre-feet
—Carryover Storage—13,461,000 acre-feet
—Watershed
—Drainage Area for Lake Oahe (at Oahe Dam)
—Including the drainage area of Garrison Dam—243,490 sq. mi.
—Excluding the drainage area of Garrison Dam—62,090 sq. mi.

2.3 Power Generation

Most of the water stored in Lake Sakakawea is eventually moved through the reservoir system which enables power production (USACE, 2004a). Runoff between March and July supplies 70 percent of the water used for annual power generation. Water is only bypassed during larger magnitude inflow years.

2.3.1. Garrison Dam and Lake Sakakawea

The primary water management functions of Garrison Dam and Lake Sakakawea are as follows (USACE, 2006, Paragraph 7–02.3, p. VII–3):

"7.02–3. . . . (1) to capture the snowmelt runoff and localized rainfall runoffs from the large drainage area between Fort Peck and Garrison Dams that are then metered out at controlled release rates to meet System requirements, while reducing flood damage in the Garrison Dam and Lake Oahe reach, particularly the urban Bismarck area;

"(2) to serve as a secondary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Oahe and Fort Randall; and

"(3) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes that draft storage during low water years."

There are general requirements for power generation as specified in the Garrison Standing Order from 1983 (Exhibit 1). This order specifies minimum releases for specific time periods. For example, over a 4 hour period, 300 MWh must be generated. The release pattern within these 4 hours to achieve at least 300 MWh can be chosen by WAPA. This requirement is designed to assure that municipal and industrial water intakes between Garrison Dam and Lake Oahe have sufficient water. There are a total of 123 intakes between Garrison Dam and Lake Oahe, which consist of 6 power plant intakes, 3 municipal water supply facilities, 6 industrial intakes, 77 irrigation intakes, 28 domestic intakes, and 3 public intakes (USACE, 2006). Another requirement states that supplementary releases are only to be made as necessary to maintain a daily average release rate of 6,000 cfs at Garrison Dam.

In addition to the Standing Order, the USACE provides WAPA with daily reservoir regulation and power production orders. These orders ensure that requirements for other uses as well as hydrological and meteorological conditions at the time are incorporated. For example, in summer, typically between May 15 and August 30, the shape of the releases is controlled due to nesting of endangered bird species below the Garrison Dam. This limits the peaking pattern for power generation. Also, in winter, release rates are determined based on requirements for ice-in and flood control conditions.

Releases at Garrison Dam in the winter that are affected by flood control considerations are defined in the Master Water Control Manual (USACE, 2006, p. VII–17) as follows:

"**7–04.7.1. Fort Peck and Garrison Flood Control Considerations.** *The winter season is the time period when the firm power demand from the System is the greatest. To enhance winter energy generation, winter releases from the upstream Fort Peck and Garrison reservoirs are often maintained at the maximum level possible that is consistent with downstream channel capacity. During the winter, channel capacity is reduced because of threat of flooding during river ice formation or when an established Missouri River ice cover raises Missouri River stages. Because of the somewhat unpredictable behavior of a downstream ice cover, the exact potential volume of winter releases from these upstream projects cannot be estimated accurately. Prewinter System reservoir storage levels are scheduled on the basis that the established winter release rate will be made most of the time through these upstream powerplants. If channel conditions during the winter are such that the established winter release rate assumed in prewinter scheduling is not possible, a release deviation will be implemented. The changed release rate may result in some imbalance in the amount of water-in-storage in individual System reservoirs by the following spring. This storage imbalance will favor the downstream flood control purpose, with additional evacuated storage space located in the largest downstream System project, Oahe. This is not a matter of great concern because open-water channel capacities* *below Fort Peck and Garrison are sufficient to allow a relatively fast restoration of System storage balance following the ice breakup if attaining a balance in the amount of water-in-storage at the large upper three reservoirs is still a goal at that time of the season."*

Additional considerations during the winter ice season, as they affect flow releases and thus hydropower generation, consist of the following (USACE, 2006, p. VII–19):

"7–04.9. System Regulation Considerations During Winter Ice Season. *The maximum flow that may be passed without damage varies through the length of the Missouri River and is dependent on channel dimensions, the degree of encroachment onto the floodplain, and improvements such as levees and channel modifications. Capacities at specific locations also vary from season to season, especially in the middle and upper river reaches, where a decrease in capacity due to the formation of an ice cover is common through the winter and early spring months. Like with most streams, the capacity of the Missouri River channel usually increases progressively downstream, although instances occur where this trend is reversed."*

7–04.9.4. Ice cover forming on the Missouri River below Fort Peck, Garrison, and Oahe Dams has a marked effect on the winter regulation of these projects. At the time the ice cover first forms below Fort Peck and Garrison Dams, the downstream channel capacities are at a minimum. As the river ice cover stabilizes, flows are normally slowly increased followed by a progressive increase in the channel capacity that continues until just prior to the end of the winter season. It is often possible to increase releases while maintaining relatively constant downstream stages. This phenomenon is discussed in more detail in two RCC Technical Reports, "Freezing of the Missouri River Below Garrison Dam," February 1973, and "Freezing of the Missouri River Below Fort Peck Dam," July 1973. (p. VII–20 to 21)

Lake Sakakawea reached its minimum operating level (1,775 feet msl) in late 1955. The Carryover Zone and Multiple Use Zone was reached only 10 years later, in 1965, due to drought conditions (Figure 2–6). The lake remained generally filled from that time through 1976. Exclusive Flood Control storage space (1,854 feet msl) was used in 1969, 1975, 1995, and 1997. During 1975, all flood control space was filled and the maximum reservoir level was 0.8 feet above the base of the surcharge pool. Since then the reservoir elevation has dropped to below the Carryover Zone and Multiple Use Zone, specifically in the periods between 1987 and 1993, and from 2000 to the present (Figure 2–7; Table 2–1).

The minimum and maximum monthly elevations on Lake Sakakawea have a range of approximately 5 to 15 feet on an annual basis (Figure 2–8). During the winter months (December to February), elevations vary only by a few feet due to the ice cover (Figure 2–9).

The power generation facilities are owned and operated by the U.S. Government. The Western Area Power Administration (WAPA; discussed in more detail in Section 2.4 below) markets and transmits the energy produced by the facility and thus requests releases from the operators within USACE specified requirements.

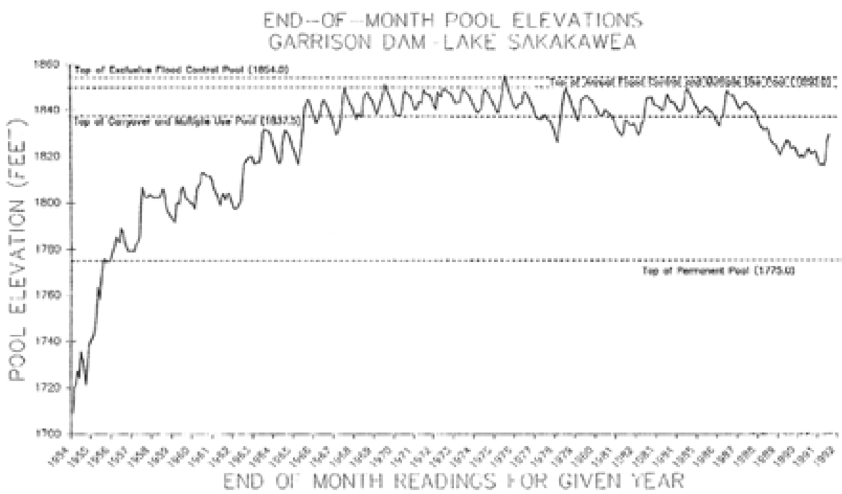

FIGURE 2–6.—*End-of month pool elevations in Lake Sakakawea between closure of Garrison Dam in 1953 and 1993 (Source: USACE, 1993a).*

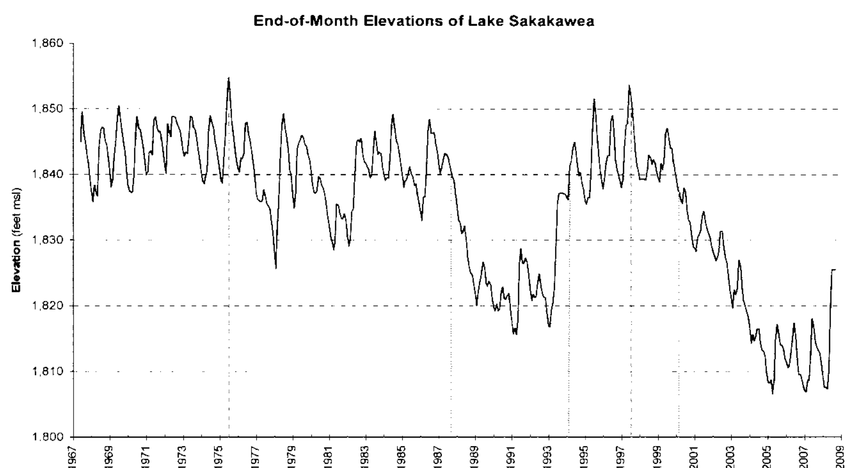

FIGURE 2–7.—*End-of month pool elevations in Lake Sakakawea between 1967 (2 years after reservoir was filled) and the present (Source of data: USACE).*

TABLE 2–1.—END-OF-MONTH ELEVATION OF LAKE SAKAKAWEA, JUNE 1967 TO SEPTEMBER 2008 (IN FEET msl)

[Retrieved on 8-October-2008]

YEAR	MONTH												FULL YEAR (Jan–Dec)			Colder Months (Dec–Apr) [1]		
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	MEAN	MIN	MAX	MEAN
1967	....	....	....	....	....	1,845.0	1,849.5	1,846.2	1,844.9	1,842.9	1,841.5	1,839.2	....	....	....	1,835.8	1,839.2	1,837.6
1968	1,837.3	1,835.8	1,838.4	1,837.2	1,836.7	1,843.8	1,846.7	1,847.2	1,847.1	1,845.2	1,844.5	1,842.6	1,835.8	1,847.2	1,841.9	1,838.1	1,842.6	1,840.6
1969	1,840.3	1,838.1	1,839.3	1,842.6	1,844.7	1,848.0	1,850.5	1,848.5	1,846.6	1,844.9	1,843.4	1,840.7	1,838.1	1,850.5	1,844.0	1,837.3	1,840.7	1,838.2
1970	1,838.4	1,837.5	1,837.3	1,837.3	1,839.9	1,846.1	1,848.8	1,847.1	1,846.8	1,845.6	1,844.0	1,842.0	1,837.3	1,848.8	1,842.6	1,839.9	1,843.6	1,841.8
1971	1,839.9	1,840.4	1,843.3	1,843.6	1,843.0	1,848.3	1,848.8	1,847.1	1,846.5	1,846.6	1,845.4	1,843.4	1,839.9	1,848.8	1,844.7	1,840.2	1,847.7	1,843.8
1972	1,841.3	1,840.2	1,847.7	1,846.5	1,845.8	1,848.8	1,848.9	1,848.7	1,847.9	1,847.3	1,846.7	1,845.3	1,840.2	1,848.9	1,846.3	1,842.8	1,845.3	1,843.7
1973	1,843.6	1,842.8	1,843.4	1,843.2	1,845.5	1,848.9	1,848.7	1,847.2	1,846.8	1,845.6	1,843.8	1,842.3	1,842.3	1,848.9	1,845.2	1,838.6	1,842.3	1,840.0
1974	1,840.4	1,839.0	1,838.6	1,839.8	1,840.5	1,846.6	1,849.0	1,847.9	1,847.1	1,845.1	1,844.0	1,842.3	1,838.6	1,849.0	1,843.4	1,838.7	1,842.7	1,840.7
1975	1,841.0	1,839.0	1,838.7	1,842.7	1,846.2	1,851.3	1,854.8	1,851.2	1,848.2	1,846.2	1,844.0	1,842.0	1,838.7	1,854.8	1,845.4	1,840.4	1,842.5	1,841.6
1976	1,840.9	1,840.4	1,842.5	1,842.4	1,843.2	1,847.8	1,848.0	1,846.2	1,845.1	1,843.5	1,841.7	1,840.0	1,840.0	1,848.0	1,843.5	1,835.8	1,840.0	1,837.1
1977	1,837.3	1,836.2	1,836.1	1,835.8	1,836.0	1,837.7	1,836.9	1,835.6	1,835.2	1,834.8	1,833.0	1,831.0	1,831.0	1,837.7	1,835.5	1,825.7	1,836.0	1,830.5
1978	1,828.0	1,825.7	1,831.7	1,836.0	1,842.5	1,847.5	1,849.3	1,847.0	1,845.7	1,843.8	1,840.9	1,839.8	1,825.7	1,849.3	1,839.8	1,834.9	1,843.9	1,838.5
1979	1,836.8	1,834.9	1,837.0	1,843.9	1,844.8	1,845.3	1,846.0	1,845.6	1,844.6	1,844.3	1,843.1	1,842.2	1,834.9	1,846.0	1,842.4	1,837.1	1,842.2	1,839.1
1980	1,840.5	1,838.5	1,837.3	1,837.1	1,837.6	1,839.7	1,839.4	1,838.4	1,837.9	1,837.1	1,835.6	1,833.6	1,833.6	1,840.5	1,837.7	1,828.5	1,833.6	1,830.9
1981	1,832.3	1,830.5	1,829.6	1,828.5	1,829.8	1,835.5	1,835.3	1,834.1	1,833.3	1,833.3	1,834.0	1,832.9	1,828.5	1,835.5	1,832.4	1,829.0	1,834.3	1,831.4
1982	1,830.6	1,829.0	1,830.1	1,834.3	1,834.8	1,840.5	1,845.0	1,845.3	1,845.0	1,845.5	1,843.0	1,842.0	1,829.0	1,845.5	1,838.8	1,839.5	1,842.0	1,841.0
1983	1,841.7	1,841.2	1,840.7	1,839.5	1,839.9	1,843.3	1,846.6	1,845.0	1,843.1	1,843.4	1,843.2	1,841.4	1,839.5	1,846.6	1,842.4	1,839.1	1,841.4	1,839.9
1984	1,840.0	1,839.1	1,839.5	1,839.5	1,842.4	1,847.7	1,849.2	1,847.2	1,845.2	1,844.6	1,843.2	1,841.6	1,839.1	1,849.2	1,843.3	1,838.1	1,841.6	1,839.6
1985	1,840.0	1,838.1	1,838.9	1,839.3	1,840.1	1,841.2	1,840.1	1,839.6	1,838.4	1,838.6	1,837.1	1,835.7	1,835.7	1,841.2	1,838.9	1,833.0	1,836.6	1,835.2
1986	1,834.3	1,833.0	1,836.6	1,836.6	1,840.5	1,846.5	1,848.4	1,846.3	1,846.3	1,846.4	1,844.7	1,843.5	1,833.0	1,848.4	1,841.9	1,840.1	1,843.5	1,841.7
1987	1,841.5	1,840.1	1,841.0	1,842.2	1,843.2	1,843.1	1,842.7	1,841.6	1,840.5	1,839.7	1,839.1	1,837.3	1,837.3	1,843.2	1,841.0	1,831.0	1,837.3	1,833.8
1988	1,835.2	1,833.0	1,832.7	1,831.0	1,831.2	1,832.2	1,830.2	1,827.4	1,825.9	1,825.0	1,824.7	1,823.2	1,823.2	1,835.2	1,829.3	1,820.1	1,823.6	1,822.1
1989	1,821.8	1,820.1	1,822.0	1,823.6	1,824.8	1,826.7	1,825.9	1,823.4	1,823.0	1,823.8	1,823.2	1,821.1	1,820.1	1,826.7	1,823.3	1,819.2	1,821.1	1,819.9
1990	1,819.8	1,819.2	1,820.3	1,819.2	1,819.4	1,821.9	1,822.9	1,821.1	1,821.0	1,821.6	1,821.9	1,819.7	1,819.2	1,822.9	1,820.7	1,815.6	1,819.7	1,817.0
1991	1,817.6	1,815.7	1,816.6	1,815.6	1,817.8	1,826.4	1,828.7	1,826.5	1,826.5	1,827.3	1,826.7	1,824.8	1,815.6	1,828.7	1,822.5	1,820.8	1,824.8	1,822.2
1992	1,822.4	1,820.8	1,821.8	1,821.3	1,821.4	1,823.4	1,824.9	1,823.0	1,821.8	1,821.3	1,821.3	1,818.8	1,818.8	1,824.9	1,821.9	1,816.8	1,820.5	1,818.5
1993	1,816.9	1,816.8	1,819.4	1,820.5	1,822.9	1,828.8	1,835.6	1,837.1	1,837.2	1,837.2	1,837.1	1,837.0	1,816.8	1,837.2	1,828.9	1,836.2	1,842.0	1,838.6
1994	1,836.5	1,836.2	1,841.3	1,842.0	1,843.8	1,845.0	1,843.5	1,841.3	1,839.8	1,840.3	1,838.7	1,837.8	1,836.2	1,845.0	1,840.5	1,835.5	1,837.8	1,836.5
1995	1,836.0	1,835.5	1,836.5	1,836.5	1,839.9	1,846.5	1,851.6	1,849.2	1,845.6	1,842.8	1,840.4	1,838.9	1,835.5	1,851.6	1,841.6	1,837.8	1,842.9	1,840.2
1996	1,837.8	1,839.5	1,841.8	1,842.9	1,842.9	1,848.2	1,849.0	1,845.8	1,842.3	1,840.8	1,839.9	1,838.9	1,837.8	1,849.0	1,842.5	1,838.0	1,847.5	1,841.6
1997	1,838.0	1,839.4	1,844.4	1,847.5	1,847.8	1,853.7	1,852.2	1,849.9	1,846.9	1,843.4	1,841.4	1,840.7	1,838.0	1,853.7	1,845.4	1,839.3	1,840.7	1,839.6
1998	1,839.3	1,839.3	1,839.4	1,839.3	1,839.2	1,840.8	1,843.0	1,842.6	1,841.6	1,842.3	1,841.8	1,840.4	1,839.2	1,843.0	1,840.8	1,838.9	1,841.7	1,840.3
1999	1,839.5	1,838.9	1,841.7	1,840.8	1,842.0	1,846.3	1,847.1	1,845.5	1,844.1	1,844.0	1,842.0	1,840.6	1,838.9	1,847.1	1,842.7	1,836.0	1,840.6	1,838.2

TABLE 2–1.—END-OF-MONTH ELEVATION OF LAKE SAKAKAWEA, JUNE 1967 TO SEPTEMBER 2008 (IN FEET msl)—Continued

[Retrieved on 8-October-2008]

YEAR	MONTH												FULL YEAR (Jan–Dec)			Colder Months (Dec–Apr)[1]		
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	MEAN	MIN	MAX	MEAN
2000	1,839.3	1,837.7	1,837.3	1,836.0	1,835.6	1,838.0	1,837.4	1,834.6	1,833.1	1,832.7	1,830.5	1,829.0	1,829.0	1,839.3	1,835.1	1,828.3	1,830.9	1,829.5
2001	1,828.7	1,828.3	1,830.4	1,830.9	1,831.6	1,833.8	1,834.4	1,832.8	1,831.8	1,831.1	1,830.5	1,829.2	1,828.3	1,834.4	1,831.1	1,826.9	1,829.2	1,827.9
2002	1,828.3	1,827.6	1,826.9	1,827.5	1,828.3	1,831.4	1,831.4	1,829.2	1,827.5	1,826.6	1,824.6	1,822.5	1,822.5	1,831.4	1,827.7	1,819.7	1,822.5	1,821.5
2003	1,821.1	1,819.7	1,822.4	1,821.7	1,822.6	1,827.0	1,826.1	1,822.9	1,820.9	1,820.1	1,819.1	1,818.4	1,818.4	1,827.0	1,821.8	1,814.3	1,818.4	1,815.9
2004	1,816.7	1,814.3	1,815.6	1,814.7	1,815.3	1,816.5	1,816.5	1,814.3	1,813.3	1,813.1	1,812.3	1,810.0	1,810.0	1,816.7	1,814.4	1,806.6	1,810.0	1,808.4
2005	1,808.4	1,808.2	1,808.7	1,806.6	1,808.8	1,814.9	1,817.2	1,815.8	1,814.1	1,814.0	1,813.5	1,812.0	1,806.6	1,817.2	1,811.9	1,810.6	1,812.5	1,811.4
2006	1,811.4	1,810.6	1,810.7	1,812.5	1,814.7	1,817.4	1,815.5	1,812.1	1,809.5	1,809.6	1,808.9	1,807.8	1,807.8	1,817.4	1,811.7	1,806.9	1,808.7	1,807.8
2007	1,807.0	1,806.9	1,808.7	1,808.6	1,813.1	1,818.1	1,816.9	1,814.6	1,813.7	1,813.2	1,812.7	1,810.9	1,806.9	1,818.1	1,812.0	1,807.3	1,810.9	1,808.5
2008	1,809.1	1,807.6	1,807.6	1,807.3	1,810.2	1,819.6	1,825.6	1,825.5	1,825.6	....	....	....	....	....	....	....	....	....
STATISTICS (JANUARY 1968 TO DECEMBER 2007)																		
NUM	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
MIN	1,807.0	1,806.9	1,808.7	1,806.6	1,808.8	1,814.9	1,815.5	1,812.1	1,809.5	1,809.6	1,808.9	1,807.8	1,806.6	1,816.7	1,811.7	1,806.6	1,808.7	1,807.8
MEAN	1,832.2	1,831.2	1,832.7	1,833.2	1,834.5	1,838.4	1,839.3	1,837.6	1,836.4	1,835.8	1,834.6	1,833.1	1,829.7	1,839.9	1,834.9	1,830.1	1,834.1	1,831.9
MAX	1,843.6	1,842.8	1,847.7	1,847.5	1,847.8	1,853.7	1,854.8	1,851.2	1,848.2	1,847.3	1,846.7	1,845.3	1,842.3	1,854.8	1,846.3	1,842.8	1,847.7	1,843.8
STDEV	10.3	10.4	10.6	11.0	10.8	10.9	11.4	11.7	11.6	11.2	10.9	11.0	10.6	11.2	10.7	10.9	11.4	11.1

[1] Rows include Jan to Apr of following year.

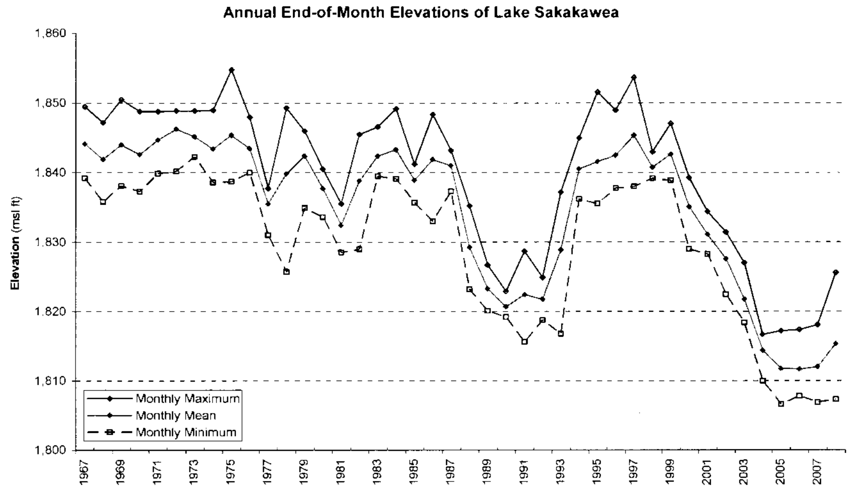

FIGURE 2–8.—*End-of-month pool elevations in Lake Sakakawea; monthly mean, minimum and maximum for each year (Source of data: USACE).*

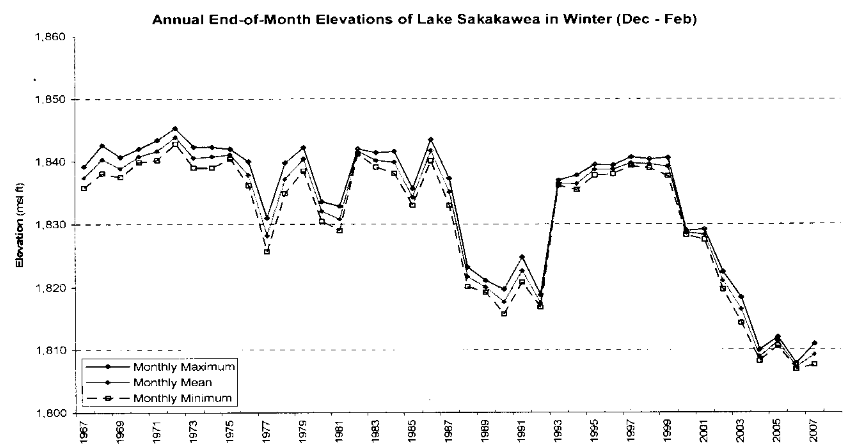

Figure 2–9.—*End-of-month pool elevations in Lake Sakakawea; monthly mean, minimum and maximum in winter only (Dec–Feb) for each year (Source of data: USACE).*

Outflows from Lake Sakakawea at Garrison Dam are commonly through the power facilities. The power facilities have a normal capacity of 38,000 cfs and a maximum capacity of 41,000 cfs (USACE, 2008). The average outflow is 22,800 cfs, resulting in an annual plant factor of approximately 60 percent (USACE, 2006). In 1975 and 1997, record high runoff in the upper Missouri River watershed required outflows of 65,000 cfs and 59,000 cfs, respectively, which partially bypassed the power facilities. The minimum mean daily release rate since 1956 occurred in 1997 at 4,100 cfs (USACE, 2006).

Flows in spring and fall may be reduced to between 10,000 and 15,000 cfs during droughts to conserve water; this rate provides the minimum protection of water supply intakes, water quality, irrigation needs, recreation, and fish and wildlife (USACE, 2004a). Flows may be 20,000 to 30,000 cfs during flood evacuation periods. Flows are also sensitive to bird nesting (USACE, 2004a, p. 3–12):

"To discourage terns and plovers from nesting too near the water during the mid-May through August nesting period, daily releases are usually fixed at a constant rate in the 19,000 to 26,000 cfs range with hourly peaking limited to 6 hours a day near 30,000 cfs. This release pattern restricts hydropower capacity to less than full powerplant capacity. During prolonged droughts, daily average releases for the birds may be in the 10,000 to 15,000 cfs range with peaking restricted even further. During large system inflow years, large flood control evacuation release rates are necessary and nesting flow restrictions are lifted."

Garrison Dam has a five unit power plant. The combined generating capacity of the five turbines at Garrison Dam is 583.3 MW (Jody Farhat, pers. communication, November 14, 2008). This reflects a recent upgrade from previously 518 MW (USACE, 2006).

Annual gross power generation at Garrison Dam was on average 2.29 million MWh from 1967 (2 years after Lake Sakakawea was filled) through 2007 (Table 2–2).[1] During this time, the annual power generation at the dam has ranged from 1.31 million MWh in 2007 to 3.35 million MWh in 1975 (Figures 2–10 and 2–11). In general, power generation has decreased over time, largely as a function of decreased runoff in the watershed caused by drought. The exception occurred during the mid-1990s when spring snowmelting and high rainfall in the Upper Missouri River watershed resulted in high power generation rates.

On a monthly basis, the range between minimum and maximum monthly power generation is generally greater with higher total annual generation (Figure 2–12). The lowest monthly generation during any year since 1967 was 82,820 MWh (November 2007). The highest monthly generation during any year since 1967 occurred in July 1997 with 377,870 MWh.

Hydropower generation is highest during the winter heating season (December to mid-February) and in the summer when air-conditioning systems are used (mid-June to early September) (Figure 2–13). Almost all of the power generated at Garrison Dam is supplied to the grid; less than 1 percent of the total power produced is used for on-site operations (Jody Farhat, personal communications, November 14, 2008).

2.3.2. Oahe Dam and Lake Oahe

The primary water management functions of Oahe Dam and Lake Oahe are similar to the functions of Garrison Dam and Lake Sakakawea, as defined in the Master Water Control manual as follows (USACE, 2006, p. VII–3):

"(1) To capture plains snowmelt and localized rainfall runoffs from the large drainage area between Garrison and Oahe Dams that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Oahe Dam to Big Bend reach, especially in the urban Pierre and Fort Pierre areas;

"(2) To serve as a primary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Big Bend, Fort Randall, and Gavins Point; and

"(3) To provide the extra water needed to meet project purposes that draft storage during low-water years, particularly downstream water supply and navigation.

"In addition, hourly and daily releases from Big Bend and Oahe Dams fluctuate widely to meet varying power loads. Over the long term, their release rates are geared to back up navigation releases from Fort Randall and Gavins Point Dams in addition to providing storage space to permit a smooth transition in the scheduled annual fall drawdown of Fort Randall. Big Bend, with less than 2 million acre-feet of storage, is primarily used for hydropower production, so releases from Oahe are generally passed directly through Big Bend."

The Carryover and Multiple Use space (1,607.5 ft msl) of Lake Oahe was filled in 1967. This space remained generally filled with the exception of the periods between 1987 and 1993, and from 2000 to the present (Table 2–3; Figures 2–14 and 2–15). Monthly variability was lowest during winter months (Figure 2–16). The variability in the elevations in Lake Oahe was very similar to the variability in Lake Sakakawea (Figures 2–7 to 2–9), as expected given the primary water management functions of Lake Oahe (stated above). Outflows are typically through the power facilities.

[1] Net energy generation is consistently about 99.5 percent of gross energy generation. The difference between gross and net is that gross includes generator loss through the transformers and the amount of power the plant uses (station service) to generate the power (James Mueller, USACE, personal communication, January 8, 2009).

The highest monthly elevations occurred in June 1995, June 1996, and July 1997 with elevations of 1,618 feet msl. In 2007, the maximum monthly lake elevation was 35 feet lower at 1,583 feet msl (June 2007).

TABLE 2–2.—GROSS ENERGY PRODUCTION IN GARRISON RESERVOIR, JUNE 1967 TO SEPTEMBER 2008 (IN MWh)

[Retrieved on 8-October-2008]

YEAR	MONTH												FULL YEAR (Jan–Dec)				Colder Months (Dec–Apr)		
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	TOTAL	MEAN	MIN	MAX	MEAN
1967	....	....	....	....	....	232,818	295,092	336,767	237,050	275,633	237,942	241,156	232,818	336,767	....	....	172,681	252,539	222,647
1968	252,539	250,001	172,681	196,858	181,466	149,118	156,431	189,139	212,389	290,561	220,158	234,317	149,118	290,561	2,505,658	208,805	226,709	274,214	255,821
1969	270,694	273,173	274,214	226,709	220,131	163,022	257,475	282,114	238,412	234,153	234,215	270,807	163,022	282,114	2,945,119	245,427	184,253	270,807	227,939
1970	238,768	229,732	184,253	216,135	249,277	249,694	253,971	260,164	202,972	254,324	255,847	226,249	184,253	260,164	2,821,386	235,116	226,249	310,917	263,027
1971	278,471	237,686	261,810	310,917	344,378	316,965	332,812	252,987	219,089	227,357	231,432	227,571	219,089	344,378	3,241,475	270,123	227,571	339,180	265,772
1972	264,805	246,236	251,070	339,180	355,277	337,281	259,622	223,343	193,055	207,270	207,332	216,580	193,055	355,277	3,101,051	258,421	184,710	252,601	220,806
1973	252,601	214,626	235,511	184,710	162,558	175,566	195,675	200,477	182,992	184,094	183,062	216,226	162,558	252,601	2,388,098	199,008	173,132	239,337	215,725
1974	239,337	220,615	229,313	173,132	193,606	216,058	250,441	265,274	217,902	274,602	224,294	229,846	173,132	274,602	2,734,420	227,868	159,040	229,846	209,749
1975	202,670	228,625	228,566	159,040	300,368	344,928	327,106	346,401	344,051	307,207	301,414	259,895	159,040	346,401	3,350,271	279,189	238,366	280,298	257,492
1976	238,366	267,342	241,560	280,298	293,607	337,657	347,855	297,624	241,298	240,857	267,802	222,627	222,627	347,855	3,276,893	273,074	145,158	261,495	208,742
1977	261,495	226,827	187,604	145,158	146,577	140,361	161,710	149,503	130,351	116,836	144,514	188,750	116,836	261,495	1,999,686	166,641	152,426	238,901	194,929
1978	238,901	223,758	170,809	152,426	147,911	282,902	365,976	359,461	297,607	294,386	288,538	216,800	147,911	365,976	3,039,475	253,290	216,800	273,286	244,758
1979	273,286	242,247	243,472	247,986	337,281	326,261	248,273	200,522	161,316	143,923	131,469	185,069	131,469	337,281	2,741,105	228,425	180,241	250,217	214,344
1980	211,978	250,217	244,215	180,241	171,693	187,355	242,163	220,382	195,389	205,592	215,010	192,581	171,693	250,217	2,516,816	209,735	144,434	223,298	196,664
1981	223,298	221,708	201,301	144,434	157,530	220,945	258,497	211,709	169,211	137,018	134,494	174,483	134,494	258,497	2,254,628	187,886	150,534	246,046	206,238
1982	229,612	246,046	230,513	150,534	220,269	205,686	241,775	196,792	165,964	182,936	273,082	214,505	150,534	273,082	2,557,714	213,143	195,282	265,769	226,011
1983	195,282	252,410	265,769	202091	158451	166,381	171,991	255,878	213,868	133,385	156,472	209,450	133,385	265,769	2,381,428	198,452	149,491	255,688	205,239
1984	255,688	234,352	177,212	149,491	133,458	133,898	219,728	268,821	241,132	229,359	235,378	208,485	133,458	268,821	2,487,002	207,250	160,436	252,369	207,842
1985	252,369	240,712	177,209	160,436	177,001	188,864	185,625	173,756	156,144	127,688	139,786	199,184	127,688	252,369	2,178,774	181,565	170,761	235,321	209,425
1986	235,321	212,537	229,322	170,761	99,653	141,125	188,609	235,182	184,242	214,922	226,168	193,816	99,653	235,321	2,331,658	194,305	97,604	231,899	181,663
1987	226,673	231,899	158,323	97,604	148,884	169,561	180,083	178,711	154,063	127,735	122,734	191,642	97,604	231,899	1,987,912	165,659	159,051	223,301	189,689
1988	198,547	223,301	175,902	159,051	168,085	166,187	172,799	160,599	117,128	95,739	94,058	159,654	94,058	223,301	1,891,050	157,588	130,908	170,372	152,551
1989	163,976	170,372	137,847	130,908	182,384	192,195	198,356	190,547	108,517	95,189	158,685	170,366	95,189	198,356	1,899,342	158,279	128,636	206,707	160,120
1990	206,707	148,555	128,636	146,336	164,180	168,175	172,163	158,428	92,532	88,832	96,474	148,656	88,832	206,707	1,719,674	143,306	103,663	173,156	145,017
1991	173,156	159,305	103,663	140,304	163,980	161,695	174,731	173,966	118,687	116,791	122,517	166,840	103,663	174,731	1,775,635	147,970	108,911	196,593	154,783
1992	196,593	164,598	108,911	136,972	169,802	164,615	172,671	160,192	115,239	86,884	84,653	156,621	84,653	196,593	1,717,751	143,146	85,072	159,708	119,047
1993	159,708	104,673	89,163	85,072	134,907	138,487	137,753	149,864	104,769	96,345	102,339	130,855	85,072	159,708	1,433,935	119,495	111,526	136,453	122,297
1994	136,453	117,532	115,117	111,526	231,975	216,358	190,774	184,486	150,159	112,592	128,289	180,847	111,526	231,975	1,876,108	156,342	111,981	199,766	160,562
1995	199,766	175,462	134,753	111,981	119,587	105,419	137,043	300,487	347,671	353,293	294,565	197,713	105,419	353,293	2,477,740	206,478	182,434	250,196	208,567
1996	221,226	191,266	182,434	250,196	290,399	335,550	367,096	359,879	331,570	261,562	197,127	185,159	182,434	367,096	3,173,464	264,455	153,772	218,714	179,118
1997	218,714	183,318	153,772	154,629	297,147	360,731	377,870	362,492	359,527	356,377	316,385	199,143	153,772	377,870	3,340,105	278,342	170,373	199,143	187,931
1998	197,614	198,563	173,961	170,373	214,778	223,976	219,973	220,021	185,343	146,834	175,793	190,242	146,834	223,976	2,317,471	193,123	190,242	235,541	215,544
1999	221,959	217,155	212,825	235,541	236,204	265,232	267,076	260,022	210,046	171,329	154,754	177,371	154,754	267,076	2,629,514	219,126	163,472	200,649	179,326

2000	187,146	200,649	163,472	167,992	197,165	209,323	210,979	204,901	151,966	122,592	174,651	153,161	122,592	210,979	2,143,997	178,666	103,331	159,385	131,686
2001	159,385	129,011	113,542	103,331	105,408	116,976	121,032	122,385	94,213	85,351	85,865	111,259	85,351	159,385	1,347,758	112,313	86,132	111,452	101,800
2002	111,452	100,760	99,396	86,132	106,810	172,552	179,593	180,714	144,581	118,357	146,246	162,429	86,132	180,714	1,609,022	134,085	142,549	164,934	154,186
2003	150,925	164,934	142,549	150,091	155,550	174,755	183,761	177,311	135,844	86,510	93,167	130,288	86,510	183,761	1,745,685	145,474	130,288	171,953	144,374
2004	156,136	171,953	132,585	130,906	126,761	140,007	145,470	138,970	116,618	92,022	97,700	119,484	92,022	171,953	1,568,612	130,718	90,236	129,719	110,276
2005	118,210	90,236	93,733	129,719	125,240	115,245	125,521	127,459	110,058	100,814	103,473	122,061	90,236	129,719	1,361,769	113,481	104,814	140,181	118,134
2006	140,181	109,310	114,305	104,814	122,996	158,479	169,765	176,082	135,781	94,534	99,072	117,784	94,534	176,082	1,543,103	128,592	100,052	121,942	112,050
2007	121,942	108,113	112,359	100,052	104,596	125,814	130,747	129,425	90,900	85,512	82,820	117,329	82,820	130,747	1,309,609	109,134	92,767	117,329	106,900
2008	117,115	110,226	97,062	92,767	98,124	110,098	114,729	119,052	104,899				92,767	119,052					
STATISTICS (JANUARY 1968 TO DECEMBER 2007)																			
NUM	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
MIN	111,452	90,236	89,163	85,072	99,653	105,419	121,032	122,385	90,900	85,351	82,820	111,259	82,820	129,719	1,309,609	109,134	85,072	111,452	101,800
MEAN	207,049	196,995	176,341	167,352	190,433	204,135	217,525	217,662	183,565	172,542	175,046	184,404	130,426	251,968	2,293,048	191,087	150,835	215,467	184,154
MAX	278,471	273,173	274,214	339,180	355,277	360,731	377,870	362,492	359,527	356,377	316,385	270,807	222,627	377,870	3,350,271	279,189	238,366	339,180	265,772
STDEV	46,092	51,293	54,583	58,839	70,316	73,284	70,593	66,272	72,898	80,590	69,785	39,825	39,164	69,461	609,547	50,796	43,119	54,891	46,665

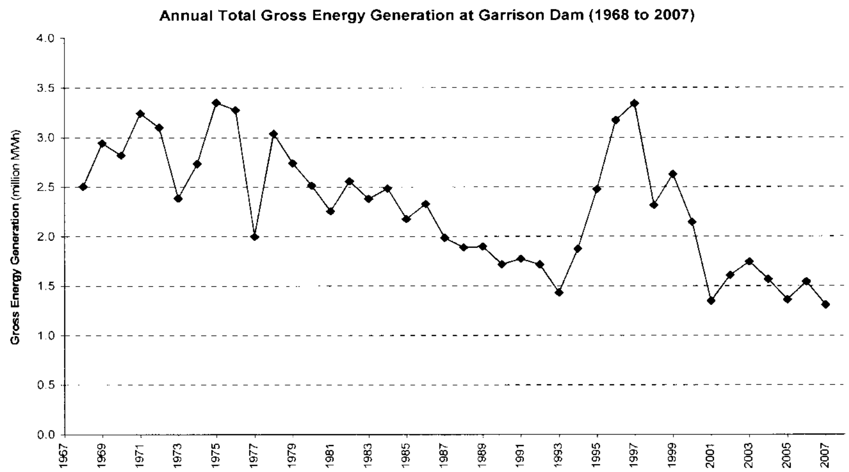

FIGURE 2–10.—*Annual total gross energy generation at Garrison Dam (Source of data: USACE).*

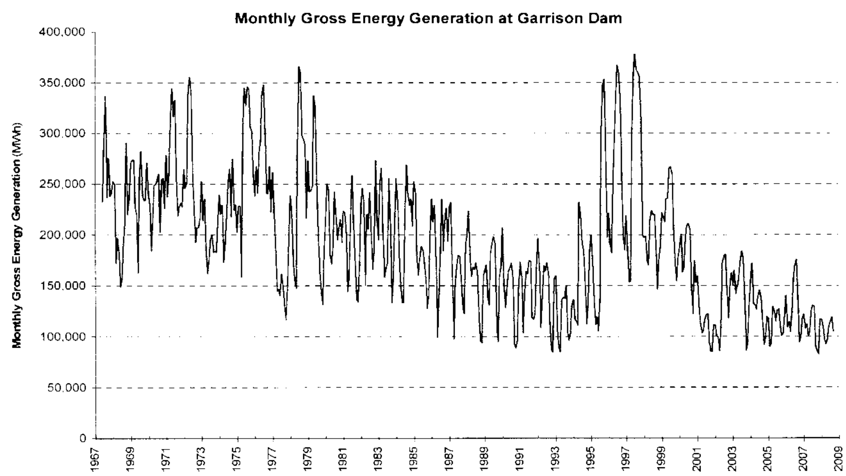

FIGURE 2–11.—*Monthly gross energy generation at Garrison Dam (Source of data: USACE).*

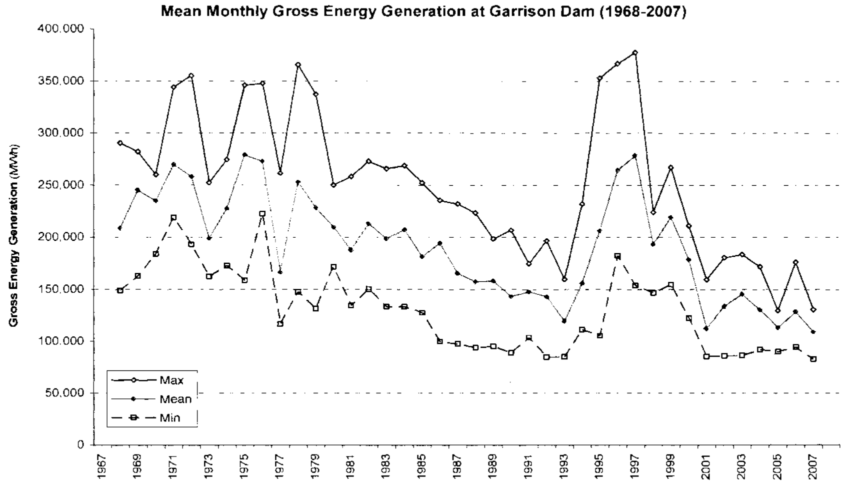

FIGURE 2–12.—*Gross energy generation at Garrison Dam; monthly mean, minimum and maximum for each year (Source of data: USACE).*

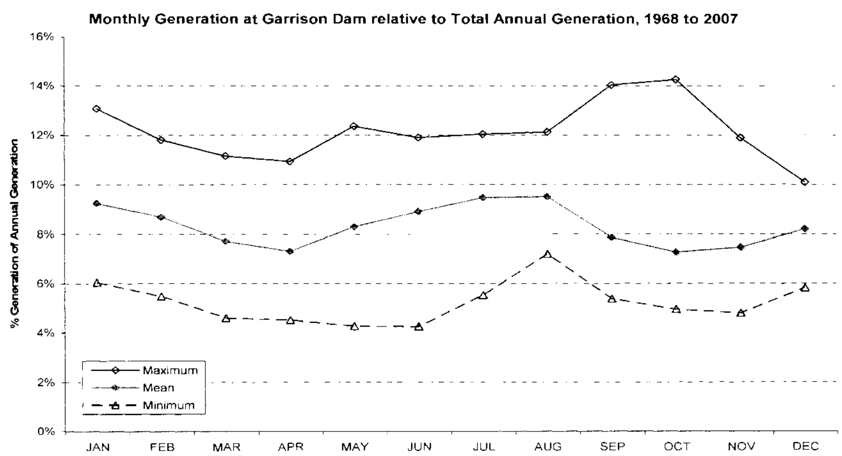

FIGURE 2–13.—*Monthly gross energy generation at Garrison Dam, relative to total annual generation Highest mean generation occurred in December, July, and August (Source of data: USACE).*

2.4 Western Area Power Administration (WAPA)

The Western Area Power Administration (WAPA) is an agency of the Department of Energy (Western). WAPA markets and transmits the power generated by the dams of the System by law at cost to non-profit preference power entities. Wholesale electrical power is transmitted through an integrated 17,000-circuit mile, high-voltage transmission system across 15 Western States including North Dakota, South Dakota, Nebraska, Utah, Nevada, California, and portions of Minnesota, Iowa, Kansas, Colorado New Mexico, Arizona, Texas, Wyoming, and Montana. The six projects in the System (including Garrison Dam and Oahe Dam) generated on average 8.3 million MWh per year between fiscal year 1997 and 2007, ranging from 5.0 million MWH in 2007 to 13.9 MWh in 1997.

2.5 Benefits of System's Hydropower Facilities

The hydropower facilities of the System are beneficial to the region as they provide dependable cost-based energy to meet Western's share of the annual peak power demands. Energy generated by these facilities have valuable characteristics that improve the reliability and efficiency of the electric power supply system, such as efficient peaking, a rapid rate of unit unloading, and rapid power availability for emergencies in the power grid (USACE, 2006). However, the limitations placed upon the power plant detailed above limits the plant from being an optimally efficient peaking facility. Another benefit is the fact that the facilities generate clean energy with a minimal carbon-footprint.

TABLE 2–3.—END-OF-MONTH ELEVATION OF LAKE OAHE, JUNE 1967 TO SEPTEMBER 2008 (IN FEET msl)

[Retrieved on 8-October-2008]

YEAR	MONTH												FULL YEAR (Jan–Dec)			Colder Months (Dec–Apr) [1]		
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	MEAN	MIN	MAX	MEAN
1967	....	....	....	....	....	1,598.3	1,599.5	1,601.5	1,602.8	1,604.2	1,606.2	1,606.9	....	....	....	1,606.9	1,609.0	1,608.4
1968	1,608.7	1,609.0	1,608.8	1,608.8	1,607.4	1,606.7	1,603.3	1,601.0	1,599.9	1,602.8	1,604.7	1,604.7	1,599.9	1,609.0	1,605.5	1,604.7	1,615.6	1,609.4
1969	1,605.1	1,608.8	1,612.8	1,615.6	1,615.8	1,613.7	1,614.3	1,610.4	1,607.6	1,606.2	1,606.7	1,607.9	1,605.1	1,615.8	1,610.4	1,605.7	1,608.7	1,607.3
1970	1,606.5	1,607.6	1,605.7	1,608.7	1,612.5	1,612.8	1,610.0	1,607.5	1,605.1	1,604.9	1,605.9	1,604.5	1,604.5	1,612.8	1,607.6	1,604.5	1,615.5	1,609.6
1971	1,606.1	1,608.5	1,613.4	1,615.5	1,616.7	1,616.2	1,614.7	1,610.5	1,607.2	1,604.9	1,602.2	1,601.2	1,601.2	1,616.7	1,609.8	1,601.2	1,609.8	1,605.3
1972	1,602.4	1,603.9	1,609.0	1,609.8	1,614.4	1,615.8	1,614.4	1,610.2	1,606.4	1,602.6	1,601.0	1,599.9	1,599.9	1,615.8	1,607.5	1,599.9	1,608.8	1,604.3
1973	1,602.3	1,603.1	1,607.3	1,608.8	1,608.5	1,607.8	1,606.1	1,603.4	1,602.4	1,602.2	1,603.8	1,604.4	1,602.2	1,608.8	1,605.0	1,604.4	1,609.2	1,607.1
1974	1,605.7	1,607.2	1,609.2	1,608.9	1,608.6	1,608.0	1,606.1	1,604.5	1,602.6	1,603.1	1,603.7	1,605.1	1,602.6	1,609.2	1,606.1	1,604.7	1,609.8	1,606.8
1975	1,604.7	1,606.7	1,607.7	1,609.8	1,612.9	1,614.5	1,616.6	1,617.1	1,613.5	1,608.7	1,604.8	1,605.0	1,604.7	1,617.1	1,610.2	1,604.9	1,606.5	1,605.8
1976	1,604.9	1,606.5	1,606.2	1,606.5	1,607.5	1,609.0	1,608.1	1,606.7	1,603.9	1,603.5	1,604.0	1,603.9	1,603.5	1,609.0	1,605.9	1,603.9	1,608.2	1,606.3
1977	1604.6	1607.4	1,608.2	1607.5	1606.3	1605.5	1602.6	1599.0	1596.9	1595.4	1594.5	1594.8	1594.5	1608.2	1601.9	1,594.8	1,614.7	1,603.5
1978	1,596.9	1,600.7	1,610.3	1,614.7	1,615.7	1,615.4	1,615.0	1,613.4	1,610.4	1,607.0	1,605.6	1,604.6	1,596.9	1,615.7	1,609.1	1,604.6	1,614.3	1,608.4
1979	1,605.9	1,607.1	1,610.0	1,614.3	1,615.3	1,615.9	1,615.2	1,613.4	1,611.6	1,608.2	1,606.0	1,605.1	1,605.1	1,615.9	1,610.7	1,604.3	1,608.1	1,606.3
1980	1,604.3	1,606.2	1,607.9	1,608.1	1,605.9	1,605.0	1,603.1	1,600.0	1,598.0	1,597.2	1,596.8	1,598.1	1,596.8	1,608.1	1,602.6	1,597.8	1,602.0	1,599.8
1981	1,599.7	1,601.4	1,602.0	1,597.8	1,594.7	1,595.0	1,595.5	1,594.2	1,592.6	1,591.1	1,591.6	1,591.4	1,591.1	1,602.0	1,595.6	1,591.4	1,604.9	1,597.7
1982	1,592.6	1,597.2	1,602.3	1,604.9	1,610.2	1,612.5	1,612.9	1,610.8	1,607.9	1,607.8	1,608.5	1,607.7	1,592.6	1,612.9	1,606.3	1,605.8	1,614.4	1,609.3
1983	1,605.8	1,607.4	1,611.4	1,614.4	1,616.0	1,615.9	1,615.8	1,613.8	1,612.6	1,609.8	1,607.6	1,605.7	1,605.7	1,616.0	1,611.4	1,605.7	1,613.3	1,609.9
1984	1,608.4	1,610.7	1,611.4	1,613.3	1,615.6	1,618.3	1,616.8	1,613.8	1,610.2	1,608.9	1,606.7	1,605.2	1,605.2	1,618.3	1,611.6	1,605.2	1,611.0	1,608.2
1985	1,606.1	1,608.6	1,611.0	1,610.0	1,609.7	1,608.2	1,605.4	1,603.2	1,601.7	1,601.2	1,599.2	1,598.9	1,598.9	1,611.0	1,605.S	1,598.9	1,616.4	1,606.5
1986	1,601.4	1,603.9	1,611.9	1,616.4	1,617.4	1,617.0	1,615.4	1,612.7	1,610.8	1,609.6	1,608.7	1,605.7	1,601.4	1,617.4	1,610.9	1,604.2	1,614.6	1,608.5
1987	1,604.2	1,606.1	1,612.1	1,614.6	1,613.7	1,613.3	1,611.6	1,610.1	1,607.8	1,605.7	1,604.0	1,604.5	1,604.0	1,614.6	1,609.0	1,604.0	1,606.7	1,605.4
1988	1,604.0	1,606.2	1,606.7	1,605.5	1,604.7	1,603.0	1,600.3	1,597.0	1,592.8	1,590.3	1,588.6	1,589.1	1,588.6	1,606.7	1,599.0	1,589.1	1,593.2	1,591.1
1989	1,589.5	1,591.2	1,593.2	1,592.5	1,590.9	1,589.3	1,587.5	1,584.7	1,583.2	1,581.0	1,583.8	1,583.9	1,581.0	1,593.2	1,587.6	1,583.9	1,590.7	1,588.1
1990	1,587.8	1,589.5	1,590.7	1,588.8	1,588.1	1,589.2	1,588.2	1,586.1	1,583.5	1,581.2	1,582.2	1,582.2	1,581.2	1,590.7	1,586.5	1,582.2	1,587.9	1,585.3
1991	1,583.4	1,586.0	1,587.9	1,587.2	1,588.5	1,592.9	1,591.2	1,588.5	1,583.3	1,584.9	1,586.5	1,587.6	1,583.3	1,592.9	1,587.3	1,587.6	1,592.2	1,590.3
1992	1,589.3	1,591.5	1,592.2	1,591.1	1,590.4	1,589.8	1,590.0	1,590.1	1,591.4	1,591.0	1,591.8	1,591.6	1,589.3	1,592.2	1,590.9	1,591.6	1,597.9	1,594.2
1993	1,592.2	1,592.7	1,596.4	1,597.9	1,600.2	1,601.9	1,608.0	1,610.4	1,610.7	1,610.3	1,609.8	1,609.5	1,592.2	1,610.7	1,603.3	1,607.6	1,611.6	1,609.5
1994	1,608.2	1,607.6	1,611.6	1,610.6	1,610.6	1,610.2	1,610.0	1,608.1	1,606.3	1,605.2	1,603.8	1,603.7	1,603.7	1,611.6	1,608.0	1,603.7	1,610.6	1,606.8
1995	1,604.0	1,607.0	1,608.6	1,610.6	1,616.7	1,618.4	1,616.2	1,613.3	1,612.3	1,611.1	1,609.5	1,608.2	1,604.0	1,618.4	1,611.3	1,607.9	1,613.1	1,610.6
1996	1,607.9	1,611.1	1,612.8	1,613.1	1,616.9	1,618.5	1,617.5	1,616.0	1,615.3	1,613.5	1,609.3	1,607.5	1,607.5	1,618.5	1,613.3	1,607.5	1,617.9	1,612.2
1997	1,607.7	1,609.9	1,617.9	1,617.9	1,617.6	1,617.8	1,618.3	1,617.1	1,616.5	1,615.3	1,612.4	1,609.8	1,607.7	1,618.3	1,614.9	1,607.7	1,609.8	1,608.8
1998	1,607.7	1,608.4	1,608.2	1,609.7	1,609.7	1,611.5	1,612.2	1,612.2	1,610.6	1,609.5	1,609.3	1,607.4	1,607.4	1,612.2	1,609.7	1,606.4	1,611.1	1,608.4
1999	1,606.4	1,607.9	1,609.2	1,611.1	1,615.6	1,617.0	1,616.9	1,617.0	1,614.7	1,610.9	1,607.4	1,606.9	1,606.4	1,617.0	1,611.8	1,605.4	1,607.3	1,606.6

TABLE 2–3.—END-OF-MONTH ELEVATION OF LAKE OAHE, JUNE 1967 TO SEPTEMBER 2008 (IN FEET msl)—Continued

[Retrieved on 8-October-2008]

YEAR	MONTH												FULL YEAR (Jan–Dec)			Colder Months (Dec–Apr) [1]		
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	MEAN	MIN	MAX	MEAN
2000	1,605.4	1,606.4	1,607.0	1,607.3	1,607.3	1,606.2	1,604.8	1,602.5	1,599.5	1,598.3	1,597.3	1,597.1	1,597.1	1,607.3	1,603.3	1,597.1	1,604.8	1,600.0
2001	1,597.7	1,598.4	1,601.9	1,604.8	1,607.7	1,608.8	1,608.7	1,605.8	1,603.0	1,601.2	1,599.4	1,598.5	1,597.7	1,608.8	1,603.0	1,596.2	1,598.9	1,598.1
2002	1,598.6	1,598.9	1,598.2	1,596.2	1,595.3	1,592.7	1,590.8	1,588.1	1,586.4	1,585.1	1,583.4	1,584.8	1,583.4	1,598.9	1,591.5	1,584.8	1,588.2	1,586.6
2003	1,585.3	1,587.2	1,588.2	1,587.5	1,588.7	1,587.4	1,586.5	1,584.4	1,581.0	1,578.2	1,576.7	1,576.9	1,576.7	1,588.7	1,584.0	1,576.9	1,582.1	1,579.5
2004	1,577.6	1,579.2	1,582.1	1,581.6	1,578.4	1,576.8	1,574.3	1,572.1	1,573.2	1,574.8	1,576.0	1,575.8	1,572.1	1,582.1	1,576.8	1,574.4	1,576.2	1,575.3
2005	1,575.2	1,576.2	1,574.4	1,574.7	1,576.5	1,577.6	1,576.4	1,573.1	1,572.9	1,573.9	1,575.6	1,575.3	1,572.9	1,577.6	1,575.2	1,575.3	1,577.6	1,576.8
2006	1,576.8	1,577.6	1,576.7	1,577.4	1,577.0	1,575.8	1,573.4	1,570.3	1,571.4	1,572.6	1,573.2	1,572.8	1,570.3	1,577.6	1,574.6	1,572.3	1,577.7	1,574.3
2007	1,572.9	1,572.3	1,575.8	1,577.7	1,580.5	1,582.8	1,581.4	1,580.1	1,580.9	1,580.8	1,582.3	1,582.2	1,572.3	1,582.8	1,579.1	1,581.8	1,583.2	1,582.5
2008	1,582.3	1,581.8	1,583.2	1,582.8	1,584.7	1,592.6	1,593.9	1,592.4	1,593.1	....	....	....	....	....	....	....	....	....
STATISTICS (JANUARY 1968 TO DECEMBER 2007)																		
NUM	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
MIN	1,572.9	1,572.3	1,574.4	1,574.7	1,576.5	1,575.8	1,573.4	1,570.3	1,571.4	1,572.6	1,573.2	1,572.8	1,570.3	1,577.6	1,574.6	1,572.3	1,576.2	1,574.3
MEAN	1,598.8	1,600.6	1,603.0	1,603.8	1,604.7	1,604.9	1,603.9	1,601.8	1,600.0	1,598.7	1,598.1	1,597.7	1,595.3	1,606.5	1,601.3	1,597.3	1,603.6	1,600.3
MAX	1,608.7	1,611.1	1,617.9	1,617.9	1,617.6	1,618.5	1,618.3	1,617.1	1,616.5	1,615.3	1,612.4	1,609.8	1,607.7	1,618.5	1,614.9	1,607.9	1,617.9	1,612.2
STDEV	10.4	10.6	11.3	12.0	12.6	12.8	13.2	13.4	12.9	12.3	11.4	11.0	11.3	12.2	11.6	10.8	12.1	11.1

[1] Rows include Jan to Apr of following year.

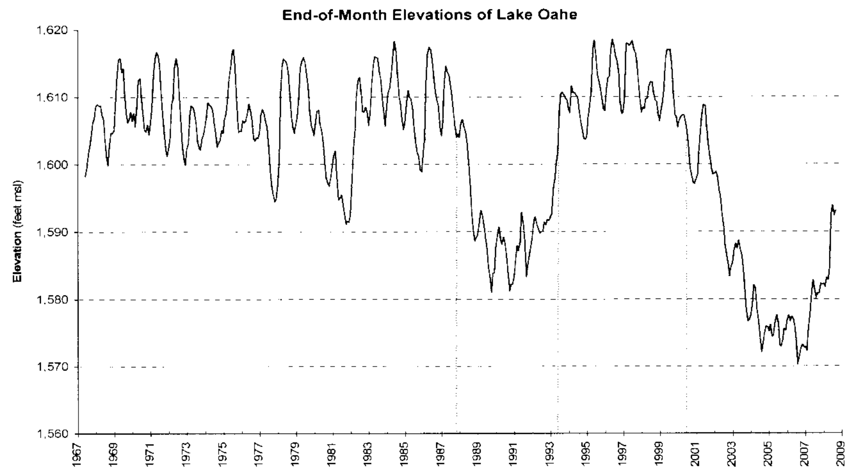

FIGURE 2–14.—*End-of month pool elevations in Lake Oahe between 1967 and the present (Source of data: USACE).*

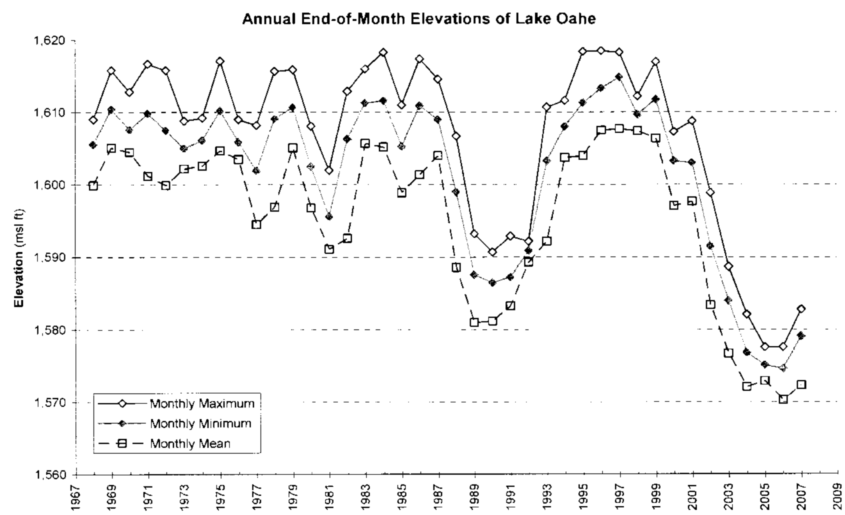

FIGURE 2–15.—*Annual end-of month pool elevations in Lake Oahe; monthly mean, minimum and maximum for each year (Source of data: USACE).*

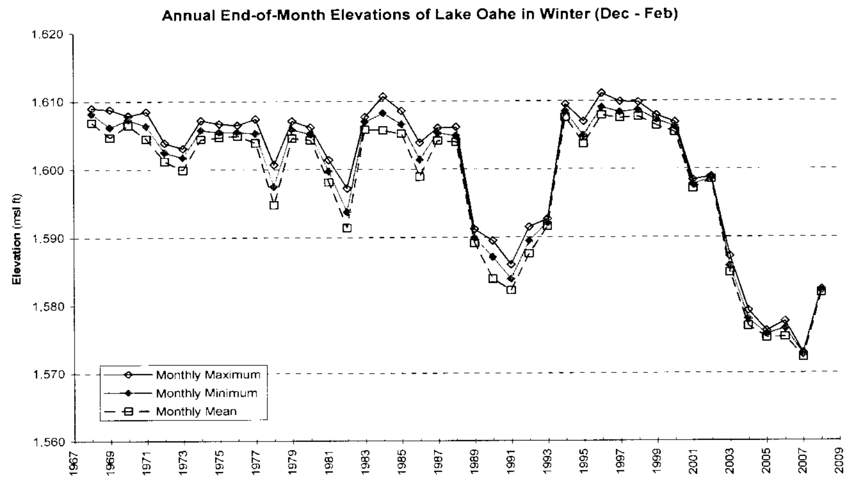

FIGURE 2–16.—*Annual end-of month pool elevations in Lake Oahe; monthly mean, minimum and maximum in winter only (Dec–Feb) for each year (Source of data: USACE).*

Costs of power generation by the System's facilities are very low compared to the costs of other types of energy generation facilities (coal, gas, oil, nuclear). WAPA conducts rate studies intermittently to adjust the rates for the power generated by the hydropower dams in the System. Rates have gradually increased from approximately $5/MWh in 1973 to $18/MWh in 2007. Based on these rates, the revenue from net energy generated at Garrison Dam has increased from approximately $12 million in 1973 to $24 million in 2007 (Figure 2–17). Highest revenues were achieved in 1996 as a result of high rainfall in the watershed which led to higher energy generation. Highest demand for hydropower exists in summer and in winter; higher energy generation in these months consequently results in higher revenues (Figure 2–18).

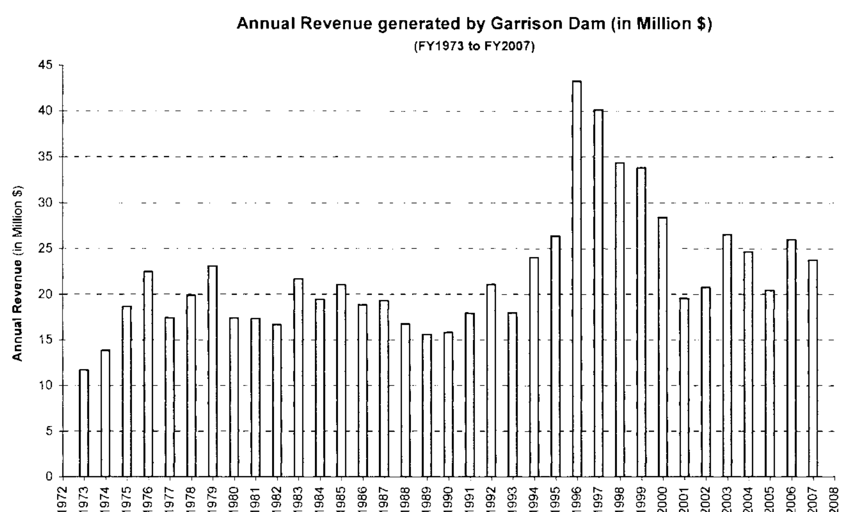

FIGURE 2–17.—*Annual revenues for net energy generated by Garrison Dam between fiscal year 1973 and fiscal year 2007 (Sources of input data: USACE).*

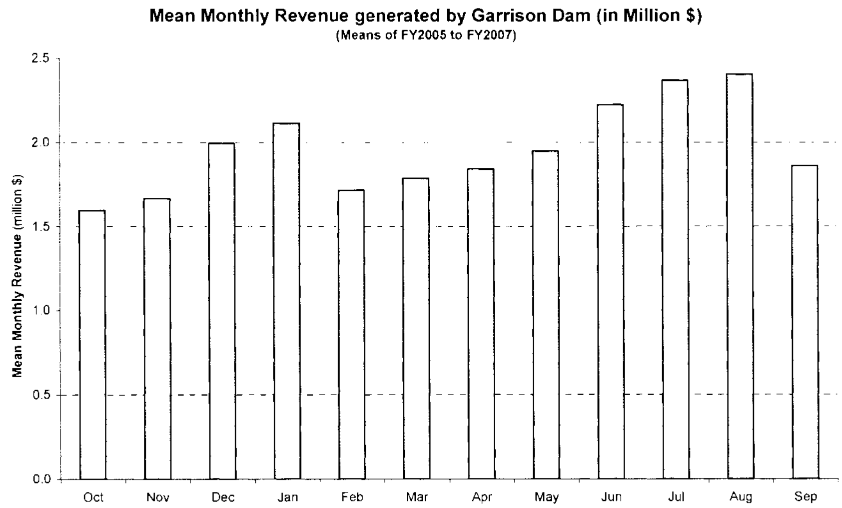

FIGURE 2–18.—*Mean monthly revenue generated by Garrison Dam for fiscal year 2005 through fiscal year 2007 (Source of input data: USACE).*

3.0 SILTATION IMPACTS ON HYDROPOWER OPERATIONS

Potential impacts from siltation in the Missouri River on hydropower operations in North Dakota consist of the following:

—Loss of storage in Lake Sakakawea
—Entrainment of sediment into the turbines at Garrison Dam
—Reduced releases at Garrison Dam in winter due to flooding risk from sediment aggradation

3.1 Loss of Storage in Lake Sakakawea

3.1.1. Sediment Sources

Sediment enters the reservoir primarily via the Missouri River and its tributaries. Another source is shoreline erosion. Due to the size of Lake Sakakawea, nearly all of the sediment that enters the reservoir remains there as sediment deposits. The USGS (1995) considers the trapping efficiency 100 percent, with only negligible amounts of suspended sediment being transported beyond Garrison Dam.

The drainage area of Lake Sakakawea is 181,400 square miles. Excluding the drainage area of the Fort Peck Lake, which traps the sediment of its own watershed, the drainage area for Lake Sakakawea is 123,900 square miles.

The largest point sources for sediment to Lake Sakakawea are the Missouri River and especially the Yellowstone River, a tributary to the Missouri River (Figure 2–3). The headwaters of the 678-mile long Yellowstone River are in Wyoming and Montana. The lower 18 miles of the Yellowstone River are within North Dakota. The Yellowstone River joins with the Missouri River at RM 1581. Downstream from the confluence, the Missouri River is free-flowing until up to the headwaters of Lake Sakakawea. The free-flowing stretch of the Missouri River depends upon Lake Sakakawea's elevation; the length of this free-flowing stretch may be as little as 15 miles (e.g., in year 1997) to as many as 50 miles (e.g., in year 1991) (NDGFD, 2002). Sediment from mainly the Missouri River and the Yellowstone River has buried the old river channel downstream of approximately RM 1535.

The Yellowstone River is largely unregulated, with only two dams in the headwaters (Yellowtail Dam and Boysen Dam; Figure 2–3). The mean annual flow of the Yellowstone River at its lowest gaging station (at Sidney, Montana) was determined as 12,250 cfs, with a maximum instantaneous flow estimated at 159,000 cfs in June 1921 (NDGFD, 2002). Some of the highest stages in the river were caused by ice dams. The construction of upstream water depletion projects have reduced flows in the Yellowstone River by approximately 24 percent from historical levels. In comparison, annual flows of the Missouri River at its lowest gaging station above the confluence with the Yellowstone River, located in Culbertson, Montana, have averaged 10,270 cfs. The peak flow in the Missouri River after closure of Fort Peck Dam was 78,200 cfs on March 1943.

The mean grain size of the suspended sediment in the Missouri River at Culbertson, Montana, near the border with North Dakota, was measured as 45 percent sand, 50 percent silt, and 5 percent clay (USACE, 1978, as listed in Wuebben and Gagnon, 1995). The corresponding grain sizes in the Yellowstone River at Sidney, Montana, were 35 percent, 60 percent and 5 percent, respectively. The mean grain size (D50) of the bed material was 0.28 mm in the Missouri River at Culbertson, and 0.25 mm in the Yellowstone River at Sidney. Both mean grain sizes fall into the "medium sand" category which has a size range of 0.25 to 0.50 mm.

The USACE (1978) estimated the sediment load from the Missouri River at Culbertson, Montana, with 13.5 million tons/year. A much greater load (41.5 million tons/year) was estimated to be supplied to Lake Sakakawea by the Yellowstone River at Sidney near the confluence with the Missouri River. According to preliminary studies by the USGS (as mentioned in Wuebben and Gagnon, 1995), these loads (total of 55 million tons/year) may have been overestimated by 30 percent.

Sediment contributed by the Missouri River includes sediment that is eroded from the river's bank and bottom, downstream of the Fort Peck dam.

The USACE (1993a) estimated that the gross storage loss for all of Lake Sakakawea since closure of the dam in 1953 and the survey date in 1988 was 907,000 acre-feet or 25,900 acre feet/year. Using a bulk density of 1.4 g/cm3, based on values provided by Geiger (1963) for sand and silt, this volume translates into a sediment supply of 45 million tons/year. This volume is similar to the volume discussed above in Wuebben and Gagnon (1995), after allowing for a 30 percent reduction as suggested.

Additional riverine sediment sources to Lake Sakakawea are numerous small tributaries such as the Little Missouri River, and shoreline erosion in the lake. Shoreline erosion occurs primarily as a result of waves acting on bluffs and other erodible topographic features. The likelihood of shoreline erosion is highest during periods of high water elevations in the reservoir. The relative contribution of shoreline erosion to the total sediment load entering Lake Sakakawea is considered to be very small, however (John Remus, pers. communication, November 21, 2008).

3.1.2. Sediment Deposition in Lake Sakakawea

Lake Sakakawea extends close to the border of North Dakota with Montana. Sediment initially accumulated in the lower elevation zones during the filling of Garrison Lake. In 1993, the USACE estimated that 3.5 percent of the capacity in the Permanent Pool was lost.

Since the pool was filled, sediments carried by the Missouri River settle out in the calmer headwaters of Lake Sakakawea. This deposition has resulted in a progressive loss of the channel capacity as well as in an upward shift of the stage-discharge relationship. Already the upper reach of the lake is silted in heavily. New sediment islands form continuously over time and gradually migrate downgradient (Figure 3–1). However, the aggradation is largely confined to the upper reaches of the reservoir (Figures 3–2 to 3–4). This is also reflected in USACE (1993a):

> ". . . the location of the sediment deposits vary significantly longitudinally throughout the reservoirs [of the System]. The majority of the sediment begins to settle out 10 to 15 miles downstream from the upstream end of the pools, and is concentrated within a 30-mile reach downstream from this point. Sediment deposits of any significant quantity have not been observed in the vicinity of the dams and/or powerhouses at any of the six dams [of the System]. Most of the sediment that presently exists in the lower elevation zones of the pools was deposited during the reservoir filling period, and little change has been noted . . . since the projects were first filled." (p. 6)

As stated above, the USACE (1993a) estimated that the gross storage loss for all of Lake Sakakawea since closure of the dam in 1953 and the survey date in 1988 was 907,000 acre-feet or 25,900 acre-feet/year. In the 20 years since that time, sedimentation has continued in the upper reaches of Lake Sakakawea. Assuming that the sediment accumulation rate from 1993 also applies for the period since the 1988 survey, an additional 518,000 acre-feet would have been deposited in Lake Sakakawea by year 2008. Accordingly, the total sediment load that has been deposited in the reservoir between 1953 and 2008 (55-year time span) is 1,425,000 acre-feet. This volume translates to a loss in storage volume of 6 percent of Lake Sakakawea at the Maximum Operating Pool level (1,854 feet msl), or 0.11 percent per year.

FIGURE 3–1.—*Upper Lake Sakakawea area, showing sediment aggradation. (The aerial photo is from June 23, 2003 (Source: Google Earth).*

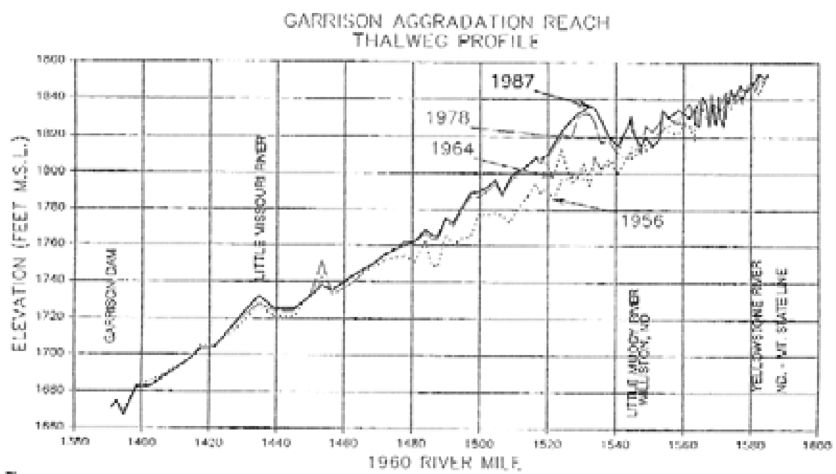

FIGURE 3–2.—*Changes in thalweg elevations in Lake Sakakawea, 1956 and 1987 (USACE, 1993a).*

FIGURE 3–3.—*Changes in average bed elevations in Lake Sakakawea, 1956 and 1987 (USACE, 1993a).*

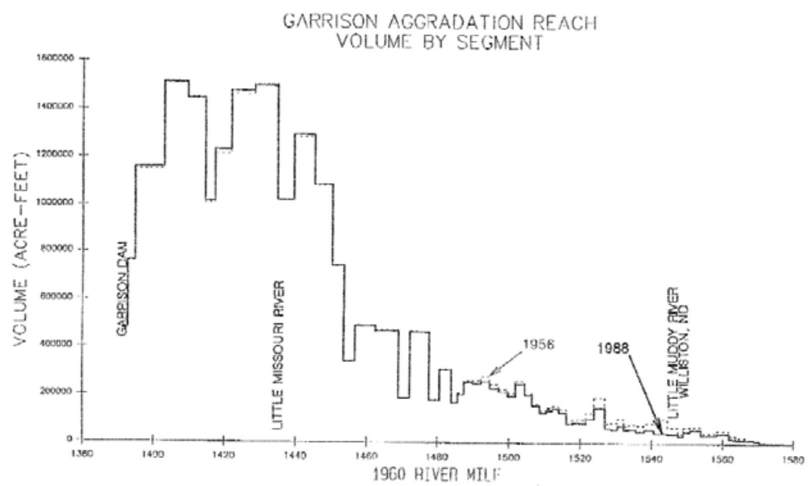

FIGURE 3–4.—*Changes in volume in Lake Sakakawea between 1956 and 1988 (USACE, 1993a).*

The actual loss might be slightly lower as a result of increased equilibration of the Missouri River channel between Fort Peck and the upper Lake Sakakawea, resulting in gradually decreasing erosion rates over time.

Using a uniform sediment aggradation rate, these values suggest that Lake Sakakawea would be filled completely with sediment 900 years after construction of the Garrison Dam. This value is only first-order approximation as it does not consider variables such as sediment trapping efficiency, climate variability over time, or potential sediment contributions from the watershed of Fort Peck Lake (which may be filled before Lake Sakakawea):

—*Sediment Trapping Efficiency.*—This first-order calculation assumes a continuous trapping efficiency of 100 percent. In reality, however, the trapping efficiency will gradually decrease toward the end of the life expectancy for the reservoir, and sediment will start to be transported passed Garrison Dam.

—*Climate Variability Over Time.*—Nine hundred years is a long time during which the regional climate is expected to vary over the short and long term. Decreasing precipitation in the Lake Sakakawea watershed will result in less sediment erosion and hence a longer life expectancy of the reservoir, and vice versa.

—*Sediment Contributions From the Watershed of Fort Peck Lake.*—Like Lake Sakakawea, Fort Peck Lake most likely captures nearly all of the sediment of its watershed. When the lake eventually fills with sediment, this sediment will bypass Fort Peck Dam and also enter Lake Sakakawea. Comparisons between 1938 and 1986 lake bed data demonstrate that there was a storage loss of 869,000 acre-feet, or 18,100 acre-feet/year (USACE, 1993a). Assuming the same loss rate for years 1987 to 2008, an added 398,000 acre-feet would have been lost. Therefore, the total loss to-date since construction would be 1,267,000 acre-feet. The volume represents a 6.8 percent loss of the gross storage volume of Fort Peck Lake of 18,688,000 acre-feet since construction 70 years ago (i.e., 0.10 percent per year). This loss rate is very similar to the loss rate of Lake Sakakawea (0.11 percent per year), suggesting a similar first-order life expectancy of 900 years. Based on these data, sediment from the Fort Peck Lake watershed will not reach Lake Sakakawea for many centuries.

3.2 Entrainment of Sediment into the Turbines at Garrison Dam

Impacts to the hydropower operation will start to occur well before Lake Sakakawea has filled with sediment. However, with an annual loss of storage capacity by 0.11 percent, and most of the deposition occurring in the upper reaches of the reservoir, impacts to the intakes to the hydropower facility are not expected for a long time. As a result, the USACE does not have any specific sediment management methods or sediment control facilities at their hydroelectric facilities at this time (Bill Mulligan, personal communication; November 13, 2008).

Eventually, impacts will consist of clogging of the intake and abrasion of the turbine blades by coarser sediment grains. The start date for these impacts depends on parameters such as grain size, water elevation in the reservoir over time, frequency of drought conditions (which will bring sediment further into the lake), geometry of the lake, flows velocities in front of the intake to the turbines, and elevation of the intake in the water column relative to the elevation of the reservoir. Based on the existing information, including USACE (1993a), most of the sediment carried into the lake by the Missouri River remains as delta deposits in the headwaters of the lake. Thus, only the finest particles that can remain in suspension for a long time are transported further downstream at present. As a rough first-order estimate, we anticipate that effects on the turbines from sediment deposition in the reservoir will be negligible for at least the next 200 years. However, a more detailed assessment must be performed if a more accurate estimate is desired.

3.3 Reduced Releases at Garrison Dam in Winter due to Flooding Risk

Siltation in the reach between Garrison Dam and Lake Oahe has resulted in increased risk of flooding in the downstream reach between the dam and the headwater of Oahe Lake. The Missouri River typically freezes in December ("ice-in"; "freeze-up"). It remains frozen in January and February, and starts to thaw in March and April ("ice-out"; "break-up") (Jody Farhat, pers. communication, November 14, 2008). A large consideration in flow releases are ice dams (Figure 3–5). Ice dams can form during freeze-up as well as during break-up (FEMA, 2005). Ice-in starts at the headwaters of Lake Oahe, and moves upstream toward Garrison Dam. Break-up ice dams normally occur in late winter or early spring during the melting period. These break-up ice dams are most common downstream of the confluence between the Missouri River and the Heart River (RM 1311) (Figure 3–6). According to FEMA (2005), these ice dams form mostly because of high flows in the Heart River during snowmelt or spring rains while the Missouri River is still covered with ice. Siltation in the river indirectly worsens such flooding, as the ice sheet in the Missouri River is at a higher elevation than it would be without aggradation.

In order to minimize the flooding risk, specifically in the Bismarck/Mandan area, the USACE releases water from Lake Sakakawea in the following manner:

—*Ice-in (December).*—The USACE releases water at a reduced rate while the ice is forming on the river. The gradually forming ice creates a "conduit" for the released water underneath it. Initially the ice surfaces are rough and "chunky", resulting in a higher risk of flooding. As a result, release rates have been reduced to as low as 16,000 cfs in past years as the ice sheet build-up advances upstream from the headwaters of Lake Oahe.

—*January–December.*—After the ice has formed on the river, it is smoothed on its underside by the flowing water, allowing for an increase in the release rate at Garrison Dam. The rate is set in a manner that prevents flow over the ice or the breakup of the ice which could cause ice dams. As specified in the Master Water Control Manual, release rates are not normally scheduled above 20,000 cfs in December (USACE, 2006). However, based on experience, water release rates of 27,000 cfs are possible. This maximum winter release rate is a reduction of the original capacity of 35,000 cfs, as a result of aggradation of the river in the headwaters of Lake Oahe.

—*Ice-out (April–March).*—The breaking up of the ice presents a risk to flooding as the moving ice can cause ice dams that block the flow of water. In addition, rainfall events may result in high discharges from the tributaries to the Missouri River in the reach between Garrison Dam and Lake Oahe. These tributary discharges are often coupled with melting snow from the watershed. The two largest tributaries are the Heart River and Knife River. Planned winter flow releases at Garrison Dam consider flows in these tributaries.

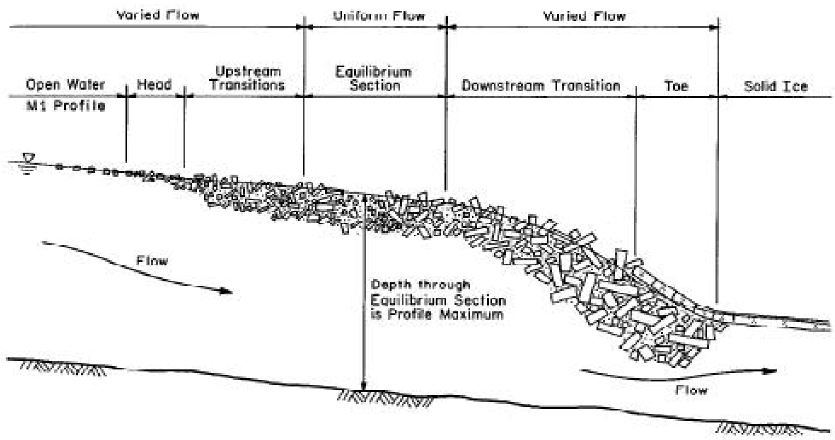

FIGURE 3–5.—*Longitudinal profile of typical break-up ice jam (Wuebben and Gagnon, 1995).*

FIGURE 3–6.—*Sediment aggradation along the Missouri River between the cities of Bismarck and Mandan, and the headwaters of Lake Oahe (Source: Google Earth).*

3.3.1. Flows

The mean annual outflow from Lake Sakakawea between 1967 (2 years after the reservoir was filled) and 2007 was 15.6 million acre-feet (Table 3–1), which translates into a mean daily flow rate of 21.5 million cfs (Table 3–2). The annual outflow ranged from a minimum of 9.6 million acre-feet in both 1993 and 2001, to a maximum of 25.2 million acre-feet in 1997 (Figure 3–7). Releases from recent years were close to the minimum due to a drought in the upper Missouri watershed.

Most of the inflow to Lake Oahe comes from water releases at Garrison Dam. A gaging station is maintained along the Missouri River at Bismarck (USGS Station 06342500), operated in cooperation with the USACE. Discharge data at Bismarck reflect the gradual filling of Lake Sakakawea until the late 1960s (Figures 3–8 and 3–9; Table 3–3). Thereafter, the discharge rate in the Missouri River gradually decreased until 1995, as also observed in power generation records and Garrison Dam release flows. Discharge rates in 1996 and 1997 were very high due to high runoff in the Upper Missouri River watershed. The discharge rates decreased in the subsequent years to their currently lowest level since the Lake Sakakawea was closed (Figure 2–7). The decrease in flow over the 20 year period between 1968 and 2007 was on average 50 percent less (Figure 3–10).

As expected, the discharge data between Bismarck (USGS data) and Garrison Dam (USACE data) coincide well (Figure 3–11). Peak discharges were slightly higher at Bismarck due to tributary runoff downstream of Garrison Dam (Figure 3–12). In general, the flow at Bismarck was 8.3 percent [2] higher compared to release flows at Garrison Dam between 1967 and 2007 (Figure 3–13). This percentage was higher (13.3 percent) during the ice-out period (March–April), presumably due to snowmelting in the watershed downstream of Garrison Dam. In specific years, the flow at Bismarck was higher by as much as 45 percent compared to release flows at Garrison Dam, which underscores the importance of managing releases at Garrison Dam to prevent flooding in Bismarck and Mandan (Figure 3–14).

The annual runoff peak typically occurs in June. The highest monthly releases occur in July and August (Figure 3–15). The lowest releases occur during the fall (October and November).

A rating curve at the Bismarck gaging station indicates that there have been major changes in the stage at this location for flows exceeding 30,000 cfs. Such flows

[2] The USGS gaging station is located upstream in Bismarck. The Heart River and Apple Creek enter the Missouri River downstream of the USGS gage. Their mean annual discharge rate is 267 cfs and 45 cfs, respectively. Thus, these two streams contribute an additional 1.3 percent to the flow of the Missouri River, before the Missouri River enters Lake Oahe.

caused an upward trend of 1 to 2 feet (Figure 3–16). This increase has caused flooding in the winter in some of the lower lying housing areas near Bismarck (USACE, 2004c). According to Mr. Ronald Sando (personal communication November 12, 2008), flooding can occur in Bismarck, south of the Bismarck Expressway. There has also been flooding in the past in the city of Mandan along the western bank of the Missouri River.

3.3.2. Sedimentation

The headwaters of Lake Oahe reach almost up to the city of Bismarck. Sediment deposition has occurred in the headwaters of Lake Oahe, just as it has in the headwaters of Lake Sakakawea (USACE, 1993b). The highest aggradation of sediment occurred in an area approximately 10 miles to the south of Bismarck (Berger, 2008). The sediment delta that formed in Lake Oahe has affected the river's flood stage in Bismarck and Mandan. At construction, the open-water channel capacity for a stage of 13 feet was 90,000 cfs (USACE, 2006). In 1975, just 20 years later, this capacity had been reduced to 50,000 cfs.

Releases at Garrison Dam result in erosion of sediment just downstream of the dam (USGS, 1995; Biedenharn et al., 2001). The river stabilizes further downstream as erosion of sediment is balanced by sediment resupplied from upstream sources. As flow velocities decrease, the carrying capacity of the river decreases as well. Sediments, both carried in suspension and as bedload, eventually settle out resulting in aggradation of the river. A study of the sedimentation from 1958 to 1985 was conducted by the USACE from RM 1390 (Garrison Dam) to RM 1336 (20 miles north of Bismarck) (USACE, 1993c). The study found that the thalweg and average bed elevations had decreased at most locations (Table 3–4). The widths of the channel varied. Tailwater elevations at Garrison Dam had decreased by approximately 7 feet between 1956 and 2003 (USACE, 2004c; Figure 3–17). Erosion in the Missouri River downstream of Garrison Dam was also shown from investigations along 21 transects by the USGS conducted between Garrison Dam and Lake Oahe between 1988 and 1991 (USGS, 1995).

The USGS (1995) also observed erosion along transects located in Bismarck and 6 miles to the south of Bismarck. This erosion was likely the result of degradation of sediment that had previously been deposited in the headwater of Lake Oahe. The elevations in Lake Oahe were lower during the study period (1988 to 1991) than during earlier years (Figure 2–14). However, elevations have fluctuated since then with higher elevations in the mid-1990s and again low elevations in recent years due to drought in the watershed. Bruce Engelhardt also stated that sedimentation in the Missouri River occurs at times in the Bismarck area (personal communication, November 13, 2008).

It is expected that the river will continue to erode sediment in the upper Garrison Reach. Erosion will continue from degradation as well as from meandering of the channel, although these processes may gradually decrease over time. Williams and Wolman (1984, as reported in USGS [1995]) estimated that 95 percent equilibrium would be reached within 2 to 90 years after completion of a dam, based on a study of 21 dams constructed on alluvial rivers, mostly in the semiarid western United States. Site-specific data for this reach of the Missouri River were not located, however, in order to narrow down this wide range.

In urban areas such as Bismarck and Mandan, the river channel has no room to widen without affecting properties. Therefore, aggradation within the river at this location results in an increased risk of flooding and the loss of property. Potential buyouts due to flooding concerns in the Bismarck-Mandan area are estimated at over $100 million (Remus, 2008). The impact of flooding is estimated to be greatest between RM 1300 and 1316, i.e., in downtown Bismarck and Mandan (FEMA, 2005). Flooding also occurs outside of urbanized areas, affecting cropland and causing soil erosion. Since flooding from ice dams occurs in winter, there are no crops that could be damaged, however.

TABLE 3–1.—MONTHLY OUTFLOW FROM LAKE SAKAKAWEA, JUNE 1967 TO SEPTEMBER 2008 (IN 1,000 ACRE-FEET)

[Retrieved on 8–October–2008]

YEAR	MONTH												FULL YEAR (Jan–Dec)				Colder Months (Dec–Apr) [1]			
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	MEAN	TOTAL	MIN	MAX	MEAN	TOTAL
1967	....	....	....	....	....	1,574	1,917	2,210	1,560	1,826	1,594	1,635	....	....	....	....	1,176	1,739	1,518	7,588
1968	1,739	1,717	1,176	1,321	1,224	990	1,006	1,219	1,366	1,897	1,439	1,551	990	1,897	1,387	16,645	1,504	1,881	1,723	8,617
1969	1,810	1,871	1,881	1,504	1,442	1,044	1,630	1,790	1,522	1,514	1,526	1,815	1,044	1,881	1,612	19,349	1,233	1,815	1,541	7,704
1970	1,616	1,554	1,233	1,486	1,706	1,642	1,610	1,648	1,293	1,626	1,655	1,474	1,233	1,706	1,545	18,543	1,474	2,066	1,744	8,720
1971	1,863	1,591	1,726	2,066	2,337	2,071	2,134	1,611	1,386	1,444	1,485	1,467	1,386	2,337	1,765	21,181	1,467	2,232	1,753	8,763
1972	1,764	1,656	1,644	2,232	2,367	2,214	1,648	1,412	1,214	1,305	1,326	1,401	1,214	2,367	1,682	20,183	1,195	1,645	1,437	7,183
1973	1,645	1,393	1,549	1,195	1,037	1,104	1,225	1,268	1,167	1,157	1,172	1,401	1,037	1,645	1,276	15,313	1,146	1,604	1,435	7,175
1974	1,604	1,481	1,543	1,146	1,283	1,404	1,589	1,680	1,378	1,747	1,446	1,500	1,146	1,747	1,483	17,801	1,041	1,578	1,401	7,007
1975	1,358	1,578	1,530	1,041	1,959	2,388	3,800	3,328	2,216	1,994	1,964	1,716	1,041	3,800	2,073	24,872	1,598	1,894	1,725	8,626
1976	1,598	1,812	1,606	1,894	2,198	2,230	2,244	1,921	1,545	1,547	1,761	1,464	1,464	2,244	1,818	21,820	957	1,803	1,406	7,030
1977	1,803	1,552	1,254	957	971	920	1,069	999	866	774	972	1,298	774	1,803	1,120	13,435	1,031	1,689	1,371	6,855
1978	1,689	1,614	1,223	1,031	974	1,829	2,365	2,346	1,932	1,949	1,978	1,424	974	2,365	1,696	20,354	1,424	1,876	1,664	8,318
1979	1,876	1,690	1,678	1,650	2,247	2,165	1,597	1,294	1,037	927	838	1,194	838	2,247	1,516	18,193	1,187	1,668	1,412	7,059
1980	1,380	1,668	1,630	1,187	1,132	1,235	1,603	1,453	1,291	1,364	1,443	1,305	1,132	1,668	1,391	16,691	980	1,539	1,347	6,734
1981	1,539	1,534	1,376	980	1,071	1,491	1,733	1,401	1,144	920	899	1,163	899	1,733	1,271	15,251	1,018	1,741	1,426	7,130
1982	1,594	1,741	1,614	1,018	1,483	1,356	1,551	1,240	1,042	1,135	1,755	1,370	1,018	1,755	1,408	16,899	1,238	1,734	1,458	7,289
1983	1,238	1,637	1,734	1,310	1,025	1,066	1,080	1,611	1,350	837	986	1,340	837	1,734	1,268	15,214	956	1,652	1,325	6,624
1984	1,652	1,531	1,145	956	839	831	1,350	1,672	1,523	1,438	1,502	1,330	831	1,672	1,314	15,769	1,042	1,645	1,358	6,789
1985	1,645	1,601	1,171	1,042	1,139	1,190	1,188	1,117	1,008	830	923	1,338	830	1,645	1,183	14,192	1,140	1,595	1,414	7,072
1986	1,595	1,454	1,545	1,140	649	890	1,167	1,466	1,148	1,332	1,424	1,227	649	1,595	1,253	15,037	630	1,499	1,166	5,831
1987	1,452	1,499	1,023	630	942	1,069	1,128	1,118	969	802	766	1,234	630	1,499	1,053	12,632	1,089	1,502	1,266	6,328
1988	1,313	1,502	1,190	1,089	1,146	1,136	1,177	1,109	816	661	664	1,127	661	1,502	1,078	12,930	940	1,250	1,097	5,484
1989	1,174	1,250	993	940	1,273	1,333	1,378	1,342	770	675	1,131	1,225	675	1,378	1,124	13,484	927	1,489	1,153	5,767
1990	1,489	1,075	927	1,051	1,180	1,201	1,211	1,117	654	616	683	1,061	616	1,489	1,022	12,265	767	1,265	1,059	5,297
1991	1,265	1,170	767	1,034	1,195	1,143	1,187	1,186	818	810	843	1,162	767	1,265	1,048	12,580	775	1,374	1,092	5,461
1992	1,374	1,173	775	977	1,185	1,156	1,183	1,115	807	612	601	1,121	601	1,374	1,007	12,079	612	1,158	859	4,293
1993	1,158	764	638	612	937	933	908	971	672	612	652	833	612	1,158	808	9,690	695	877	778	3,889
1994	877	749	735	695	1,435	1,323	1,168	1,134	932	704	806	1,137	695	1,435	975	11,695	730	1,282	1,028	5,140
1995	1,282	1,124	867	730	775	659	813	1,832	2,199	2,209	1,852	1,244	659	2,209	1,299	15,586	1,131	1,677	1,335	6,674
1996	1,409	1,213	1,131	1,677	2,246	2,106	2,252	2,218	2,091	1,615	1,231	1,171	1,131	2,252	1,697	20,360	965	1,407	1,140	5,699
1997	1,407	1,170	986	965	1,916	2,524	3,523	3,069	2,771	3,040	2,520	1,345	965	3,523	2,103	25,236	1,155	1,368	1,282	6,409
1998	1,354	1,368	1,187	1,155	1,489	1,529	1,476	1,476	1,260	1,051	1,220	1,287	1,051	1,529	1,321	15,852	1,287	1,615	1,472	7,361
1999	1,521	1,483	1,455	1,615	1,611	1,769	1,761	1,714	1,393	1,157	1,040	1,203	1,040	1,769	1,477	17,722	1,128	1,385	1,231	6,154

TABLE 3–1.—MONTHLY OUTFLOW FROM LAKE SAKAKAWEA, JUNE 1967 TO SEPTEMBER 2008 (IN 1,000 ACRE-FEET)—Continued

[Retrieved on 8–October–2008]

YEAR	MONTH												FULL YEAR (Jan–Dec)				Colder Months (Dec–Apr) [1]			
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	MEAN	TOTAL	MIN	MAX	MEAN	TOTAL
2000	1,277	1,385	1,128	1,161	1,371	1,445	1,448	1,422	1,068	874	1,246	1,111	874	1,448	1,245	14,936	744	1,155	948	4,741
2001	1,155	940	791	744	756	823	848	859	680	627	630	793	627	1,155	804	9,646	642	804	748	3,742
2002	804	735	768	642	787	1,243	1,279	1,300	1,043	852	1,071	1,207	642	1,300	978	11,731	1,066	1,240	1,151	5,755
2003	1,133	1,240	1,066	1,109	1,151	1,265	1,319	1,296	1,003	663	699	979	663	1,319	1,077	12,923	979	1,330	1,104	5,522
2004	1,181	1,330	1,024	1,008	969	1,071	1,103	1,059	894	707	758	934	707	1,330	1,003	12,038	721	1,035	877	4,384
2005	950	721	744	1,035	1,014	893	933	954	840	773	797	945	721	1,035	883	10,599	819	1,097	922	4,611
2006	1,097	859	891	819	942	1,181	1,265	1,353	1,078	743	782	943	743	1,353	996	11,953	802	980	902	4,512
2007	980	877	910	802	820	955	980	984	692	666	645	915	645	984	852	10,226	744	924	849	4,247
2008	924	879	785	744	790	853	837	854	748	....	....	....	....	....	....	....	....	....	....	....
STATISTICS (JANUARY 1968 TO DECEMBER 2007)																				
NUM	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
MIN	804	721	638	612	649	659	813	859	654	612	601	793	601	984	804	9,646	612	804	748	3,742
MEAN	1,417	1,358	1,206	1,141	1,306	1,370	1,498	1,478	1,222	1,155	1,178	1,244	877	1,754	1,298	15,573	1,024	1,484	1,260	6,300
MAX	1,876	1,871	1,881	2,232	2,367	2,524	3,800	3,328	2,771	3,040	2,520	1,815	1,464	3,800	2,103	25,236	1,598	2,232	1,753	8,763
STDEV	277	321	342	376	476	480	632	522	472	545	460	223	229	577	329	3,943	257	328	277	1,383

[1] Rows include Jan to Apr of following year.

TABLE 3–2.—AVERAGE DAILY OUTFLOW FOR THE MONTH FROM LAKE SAKAKAWEA, JUNE 1967 TO SEPTEMBER 2008 (IN 1,000 cfs)

[Retrieved on 8-October-2008]

YEAR	MONTH												FULL YEAR (Jan–Dec)			Colder Months (Dec–Apr) [1]		
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	MEAN	MIN	MAX	MEAN
1967	....	....	....	....	....	26.5	31.2	35.9	26.2	29.6	26.8	26.6	....	....	....	19.1	29.8	25.2
1968	28.3	29.8	19.1	22.2	19.9	16.6	16.4	19.8	23.0	30.9	24.2	25.2	16.4	30.9	23.0	25.2	33.7	28.8
1969	29.4	33.7	30.6	25.3	23.4	17.5	26.5	29.1	25.6	24.6	25.6	29.5	17.5	33.7	26.7	20.1	29.5	25.8
1970	26.3	28.0	20.1	25.0	27.7	27.6	26.2	26.8	21.7	26.4	27.8	24.0	20.1	28.0	25.6	24.0	34.7	29.2
1971	30.3	28.7	28.1	34.7	38.0	34.8	34.7	26.2	23.3	23.5	24.9	23.9	23.3	38.0	29.3	23.9	37.5	29.1
1972	28.7	28.8	26.7	37.5	38.5	37.2	26.8	23.0	20.4	21.2	22.3	22.8	20.4	38.5	27.8	20.1	26.8	24.0

1973	26.8	25.1	25.2	20.1	16.9	18.6	19.9	20.6	19.6	18.8	19.7	22.8	16.9	26.8	21.2	19.3	26.7	24.0
1974	26.1	26.7	25.1	19.3	20.9	23.6	25.8	27.3	23.2	28.4	24.3	24.4	19.3	28.4	24.6	17.5	28.4	23.5
1975	22.1	28.4	24.9	17.5	31.9	40.1	61.8	54.1	37.2	32.4	33.0	27.9	17.5	61.8	34.3	26.0	31.8	28.7
1976	26.0	31.5	26.1	31.8	35.7	37.5	36.5	31.2	26.0	25.2	29.0	23.8	23.8	37.5	30.0	16.1	29.3	23.5
1977	29.3	28.0	20.4	16.1	15.8	15.5	17.4	16.2	14.6	12.6	16.3	21.1	12.6	29.3	18.6	17.3	29.1	23.0
1978	27.5	29.1	19.9	17.3	15.8	30.7	38.5	38.3	32.5	31.7	33.2	23.2	15.8	38.5	28.1	23.2	30.5	27.8
1979	30.5	30.4	27.3	27.7	36.5	36.4	26.0	21.0	17.4	15.1	14.1	19.4	14.1	36.5	25.2	19.4	29.0	23.4
1980	22.4	29.0	26.5	19.9	18.4	20.8	26.1	23.6	21.7	22.2	24.2	21.2	18.4	29.0	23.0	16.5	27.6	22.5
1981	25.0	27.6	22.4	16.5	17.4	25.1	28.2	22.8	19.2	15.0	15.1	18.9	15.0	28.2	21.1	17.1	31.4	23.9
1982	25.6	31.4	26.3	17.1	24.1	22.8	25.2	20.2	17.5	18.5	29.5	22.3	17.1	31.4	23.4	20.1	29.5	24.4
1983	20.1	29.5	28.2	22.0	16.7	17.9	17.6	26.2	22.7	13.6	16.6	21.8	13.6	29.5	21.1	16.0	26.9	22.0
1984	26.9	26.6	18.6	16.0	13.7	14.0	22.0	27.1	25.6	23.4	25.2	21.6	13.7	27.1	21.7	17.5	28.8	22.7
1985	26.7	28.8	19.0	17.5	18.5	20.0	19.3	18.2	16.9	13.5	15.5	21.8	13.5	28.8	19.6	19.2	26.2	23.6
1986	25.9	26.2	25.1	19.2	10.6	14.9	19.0	23.8	19.3	21.7	23.9	20.0	10.6	26.2	20.8	10.6	27.0	19.6
1987	23.6	27.0	16.6	10.6	15.3	18.0	18.3	18.2	16.3	13.0	12.9	21.0	10.6	27.0	17.6	183	261	212
1988	21.3	26.1	19.4	18.3	18.6	19.1	19.1	18.0	13.7	10.7	11.2	18.3	10.7	26.1	17.8	15.8	22.5	18.4
1989	19.1	22.5	16.2	15.8	20.7	22.4	22.4	21.8	12.9	11.0	19.0	19.9	11.0	22.5	18.6	15.1	24.2	19.3
1990	24.2	19.4	15.1	17.7	19.2	20.2	19.7	18.2	11.0	10.0	11.5	17.3	10.0	24.2	17.0	12.5	21.1	17.8
1991	20.6	21.1	12.5	17.4	19.4	19.2	19.3	19.3	13.8	13.2	14.2	18.9	12.5	21.1	17.4	12.6	22.3	18.1
1992	22.3	20.4	12.6	16.4	19.3	19.4	19.2	18.1	13.6	10.0	10.1	18.2	10.0	22.3	16.6	10.3	18.8	14.3
1993	18.8	13.8	10.4	10.3	15.2	15.7	14.8	15.8	11.3	9.9	11.0	13.6	9.9	18.8	13.4	11.7	14.3	13.0
1994	14.3	13.5	12.0	11.7	23.3	22.2	19.0	18.4	15.7	11.4	13.6	18.5	11.4	23.3	16.1	12.3	20.9	17.2
1995	20.9	20.2	14.1	12.3	12.6	11.1	13.2	29.8	37.0	35.9	31.1	20.2	11.1	37.0	21.5	18.4	28.2	22.2
1996	22.9	21.1	18.4	28.2	36.5	35.4	36.7	36.1	35.1	26.3	20.7	19.0	18.4	36.7	28.0	16.0	22.9	19.0
1997	22.9	21.1	16.0	16.2	31.1	42.5	57.3	49.9	46.5	49.4	42.3	21.9	16.0	57.3	34.8	19.3	24.6	21.4
1998	22.0	24.6	19.3	19.4	24.2	25.7	24.0	24.0	21.2	17.1	20.5	20.9	17.1	25.7	21.9	20.9	27.1	24.6
1999	24.7	26.7	23.7	27.1	26.2	29.7	28.6	27.9	23.4	18.8	17.5	19.6	17.5	29.7	24.5	18.3	24.1	20.5
2000	20.8	24.1	18.3	19.5	22.3	24.3	23.5	23.1	18.0	14.2	20.9	18.1	14.2	24.3	20.6	12.5	18.8	15.8
2001	18.8	16.9	12.9	12.5	12.3	13.8	13.8	14.0	11.4	10.2	10.6	12.9	10.2	18.8	13.3	10.8	13.2	12.5
2002	13.1	13.2	12.5	10.8	12.8	20.9	20.8	21.1	17.5	13.8	18.0	19.6	10.8	21.1	16.2	17.3	22.3	19.2
2003	18.4	22.3	17.3	18.6	18.7	21.3	21.4	21.1	16.9	10.8	11.7	15.9	10.8	22.3	17.9	15.9	23.1	18.4
2004	19.2	23.1	16.7	16.9	15.8	18.0	17.9	17.2	15.0	11.5	12.7	15.2	11.5	23.1	16.6	12.1	17.4	14.6
2005	15.4	13.0	12.1	17.4	16.5	15.0	15.2	15.5	14.1	12.6	13.4	15.4	12.1	17.4	14.6	13.8	17.8	15.4
2006	17.8	15.5	14.5	13.8	15.3	19.8	20.6	22.0	18.1	12.1	13.1	15.3	12.1	22.0	16.5	13.5	15.9	15.1
2007	15.9	15.8	14.8	13.5	13.3	16.0	15.9	16.0	11.6	10.8	10.8	14.9	10.8	16.0	14.1	12.5	15.3	14.1
2008	15.0	15.3	12.8	12.5	12.9	14.3	13.6	13.9	12.6	....	....	....	....	....	....	....	....	....

STATISTICS (JANUARY 1968 TO DECEMBER 2007)

NUM	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40

TABLE 3–2.—AVERAGE DAILY OUTFLOW FOR THE MONTH FROM LAKE SAKAKAWEA, JUNE 1967 TO SEPTEMBER 2008 (IN 1,000 cfs)—Continued

[Retrieved on 8-October-2008]

YEAR	MONTH												FULL YEAR (Jan–Dec)			Colder Months (Dec–Apr)[1]		
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	MEAN	MIN	MAX	MEAN
MIN	13.1	13.0	10.4	10.3	10.6	11.1	13.2	14.0	11.0	9.9	10.1	12.9	9.9	16.0	13.3	10.3	13.2	12.5
MEAN	23.0	24.2	19.6	19.2	21.2	23.0	24.4	24.0	20.5	18.8	19.8	20.3	14.5	29.1	21.5	17.0	25.1	21.0
MAX	30.5	33.7	30.6	37.5	38.5	42.5	61.8	54.1	46.5	49.4	42.3	29.5	23.8	61.8	34.8	26.0	37.5	29.2
STDEV	4.5	5.7	5.6	6.3	7.7	8.1	10.3	8.5	7.9	8.9	7.7	3.6	3.8	9.3	5.4	4.1	5.7	4.6

[1] Rows include Jan to Apr of following year.

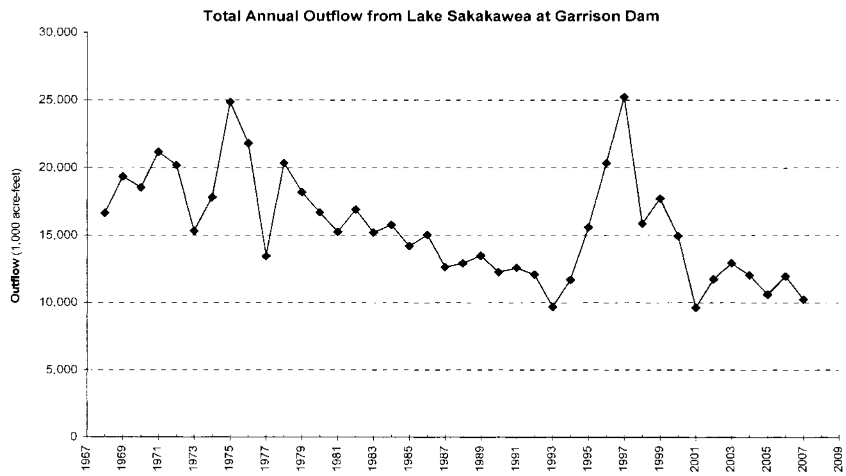

FIGURE 3–7.—*Annual total outflow from Lake Sakakawea at Garrison Dam from 1968 to 2007 (Source of data: USACE).*

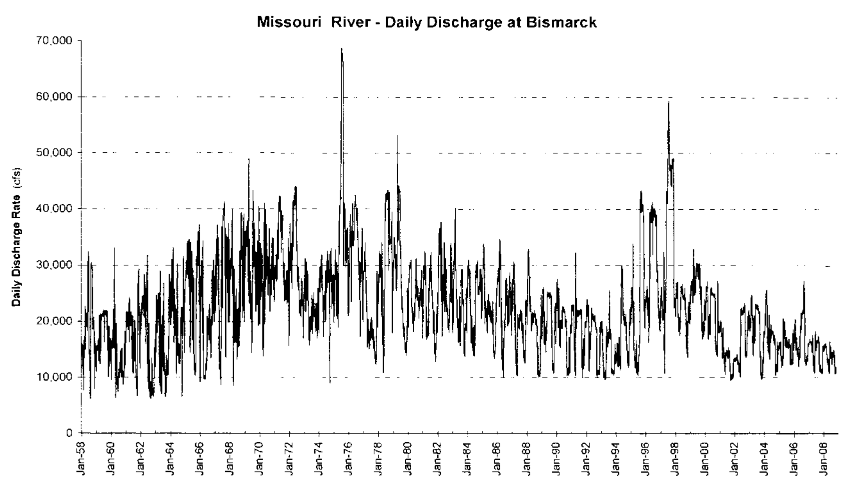

FIGURE 3–8.—*Daily Discharge in the Missouri River at Bismarck from 1958 to 2008 (Source of data: USGS).*

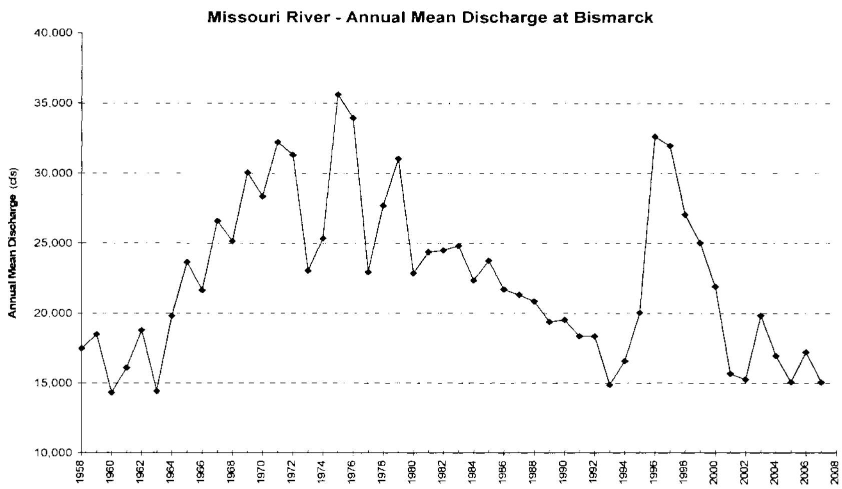

FIGURE 3–9.—*Annual mean discharge at Bismarck from 1958 to 2007 (Source of data: USGS).*

TABLE 3–3.—MONTHLY MEAN FLOW AT BISMARCK

[USGS Gaging Station 06342500]

Year	Month												Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1958	14,190	13,270	15,370	19,090	20,770	29,370	14,730	17,680	29,710	20,430	16,750	14,970	18,861
1959	14,580	15,990	16,150	16,800	21,000	21,340	20,950	21,680	21,220	16,200	15,590	14,970	18,039
1960	15,110	18,360	19,600	14,190	13,260	8,445	10,840	12,760	12,560	10,000	12,330	15,120	13,548
1961	20,620	20,090	20,880	20,790	19,340	14,350	13,760	16,590	9,369	16,410	25,180	16,080	17,788
1962	21,710	23,540	24,080	23,540	22,310	22,140	13,800	9,271	8,121	8,399	8,155	14,330	16,616
1963	20,270	20,200	22,440	17,000	9,234	16,720	17,140	9,821	9,683	11,600	17,010	24,590	16,309
1964	24,320	28,000	25,850	20,550	17,780	21,390	14,590	13,600	18,920	17,150	23,770	21,780	20,642
1965	28,230	31,430	31,390	29,090	23,870	27,630	22,610	14,490	13,140	29,460	33,950	31,260	26,379
1966	20,680	27,810	25,760	10,510	10,900	13,350	18,700	20,230	17,440	21,090	25,600	23,060	19,594
1967	27,020	32,610	31,710	19,220	10,900	27,130	32,920	39,400	28,760	32,390	28,900	27,350	28,193
1968	27,690	33,310	23,700	23,570	21,500	18,570	17,950	22,380	24,910	35,080	26,360	28,270	25,274
1969	32,350	34,840	33,550	32,350	26,060	19,930	29,740	33,300	28,880	26,860	28,520	31,690	29,839
1970	26,980	29,840	22,530	28,020	31,950	31,050	28,720	29,920	24,170	28,730	31,060	27,310	28,357
1971	28,300	29,850	32,760	38,220	40,950	37,360	36,910	28,910	26,260	26,450	27,240	24,150	31,447
1972	31,220	30,500	34,370	40,370	42,030	40,800	30,130	26,230	22,650	22,970	24,910	21,220	30,617
1973	28,190	27,220	27,860	22,660	18,000	19,690	21,450	21,910	20,930	20,340	21,110	23,970	22,778
1974	27,500	28,740	28,360	21,850	23,030	25,680	28,060	29,780	25,920	29,480	26,400	25,920	26,727
1975	24,470	30,180	27,350	22,650	35,450	43,540	64,610	57,010	39,700	34,210	34,390	29,100	36,888
1976	28,060	34,640	29,570	34,700	38,030	40,880	39,680	34,990	29,410	28,370	32,460	26,500	33,108
1977	29,100	30,700	23,580	17,950	17,200	17,250	18,850	17,790	16,230	14,050	17,190	22,980	20,239
1978	27,770	30,710	26,070	23,060	17,550	33,030	42,410	42,260	35,460	34,550	35,040	24,710	31,052
1979	31,730	32,550	29,180	33,950	40,120	40,370	28,940	22,870	18,850	16,650	15,250	20,570	27,586
1980	23,310	29,790	28,630	22,090	19,630	22,380	27,520	25,350	23,610	23,750	25,620	22,270	24,496
1981	26,150	29,700	25,170	17,630	19,330	27,490	30,350	25,120	20,430	16,940	16,130	20,320	22,897
1982	27,850	34,790	31,130	24,830	26,560	26,310	27,580	22,490	19,810	20,750	31,480	26,120	26,642
1983	21,210	31,640	32,790	24,010	18,790	19,660	19,790	27,470	25,090	16,230	18,490	22,480	23,138
1984	28,430	28,810	22,950	18,290	16,030	16,650	23,350	29,010	27,760	25,860	27,690	23,380	24,018
1985	27,980	31,490	22,230	20,660	21,320	23,160	22,030	20,810	19,340	14,340	15,850	22,870	21,840
1986	27,710	28,610	31,730	22,470	12,840	15,640	20,940	26,290	21,610	23,250	26,340	22,020	23,288
1987	25,720	29,530	20,590	12,580	16,510	19,940	20,820	20,930	18,290	14,910	14,490	23,040	19,779
1988	23,930	31,280	24,380	21,140	20,520	21,040	21,210	19,780	15,050	11,110	11,170	20,400	20,084
1989	20,190	24,540	17,370	17,020	22,550	24,870	24,820	24,400	14,640	11,630	20,150	21,210	20,283
1990	26,020	21,930	17,820	19,010	20,520	22,150	21,720	19,720	12,680	11,000	12,070	18,590	18,603

TABLE 3–3.—MONTHLY MEAN FLOW AT BISMARCK—Continued

[USGS Gaging Station 06342500]

Year	Month												Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1991	21,900	22,290	14,570	18,370	21,480	21,560	21,610	21,840	15,500	14,170	14,810	19,450	18,963
1992	23,050	21,160	14,240	17,180	20,910	20,620	20,730	19,410	14,700	10,970	10,930	18,650	17,713
1993	19,330	14,270	10,670	10,420	15,930	17,020	19,270	17,650	12,900	11,040	11,520	13,590	14,468
1994	14,160	13,640	13,490	12,520	25,520	25,400	20,870	19,920	17,160	13,690	14,590	20,810	17,648
1995	23,080	24,250	17,780	13,130	13,840	11,660	13,580	32,180	42,670	40,150	34,980	21,710	24,084
1996	24,440	23,620	20,730	31,350	38,960	38,470	39,500	39,320	38,060	28,510	22,470	20,260	30,474
1997	24,340	22,660	21,700	18,380	32,310	42,580	56,770	48,100	45,060	48,180	43,240	23,550	35,573
1998	23,490	26,230	20,750	19,270	23,530	25,890	24,490	24,640	21,430	15,640	19,870	21,610	22,237
1999	24,570	26,690	26,610	27,080	26,480	29,930	28,830	28,500	24,660	20,240	17,970	20,420	25,165
2000	22,090	25,910	19,950	19,940	22,190	25,470	24,940	24,660	19,400	14,690	20,880	18,740	21,572
2001	19,480	17,740	16,060	14,090	12,430	14,550	14,190	14,130	11,290	10,160	10,510	13,250	13,990
2002	13,360	13,530	13,030	11,800	12,630	22,030	21,780	22,260	18,820	14,240	18,370	21,020	16,906
2003	19,280	23,560	18,710	19,210	19,490	22,810	22,660	21,850	17,160	10,770	11,460	15,960	18,577
2004	19,950	24,610	19,180	17,590	15,450	18,440	18,090	17,230	15,060	11,590	12,580	15,600	17,114
2005	16,000	13,540	12,870	17,850	17,430	16,160	16,220	16,140	14,810	13,070	13,680	16,060	15,319
2006	18,690	16,100	15,130	13,920	15,130	20,280	21,350	22,970	20,080	12,830	13,470	15,780	17,144
2007	16,470	16,430	15,990	14,090	13,270	16,770	16,300	16,670	12,840	11,410	....	....	15,024
Mean 1958–2007	23,445	25,454	22,767	20,921	21,656	23,979	24,576	24,234	21,244	19,840	21,183	21,409	22,538
Mean 1968–2007	24,139	26,036	22,628	21,382	22,836	24,927	26,219	25,905	22,332	20,222	21,301	21,681	23,274

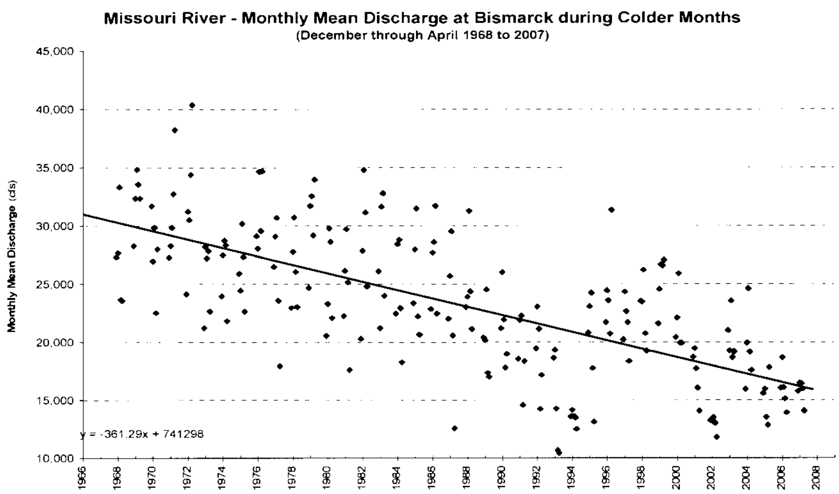

FIGURE 3–10.—*Monthly mean discharge rates at Bismarck during the five colder months (December to April) from 1968 to 2007 (Source of data: USGS).*

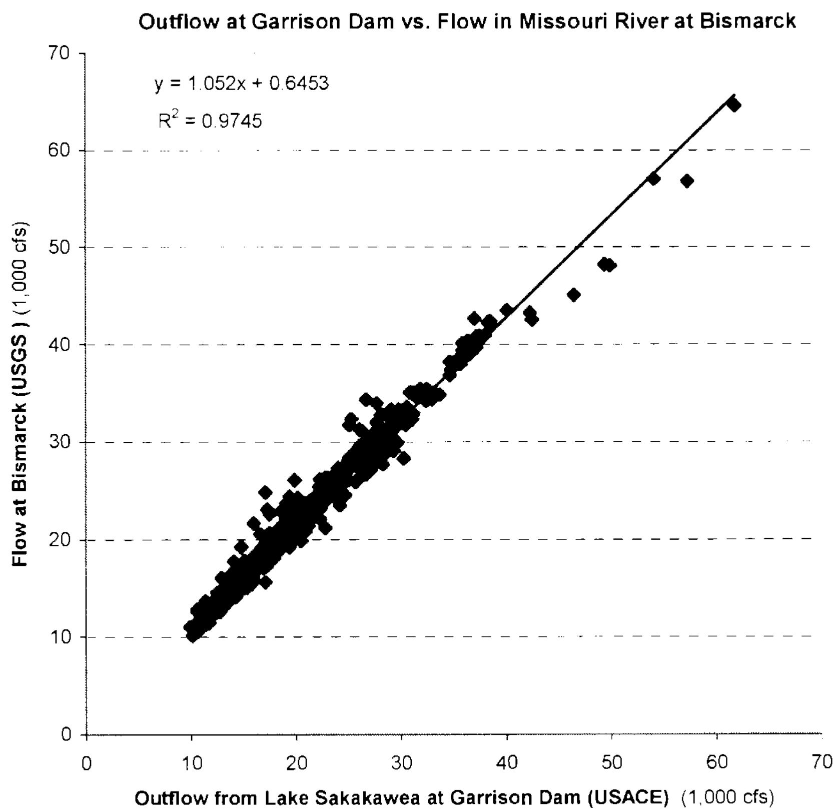

FIGURE 3–11.—*Monthly outflow at Garrison Dam vs. monthly discharge at Bismarck (1968 to 2007) (Sources of data: USACE, USGS).*

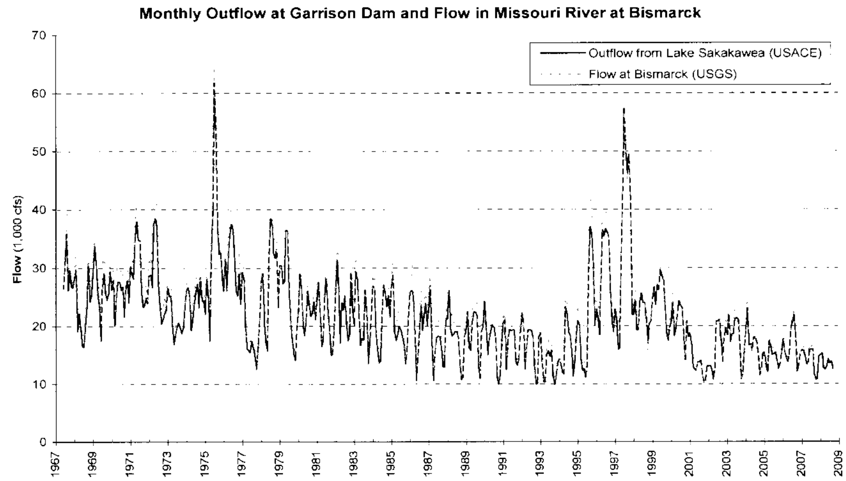

FIGURE 3–12.—*Monthly outflow at Garrison Dam and monthly discharge at Bismarck (1967 to 2008). Higher discharges at Bismarck reflect the added runoff from the watershed downstream of Garrison Dam (Sources of data: USACE, USGS).*

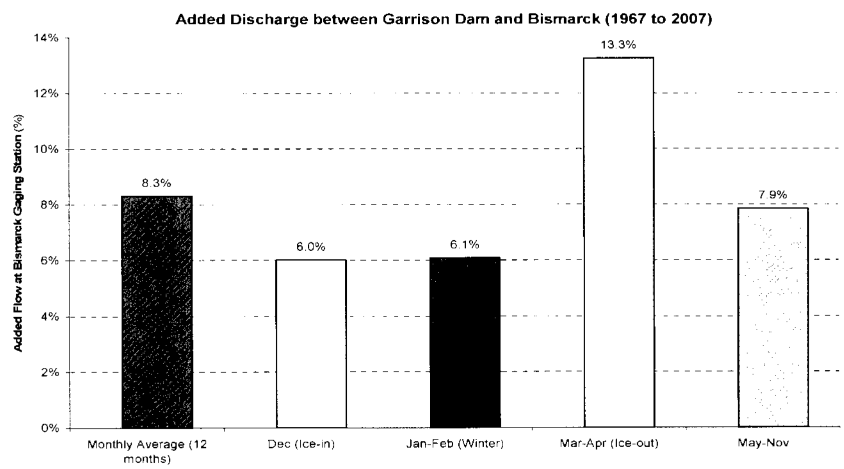

FIGURE 3–13.—*Residual discharge after subtracting outflow at Garrison Dam from the discharge at Bismarck, reflecting the runoff from the watershed between Garrison Dam and Bismarck (1967 to 2007) (Sources of data: USACE, USGS).*

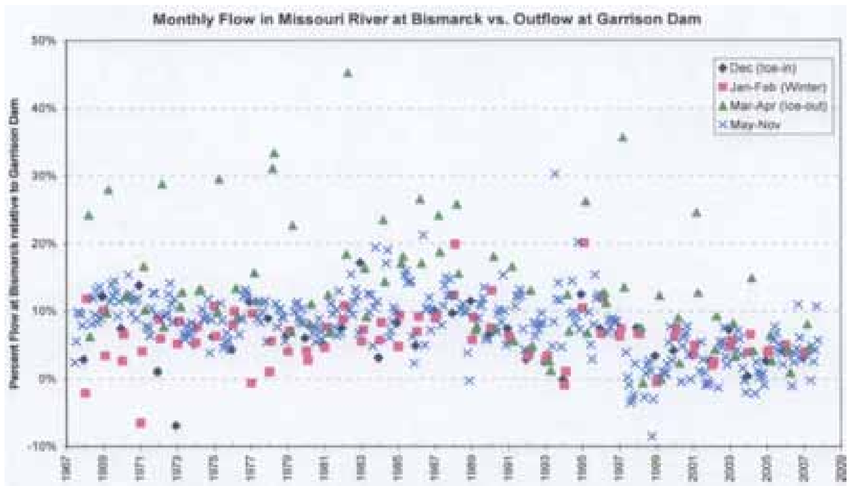

FIGURE 3–14.—*Percent flow at Bismarck relative to the outflow at Garrison Dam for different periods of the year (1967 to 2007). Highest additional discharge occurred during the spring melting season. (Sources of data: USACE, USGS).*

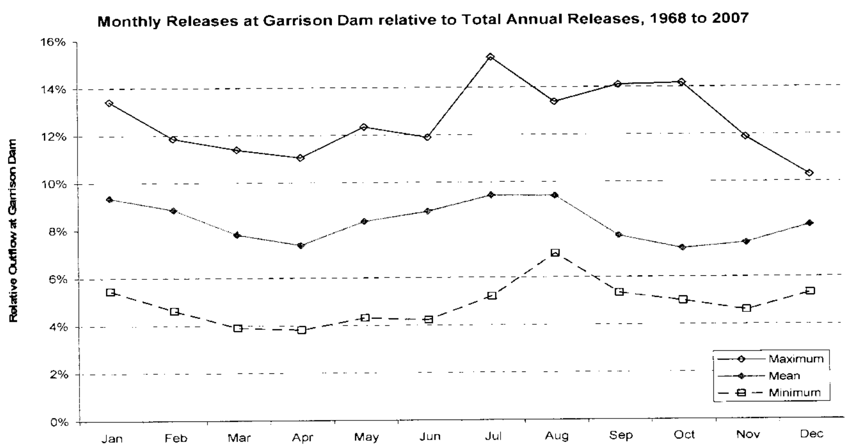

FIGURE 3–15.—*Monthly releases at Garrison Dam, relative to total annual releases, showing that highest releases occur during the peak demand periods in December, July, and August (Sources of data: USACE).*

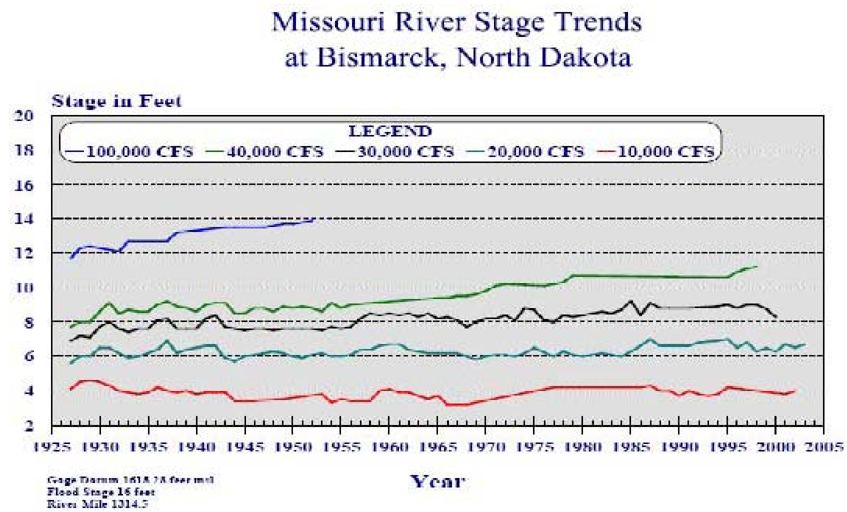

FIGURE 3–16.—*Stage-discharge relationship in Bismarck, reflecting an increase of the stage at high flows (USACE, 2004c).*

3.3.3. Hydropower Generation

Water release rates at Garrison Dam for ice-in vary from year to year depending on the specific conditions and needs of other uses. Under "normal conditions", the USACE would release from "the top of the maintenance zone" and gradually release the water over the winter. However, reduced runoff in the watershed has resulted in a decline in power generation between 1967 and 2008 by almost a factor of 2 (Figure 2–10). Using linear regression, the decline was approximately 8 percent greater during the 5-month-long colder period (December to April) than during the other months of the year (Figure 3–18). Specifically, the greatest decline in the colder period occurred during January–February and ice-out (March–April) (Figure 3–19).

TABLE 3–4.—CHANNEL CHANGES DOWNSTREAM OF GARRISON DAM BETWEEN 1958 AND 1985 (USACE, 1993c).

[QUALITATIVE ACTIVE CHANNEL CHANGES 1958 TO 1985 FOR A DISCHARGE OF 20,000 CFS]

1960 R.M.	THALWEG ELEV	AVE. BED ELEV	AVE DEPTH	WIDTH	AREA	D50 GRAIN SIZE
1388.19	-	-	-	+	-	+
1387.09	-	-	+	-	-	+
1385.88	-	-	-	+	-	+
1384.86	-	-	-	-	-	+
1383.33	-	-	+	-	-	+
1382.25	-	-	*	-	-	-
1381.34	-	-	-	-	-	+
1380.43	-	-	+	-	-	+
1379.68	-	-	-	+	-	+
1379.00	-	-	-	+	-	+
1378.42	-	-	*	*	-	+
377.53	*	-	-	+	-	+
1376.71	-	-	-	-	+	+
375.89	-	-	-	-	-	+
374.91	-	-	-	-	-	+
1374.58	-	-	*	-	-	+
1373.80	+	-	+	+	+	+
1372.50	-	-	+	*	+	+
1371.37	-	-	-	-	-	+
1370.29	+	-	*	*	-	+
1368.89	*	-	-	+	+	+

TABLE 3–4.—CHANNEL CHANGES DOWNSTREAM OF GARRISON DAM BETWEEN 1958 AND 1985 (USACE, 1993c).—Continued

[QUALITATIVE ACTIVE CHANNEL CHANGES 1958 TO 1985 FOR A DISCHARGE OF 20,000 CFS]

1960 R.M.	THALWEG ELEV	AVE. BED ELEV	AVE DEPTH	WIDTH	AREA	D50 GRAIN SIZE
1367.40	-	-	-	-	-	+
1366.24	-	-	+	-	-	+
1364.87	+	-	+	-	-	+
1363.86	+	-	-	-	-	+
1362.55	+	-	-	+	-	-
1360.40	-	-	+	-	-	-
1358.50	*	-	-	+	+	+
1356.50	*	-	+	+	+	+
1353.85	+	-	-	-	-	+
1351.83	+	-	-	*	*	+
1349.46	-	-	-	+	+	+
1346.46	-	-	+	+	+	-
1344.72	-	-	+	-	-	-
1343.30	-	-	-	+	-	-
1341.40	+	-	-	+	+	+
1339.67	-	-	*	+	+	-
1338.05	-	-	+	+	+	+
1336.82	-	-	-	+	+	-
1335.91	-	-	*	-	+	+

* NO CHANGE OR INCOMPLETE DATA.
- MEASURED UNITS HAVE DECREASED FOR THAT PARAMETER OR MSL ELEVATION HAS DECREASED.
+ MEASURED UNITS HAVE INCREASED FOR THAT PARAMETER OR MSL ELEVATION HAS INCREASED.

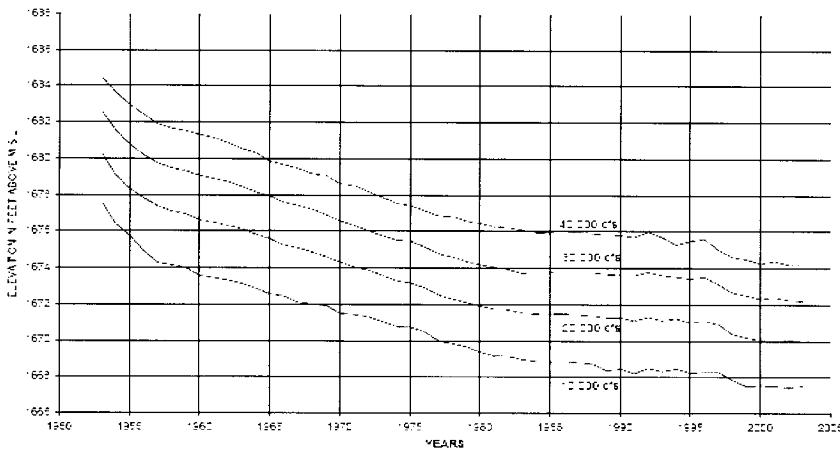

FIGURE 3–17.—*Tailwater elevation changes at Garrison Dam at different flows, reflecting the degradation of the channel since the construction of the dam (USACE, 2004c).*

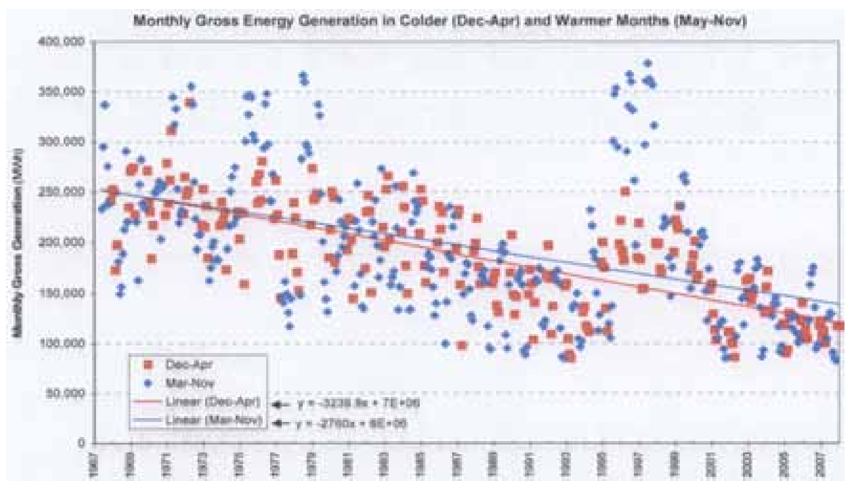

FIGURE 3–18.—*Monthly gross energy generation in colder and warmer periods, showing a slightly greater decrease during colder months over time compared to warmer months (Source of data: USACE).*

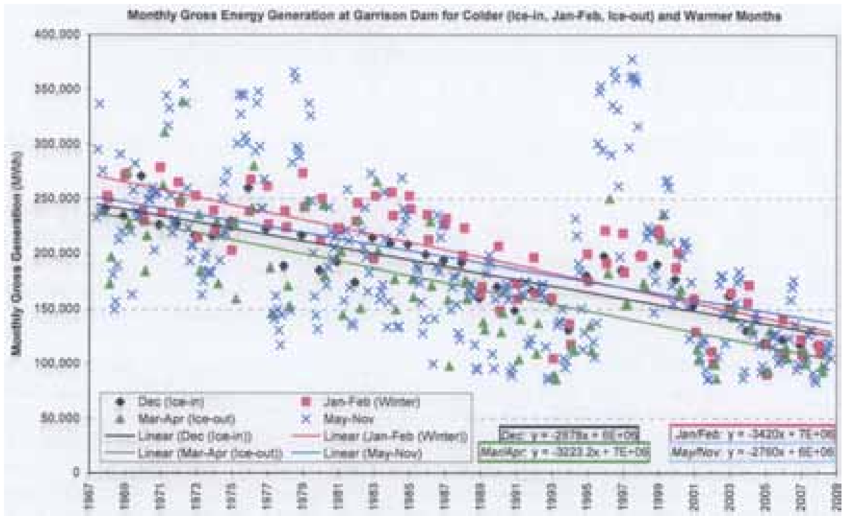

FIGURE 3–19.—*Monthly gross energy generation in colder and warmer periods, with higher resolution during colder months (Source of data: USACE).*

Power generation during the colder period accounted for 58 percent of the total annual power generation; this value has decreased to 53 percent (Figure 3–20). Although there are other potential causes for a relatively greater decline during the winter months (such as the statistical effect of the floods in the mid-1990s), the decline could have been caused by aggradation in the Missouri River in the headwater of Lake Oahe.

Siltation in the river has resulted in aggradation and widening of the river channel south of Bismarck. In urban areas such as Bismarck and Mandan the river channel cannot widen without an increased risk of flooding and the loss of property. As a result, the flow release rates have been reduced over time to prevent flooding. This effect is expected to continue. The risk is higher during wet years when the elevation of Lake Oahe is higher, and consequently its headwaters extend further north, and thus more sediments is being deposited again closer to the urban areas of Bismarck and Mandan than at the present time. It is likely that power generation in winter during wet years will decrease as a result. However, high inflows to the reservoir during wet years may require higher water release rates even during the colder months. This condition occurred during the wet years between 1995 and 2000 when release rates (and thus energy generation) during colder months were approximately 50 percent higher than during subsequent years (i.e., from year 2001 to the present) (Figure 3–18).

One of the biggest impacts to hydropower generation from ice dams is the reduction in flexibility of hydropower generation in winter (if the risk for flooding is to be reduced). Specifically, as stated above, the power plant cannot be operated as an optimally efficient peaking facility.

Prevention of flooding means that the water from Lake Sakakawea is released at a different time of the year, generating power at that time. Since rates applied to power generated at the Garrison Dam do not vary on a month-by-month basis, annual revenues from power generation are thus not lost. The total annual revenue from energy generation would only be adversely affected if water is released from Lake Sakakawea during warmer months in excess of the maximum generating capacity of Garrison Dam (41,000 cfs), in order to prepare for reduced releases during the colder months.

However, winter is one of the peak power demand periods. Thus, reduced power generation capacity in winter at the Garrison Dam power plant may mean that power from other, potentially more expensive sources needs to be generated to accommodate demand.

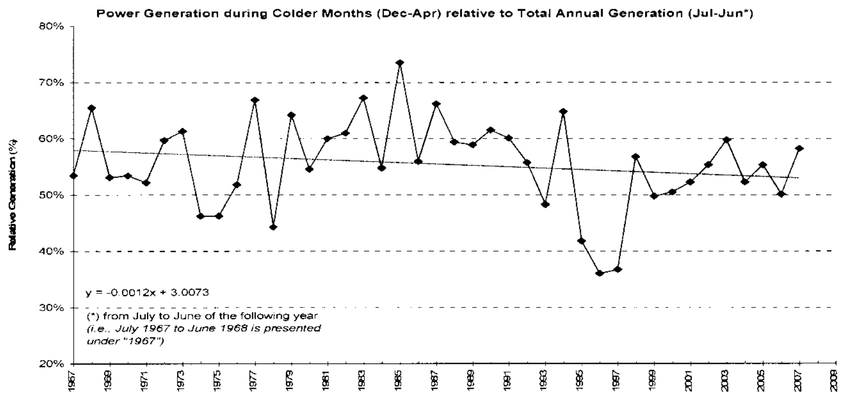

FIGURE 3–20.—*Power generation during colder months (5-month period) relative to total annual generation (Source of data: USACE).*

4.0 RECOMMENDATIONS

Releases from Garrison Dam by the USACE for various uses already aim to minimize flooding. Detailed monitoring data should continue to be collected to allow for effective adaptive management measures of the operations of Garrison Dam to maximize the benefit of the dam and the overall System, while minimizing impacts. This is particularly important in light of the fact that there are a number of natural variables that change regularly (daily, as well as longterm), such as rainfall, temperature, flow, erosion and deposition patterns, etc. In addition, the river serves multiple uses that also need to be balanced, e.g., navigation, flood protection, irrigation, recreation, etc. Specifically in winter, flood protection from ice dams is a more important driver for the determination of the release rates.

Dredging could be considered on a temporary and localized basis for flood control, but a larger-scale dredging operation would most likely be cost-prohibitive. Dredging has been conducted for selected water intakes which are affected by sedimentation (such as the power plant Leland Olds in Stanton). Small-scale dredging for similar purposes is probably cost-effective.

The risk of flooding will increase once the current drought has passed, and Lake Oahe again has full pool elevations. Higher pool elevations imply that sediment carried by the Missouri River will be settling out closer to the city of Bismarck than at present which will result in further aggradation. A higher risk of flooding requires further reduction in hydropower generation at Garrison Dam. The existing flood plain and zoning should be reviewed in the cities of Bismarck and Mandan to determine if additional steps should be undertaken to better accommodate high flows in the Missouri River. Supposedly, there has been additional development down close to the river edge around the city. Such developments should be avoided, or potentially even reversed if feasible. Similarly, the flood plain and zoning in other potentially affected areas (i.e., non-urban areas) should be reviewed. Further, appropriate bank stabilization measures should be considered in areas most heavily affected by flooding. After all, when reservoir levels are high during wetter years, more water needs to be passed through the river, which will limit the reduction in flow that can be achieved in the winter (as occurred during the wet period from 1995 to 2000; Figure 3–18).

As suggested by the Water Commission in their comments to the draft report, it is recommended to conduct a study that more quantitatively demonstrates that higher elevations in Lake Oahe will result in a decrease in flow velocities due to aggradation. This study would need to address the range of variables that affect the flow in order to extract the impact of lake elevations on outflow rates. A first-order assessment was conducted during this study, comparing average outflow rates at Garrison Dam with elevation in Lake Oahe, although the available data were insufficient to quantitatively address the range of variables. The recommended assessment should include an estimate of future trends of sedimentation and resulting impacts.

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PERSONAL COMMUNICATION

Larry Cieslik, Chief, Reservoir Control Center, U.S. Army Corps of Engineers; November 6, 2008.

Bruce Engelhardt, Investigations Section Chief, North Dakota State Water Commission; November 11, 2008.

Jody Farhat, P.E., Power Production Team Leader, Missouri River Basin Water, Management Division, Northwestern Division, U.S. Army Corps of Engineers, Omaha, NE; November 10, 2008.

James Mueller, Chief, Maintenance Engineering Section, U.S. Army Corps of Engineers; January 8, 2009.

Bill Mulligan, Chief, Civil Works Project Management, U.S. Army Corps of Engineers, Omaha, NE; November 17, 2008.

John Remus, Chief, Hydrologic Engineering Branch, U.S. Army Corps of Engineers, Omaha, NE; November 7, 2008.

Ronald Sando, Water Resources Consultant, Missouri River Joint Water Board; October 24, 2008.

John Stonebarger, UGP Energy Marketing Supervisor, Western Area Power Administration, November 10, 2008.

U.S. Geological Survey, North Dakota Water Science Center, Bismarck, ND; November 12, 2008.

Peter Whiting, Associate Dean of the College of Arts and Sciences, and Associate Professor of Geological Sciences, Case Western Reserve University, Cleveland, OH; October 23, 2008.

Acknowledgment

We greatly appreciate the time and effort of the persons listed above to provide helpful documentation and information for this project.

EXHIBIT 1—COMBINED RESERVOIR REGULATION AND POWER PRODUCTION ORDER NO. ST–2, 1983

Garrison Standing Order
To: Garrison Office Attn: Project Engineer
From: Reservoir Control Center
Re: Garrison Combined Reservoir Regulation and Power Production Order No. St–2, 1983. This order will apply when referenced in the Daily Reservoir Regulation and Power Production Orders.

1. Minimum energy generation shall be maintained to avoid low pumping stages below Garrison as follows:

Period Minimum Energy for Period
4 hours 300 MWh
5 hours 400 MWh
6 hours 550 MWh
7 hours 700 MWh 8 hours 850 MWh

The WAPA power systems dispatcher shall be advised whenever it appears that loading is falling below the above minimums so that plant loading can be increased. The above minimums have been furnished to WAPA.

2. Unless otherwise specified in daily reservoir regulation and power production orders supplementary releases will be made only as necessary to maintain daily average discharge of 6,000 cfs. The WAPA dispatcher will be notified as far in advance as possible of the intent to make supplementary releases.

APPENDIX E—IMPACT OF SILATION OF THE MISSOURI RIVER ON FISH AND WILDLIFE IN NORTH DAKOTA

1.0 INTRODUCTION

The contemporary Missouri River in North Dakota is highly modified from its natural character due to the Flood Control Act of 1944. The Flood Control Act was Federal legislation that led to the establishment of the Pick-Sloan Plan to construct six large dams on the Missouri River mainstem from Nebraska to Montana.

The completion of the Pick-Sloan Plan has had several implications for the ecology of the river. The creation of reservoirs has converted riverine to lacustrine habitat (NRC, 2002; Galat et al., 2005) by stabilizing river flows (Hesse and Mestl, 1993; Galat and Lipkin, 2000). The stabilization of flows and the presence of dams cause sediment to become trapped in the reservoirs, resulting in a sediment deficit downstream (Macek-Rowland, 2000; Galat et al., 2005). Reservoirs also reduce channel meandering, resulting in a decline in off-channel habitat (Shields et al., 2000).

North Dakota contains one dam, Garrison Dam, and its associated reservoir, Lake Sakakawea. The reservoir known as Lake Oahe, formed by the Oahe Dam in South Dakota, also extends into North Dakota from the south. Therefore, from an ecological perspective, the Missouri River in North Dakota may be thought of as having four parts:

—*The Williston Reach.*—The riverine segment close to the Montana border, into which the Yellowstone River flows and which flows into Lake Sakakawea;

—*Lake Sakakawea.*—The reservoir formed by Garrison Dam (closed in 1953), whose entire range is within the state of North Dakota;
—*The Garrison Reach.*—The riverine segment from Garrison Dam to the headwaters of Lake Oahe; and
—*Lake Oahe.*—The reservoir formed by Oahe Dam in South Dakota (closed in 1958) and which is in both North Dakota and South Dakota.

2.0 DESCRIPTION OF THE RESOURCE

The creation of these reservoirs has resulted in a suite of ecological changes, including the creation of major warm water sport fisheries. It has also resulted in declines for many of the native fish that were adapted to the pre-impoundment conditions. Therefore, in this section, we will define the "resource" as two groups of animals: those that constitute a conservation concern and those that are important for recreational purposes (hunting and fishing). These are hereafter referred to as "Conservation Species" and "Recreational Species," respectively.

2.1 Conservation Species

Within the first group, we include those animals that are listed as species of conservation priority in the North Dakota Wildlife Action Plan (NDWAP) of 2005. The NDWAP report uses a "conservation priority" system that rates a species at a particular "level" of conservation priority.[1] The report then divides the State of ND into geographic focus areas. Our intent is to include in the "conservation species" group all those species of conservation priority that are listed in the NDWAP's "Missouri River and Breaks" section, which lists all of the animals of conservation priority that fall within the Missouri River focus area in the State of ND. The section can be found on page 71 of the NDWAP report.

We do not include the species of conservation priority that are not listed in the "Missouri River and Breaks" geographic focus area as per the NDWAP report of 2005. Such animals have ranges that fall outside of the Missouri River mainstem system.

The species listed under the "Missouri River and Breaks" geographic focus area of the NDWAP are:

—*Birds.*—Bald eagle (Haliaeetus leucocephalus), piping plover (Charadrius melodius), least tern (Sterna antillarum), red-headed woodpecker (Melanerpes erythrocephalus), golden eagle (Aquila chyrsaetos)
—*Mammals.*—River otter (Lotra Canadensis)
—*Reptiles and Amphibians.*—Smooth softshell turtle (Apalone mutica), false map turtle (Graptemys pseudogeographica)
—*Fish.*—Sturgeon chub (Macrhybopsis gelida), pearl dace (Margariscus margarita), blue sucker (Cycleptus elongatus), paddlefish (Polydon sp athula), pallid sturgeon (Scaphirhynchus albus), flathead catfish (Pylodictis olivaris), flathead chub (Platygobio gracilis), sicklefin chub (Macrhybopsis meeki), yellow bullhead (Ameiurus natalis)

The pallid sturgeon, in addition to being listed as a species of conservation priority, is also a federally endangered species. The piping plover and the least tern are also federally threatened species.

While the NDWAP report lists the pearl dace (Margariscus margarita) and the yellow bullhead (Ameiurus natalis) in the "Missouri River and Breaks" section, we do not include the yellow bullhead and the pearl dace in our analysis. These fish either do not use the Missouri River mainstem, or only very rarely make use of it, and so they fall outside the scope of this report.

2.2 Recreational Species

The recreational species group includes the most popular game fish as described in the creel surveys prepared for the year 2006 by NDGF (Brooks et al., 2007a, 2007b). According to these surveys, the most popular sport fish in Lake Sakakawea, by estimated number of fish caught during 2006, in order of popularity, are: walleye, sauger, northern pike, Chinook salmon, white bass, and channel catfish. The order from most popular to least popular in Lake Oahe is walleye, channel catfish, sauger, northern pike, white bass, and Chinook salmon. Full details, including the estimates

[1] "Level I species are those having a high level of conservation priority because of declining status in North Dakota or across their range; or have a high rate of occurrence in North Dakota, constituting the core of the species breeding range, but may be at-risk range-wide. Level II species are those having a moderate level of conservation priority; or a high level of conservation priority but a substantial level of non-[State wildlife grant] funding is available to them. Level III species are those having a moderate level of conservation priority but are believed to be peripheral or non-breeding in North Dakota" (Hagen et al., 2005, p.10).

and the methods used to accomplish these estimates, are available in Brooks et al (2007a, 2007b).

The recreational species group also includes a bird species that is important for recreational hunting on the Missouri River: the Canada goose (Branta Canadensis).[2] The Canada goose is a game species, and over 100,000 of them are shot in the State of North Dakota every year (Richkus et al., 2008), a significant proportion of which are shot on the Missouri River mainstem and floodplain. We also include beavers and muskrats, as hunting and trapping occurs for these animals on the Missouri River (Fred Ryckman, 2008, personal communication). White-tailed deer is another game species that is hunted on the Missouri River floodplain. However, the species is not evaluated here because neither the literature nor the interviews indicated that siltation has any effect on white-tailed deer.

3.0 AREAS WHERE THE RESOURCE COULD BE IMPACTED BY SEDIMENTATION

In this section we summarize sediment dynamics in the Missouri River in North Dakota for each of the four river sections defined in Section 1. We also summarize the key areas in which increased sedimentation will affect the resource.

3.1 Williston Reach

Suspended sediment in the Williston Reach comes from the mainstem upstream, beginning at the Fort Peck Dam in Montana, and from the Yellowstone River, which flows into the Missouri River near the western edge of the North Dakota/Montana border. The sediment load from the Yellowstone River supports near pre-impoundment levels of turbidity in the Williston reach; therefore, the reach exhibits many of the characteristics of the pre-impoundment Missouri River (Ryckman, 2000; Lambing and Cleasby, 2006; Steven Krentz, 2008, personal communication). When this sediment load meets the slow-moving headwaters of Lake Sakakawea, it settles out and forms a delta. This reach connects fish that reproduce successfully in the Yellowstone River (such as paddlefish, pallid sturgeon, and blue suckers) with the Missouri River.

3.2 Lake Sakakawea

Lake Sakakawea is a reservoir of approximately 286 kilometers in length (Galat et al., 1996). It has a delta that is 61 kilometers in length, formed by the deposition of sediment from the Williston reach (Galat et al., 2005). Lake Sakakawea's waters are colder, clearer, deeper, and have a more stable hydrograph (seasonal floods have been eliminated; Hesse and Mestl, 1993; Galat and Lipkin, 2000) than the Missouri River mainstem before dam construction. The ecology of the Lake Sakakawea delta has not been studied intensively (Fred Ryckman, 2008, personal communication). However, it has been observed that the waters beyond the delta are clear, and that this area supports a large fishery with abundant walleye, northern pike, and sauger populations. Paddlefish are often found in Lake Sakakawea, although they do not reproduce successfully there (Fred Ryckman, 2008, personal communication; Scarnecchia et al., 2008).

3.3 Garrison Reach

Whereas the Williston reach contains near pre-regulation levels of sediment due to import from the sediment-rich Yellowstone River and from the mainstem upstream, the Garrison reach between Garrison Dam and the headwaters of Lake Oahe is relatively deprived of sediment due to the retention of sediment in Lake Sakakawea. Major sources of sediment in this reach come from tributaries (Macek-Rowland, 2000) and from river-bed erosion on the mainstem. Among these tributaries, the Heart River is the most important contributor of sediment (Macek-Rowland, 2000). The Garrison reach is not well-studied, and little is known about the ecology of this segment of the river (Steven Krentz, 2008, personal communication).

3.4 Lake Oahe

Lake Oahe, formed by the Oahe Dam in South Dakota, is the longest of the six Pick-Sloan Reservoirs, 372 kilometers in length (Galat et al., 1996). A sediment load from the Garrison reach forms a delta that is 103 kilometers in length (Galat et al., 2005). Only a third of Lake Oahe is located within North Dakota, with the remainder in South Dakota. Lake Oahe supports a fishery with abundant walleye, northern pike, and sauger populations. Paddlefish are found in Lake Oahe, although it is unclear where they reproduce, as they are not known to reproduce in the reservoir itself (Fred Ryckman, 2008, personal communication).

[2] Steve Dyke, a conservation biologist for NDGF suggested we consider the Canada goose as part of this assessment.

3.5 Key Areas Where the Resource Could be Impacted by Sedimentation

An increased sediment load in the reservoirs would mean increased sediment aggradation due to the decreased maximum water velocity associated with reservoirs and the considerably limited ability of reservoirs to transport sediment downstream. Aggradation would cause deltas to increase in size (Palmieri et al., 2001, cited in Kaemingk et al., 2007) and could lead to sediment accumulation behind dams. An increased sediment load would also increase turbidity in the inter-reservoir reaches. In the reservoirs, turbidity would increase in the headwaters while the remainder of the reservoir would remain clear, due to the low water velocity in reservoirs that would cause suspended sediment to settle out (Blevins, 2006). The impacts on different species of fish and wildlife would not be uniform, as some species benefit in some reaches while others are negatively affected. These differences are the result of a particular species' life-cycle characteristics as they relate to each particular portion of the river.

As we discuss below, many of the key recreation species of fish require clear and sediment-free water for their prosperity. Therefore, sedimentation and increased turbidity have negative impacts on their populations. However, current conditions do allow for abundant recreational fisheries.

An increased sediment load could presumably have benefits for some of the conservation species that are adapted to life in a turbid environment. However, other physical factors being equal, increased sediment loading alone is not likely to be sufficient to restore or support the populations of these species.

Other conservation species would benefit from an increase in the amount of sandbar habitat available. Increased sedimentation could potentially generate new sandbar habitat; the deficit of sandbar habitat is in many areas a result of reduced sediment load due to sediment retention by dams (NRC, 2002). Colonization of sandbars by cottonwood and willow trees constitutes another important part of habitat generation for many species. However, such colonization would require seasonal floods of a magnitude commensurate with those of the Missouri River during pre-regulation times, which are now absent (Johnson, 2002; Bovee and Scott, 2002). Thus, increased sedimentation alone may not generate suitable sandbar habitat unless a hydrologic regime that suits colonization by cottonwood and willow trees is allowed to occur.

4.0 LITERATURE AND DATA COLLECTION METHODOLOGY

Our approach to literature collection was to first conduct as series of informational interviews with key personnel in the following institutions:

—North Dakota Game and Fish
—United States Fish and Wildlife Service, Bismarck Office
—United States Geological Survey
—University of North Dakota
—North Dakota State University
—University of Nebraska
—United States Army Corps of Engineers, Omaha District

Through these interviews, we derived a list of the species to evaluate in this section. We were also able to obtain key pieces of literature that reviewed the life-cycle of key species in the State of North Dakota.

The second step was to complete an Internet search using key terms from species names and relying on search engines that investigated government, academic, and professional Web sites. Through this literature search we were able to obtain some reports (government or academic) that described species of interest in States other than North Dakota, if the in-State literature on a particular species was lacking.

The third step of literature collection involved searching through Berger's extensive database of information on the ecology of the Missouri River. Through our participation with other projects focused on the Missouri River, Berger has assembled a large library of peer-reviewed and government documents pertaining to various aspects of ecology on the Missouri River. We were able to focus a search of this library for literature that would provide information about the key species in this analysis. This library was also useful in establishing the basic ecological situation of the Missouri River and in characterizing pre-regulation versus post-regulation characteristics and conditions.

5.0 IDENTIFICATION AND DISCUSSION OF POTENTIAL SILTATION IMPACTS TO FISH AND WILDLIFE

In this section we discuss the impacts of siltation to fish and wildlife in the mainstem Missouri River in North Dakota, broken into the two groups of species identified in Section 3.

5.1 Conservation Species

This group consists of seven fish, two reptiles, five birds, and one mammal. All of these species have shown enough certainty of decline for them to have been listed as species of conservation priority, either at the State or national levels.

5.1.1. Fish

All of the seven fish are endemic to the Missouri River mainstem in North Dakota. This means that they have evolved in a highly turbid environment. For some species, declines in population have been directly attributed to declines in water turbidity (flathead catfish, all chubs, pallid sturgeon). While the general life-cycle characteristics and habitat needs of these fish species is well-established in the scientific literature, fish ecology in the North Dakota portion of the Missouri River mainstem is not well-studied (Fred Ryckman, 2008, personal communication; Chris Guy, 2008, personal communication).

However, several ecological conditions are thought to impact the health of conservation priority fish in the Missouri River mainstem in North Dakota. For instance, there is enough information to conclude that siltation has a positive impact on some species in some portions of the river, but a negative impact on those same species when it occurs elsewhere. This is especially true concerning fish reproduction. Many of the conservation species are gravel spawners (paddlefish, pallid sturgeon, blue sucker), and if gravel substrates become covered with a layer of silt, these habitats become unsuitable for the fish species (AFS, 2008). This is especially true in areas of the river with low water velocity, such as the reservoirs, where silt may easily settle out. In areas of high water velocity, however, it is less of a problem because the high water velocity prevents the silt from settling onto the gravel substrate (USFWS, 1993a).

The Williston reach currently does have high turbidity due to sediment loads from the Yellowstone River, while the Garrison reach is relatively deprived of sediment due to retention behind Garrison Dam (Galat et al., 2005).

Blue Sucker

The blue sucker is a species of Level I conservation priority in North Dakota. The species currently occupies Lake Oahe and the Garrison reach. In addition, small populations have been found in the Williston reach, but they do not appear to be reproducing successfully there. The reasons for this are unclear (Fred Ryckman, 2008, personal communication).

Blue suckers are adapted to live in the swift current of large, turbid rivers (Hagen et al., 2005). Berry et al. (2004) found that blue suckers used waters of 10 to 50 nephelometric turbidity units (NTUs) of turbidity. They are mostly found in riffles and narrow chutes, and require gravel bottoms free of sediment (Hagen et al., 2005).

Population decline over the years has been attributed to habitat modification, specifically caused by temperature alteration and turbidity reduction (Berry et al. 2004; Hagen et al., 2005). Population recruitment[3] has been observed in the Missouri River, however, blue sucker reproduction has never been observed in the mainstem. As such, it is likely that the young-of-year fish that add to the blue sucker populations in the mainstem are spawned in the tributaries, after which they migrate into the mainstem (Steven Krentz, 2008, personal communication).

Increases in water turbidity in high-velocity reaches will likely have a positive impact on this species. However, in waters of lower velocity, an increased silt load may cause gravel substrates to become covered by silt, resulting in a negative impact on blue sucker.

Flathead, Sicklefin, and Sturgeon Chubs

Sturgeon and sicklefin chubs are species of Level I conservation priority according to the NDWAP, while flathead chubs are species of Level II conservation priority.

All of these chubs are adapted for life in turbid, free-flowing rivers with an abundance of sloughs, sandbars, and woody debris (Hesse, 1994, cited in Everett et al., 2004). Turbidity is a major variable affecting sicklefin and sturgeon chub presence in rivers (USFWS, 2001; Bonner and Wilde, 2002; Fisher et al., 2002; Everett et al., 2004). Note that flathead chubs are more likely to use sandbar habitat than sturgeon or sicklefin chubs (Fisher et al., 2002).

Reduced turbidity is likely the reason why chubs are no longer found in the reservoirs of Lake Sakakawea or Lake Oahe, nor are they found in the Garrison reach (Scarnecchia et al., 2002; Fred Ryckman, 2008, personal communication). Their

[3] Recruitment is defined as "the addition of new individuals to a population by reproduction" (Smith and Smith, 2008).

presence has been observed in the Williston reach, which retains pre-regulation levels of turbidity (Scarnecchia et al., 2002).

As chubs are not currently known to inhabit the reservoirs, it is difficult to determine whether increased sediment loading in these reservoirs would serve to re-establish or support their populations. Increased aggradation in the Garrison reach might be more likely to have a positive impact on chubs, as this reach, though modified, retains a riverine as opposed to lacustrine character. Particularly given the positive association between chub presence and water turbidity (USFWS, 2001; Bonner and Wilde, 2002; Fisher et al., 2002; Everett et al., 2004), it is reasonable to predict that increases in turbidity would have a positive impact on these fish, so long as this occurs in an environment that is in all other respects inhabitable by chubs. The reservoirs do not seem to meet this qualification, while the Garrison reach does. However, scientific research on chub reproduction in North Dakota is inadequate to fully assess how sedimentation will affect their ability to reproduce successfully.

Flathead Catfish

Flathead catfish are an endemic species of Level III conservation priority in the State of North Dakota. This species is known to use pools with instream structure, such as snags, rubble, and bridge supports (Berry et al., 2001). They are commonly found in waters with high turbidity (USGS, 1998), and reproduce in holes along the river's banks (Berry et al., 2001). Currently, the flathead catfish of North Dakota are known to inhabit Lake Oahe exclusively, and are not found in the other portions of the river in the State (Hagen et al., 2005).

The NDWAP cites reduced turbidity, temperature reduction, and population fragmentation as reasons behind flathead catfish decline in North Dakota (Hagen et al., 2005). Other studies have placed special emphasis on the role of decreased turbidity in flathead catfish decline (USGS, 1998; Berry et al., 2001). As such, increases in turbidity would likely have a positive impact on this species, however, it is unknown whether increased turbidity alone would be sufficient to restore and support populations of this species and return it to the reaches from which it has been expelled. Given its preference for slower waters (Hagen et al., 2005), it may be unrealistic to expect flathead catfish to return to areas of high-velocity flow, even if the turbidity in these areas increases.

Paddlefish

This species is listed as a species of Level II conservation priority. While it is legal to fish for paddlefish, given its conservation status, the volume of the catch is subject to restrictions.

Paddlefish do not rely on visual cues for spawning, migration, or feeding (Firehammer et al., 2001), and typically grow successfully in turbid environments. However, sedimentation poses a problem for paddlefish egg-laying. Paddelfish spawn in the spring (Hagen et al., 2005) and require clean, well-oxygenated gravel substrates in order to deposit eggs successfully (Jennings and Zigler, 2000). Some research suggests that paddlefish are particularly susceptible to losing their spawning habitat as gravel substrates are covered with silt (Sparks,1984, Turner and Rablais, 1991, Holland-Bartels, 1992, and Schmulbach et al., 1992, cited in Jennings and Zigler, 2000). This is likely a reason why they do not spawn in the Missouri River reservoirs, where slow-moving currents cause suspended sediment to settle out and cover gravel spawning beds (Fred Ryckman, 2008, personal communication).

Hagen et al. (2005) note that the lower water velocity brought about by the Missouri River reservoirs has allowed silt to cover existing gravel substrates and make them unsuitable as reproductive substrates for paddlefish. For this reason, paddlefish do not reproduce within the Missouri River reservoirs. Most observed paddlefish reproduction occurs in the Yellowstone River. Larvae produced in the Yellowstone drift into the Williston reach, and eventually enter into Lake Sakakawea (Scarnecchia et al., 2008; Fred Ryckman, 2008, personal communication).

They do not reproduce successfully within the reservoir, yet adult paddlefish are abundant in Lake Sakakawea. Paddlefish are also found in Lake Oahe, however, scientists do not know where these fish originate from (Fred Ryckman, 2008, personal communication).

Therefore, turbidity in high-velocity reaches such as the Williston reach or in tributaries such as the Yellowstone River does not have an adverse impact on paddlefish. As reproduction does not occur in the reservoirs anyhow, increased turbidity in the reservoirs is not likely to limit paddlefish populations because they can forage successfully in turbid environments. Further research clarifying the importance of the Garrison reach for paddlefish in North Dakota would clarify the potential impacts of increased sedimentation in that area. Available research suggests that increased turbidity in a high-velocity environment benefits paddlefish.

Pallid Sturgeon

The pallid sturgeon was listed as a federally-endangered fish in 1990. In addition, they are a species of Level II conservation priority in North Dakota.

Pallid sturgeon are morphologically adapted for benthic dwelling in swift, turbid waters (Forbes and Richardson, 1905; Kallemeyn, 1983; Gilbraith et al., 1988). They are known to use waters of 31.3 NTU (J. Erickson, 1992, cited in USFWS, 1993b), and to have a current velocity of 10 to 30 centimeters per second (J. Erickson, 1992, cited in USFWS, 1993b). Young-of-year and juvenile pallid sturgeon use sandbar habitat (Yerk and Baxter, 2001, Kapuscinski and Baxter, 2003, and Doyle and Starostka, 2003, cited in USFWS, 2003). Mostly they are found over sand or gravel substrate (Sheehan et al., 2002 cited in USFWS, 2003; Hagen et al., 2005). The population declines leading to their listing as a federally-endangered species have been attributed to widespread habitat destruction throughout their range (Gilbraith et al., 1988; Kallemeyn, 1983; NRC, 2002; USFWS, 2003, 2007).

Little is known about the pallid sturgeon's reproductive biology (USFWS, 1993b; USFWS, 2003). It is thought that they spawn during July and August (Forbes and Richardson, 1905) over hard rock, rubble, or gravel substrate (USFWS, 2003). These characteristics are similar to the well-studied shovelnose sturgeon (USFWS, 1993b).

Pallid sturgeon are known to spawn successfully in the relatively unregulated Yellowstone River (Pat Braaten, 2008, personal communication). However, no natural pallid sturgeon recruitment has been observed in the Missouri River since monitoring began in earnest approximately 20 years ago (Pat Braaten, 2008, personal communication; Chris Guy, 2008, personal communication). Pallid sturgeon larvae are known to drift close to the river-bottom (Braaten et al., 2008) and it is hypothesized, though not empirically confirmed, that for this reason larvae are suffocated and killed as they move into the sediment-laden and slow-moving delta headwaters of Lake Sakakawea after drifting in from the Yellowstone River (Pat Braaten, 2008, personal communication; Fred Ryckman, 2008, personal communication).

The particular effects of siltation on pallid sturgeon are not well understood, and would not be uniform across the Missouri River with its diversity of flows, temperatures, and depths. Mitigation measures dealing explicitly with sedimentation as it effects pallid sturgeon have not been attempted in North Dakota (Chris Guy, 2008, personal communication; Pat Braaten, 2008, personal communication).

Note that the declines in pallid sturgeon populations have been attributed to habitat destruction throughout their range. This suggests that neither the re-introduction of water turbidity, or increases in siltation, are likely to suffice to restore their populations by themselves.

5.1.2. BIRDS

Bald Eagle

The bald eagle was listed as a federally endangered species in 1967, but was delisted in 2007. It is a species of Level II conservation priority in North Dakota.

Bald eagles build their nests in large trees. In North Dakota, cottonwoods are particularly important nest trees and the majority of bald eagles making use of the Missouri River mainstem and floodplain habitat use cottonwood trees (Aron, 2005). They forage by perching in trees and viewing the water in order to capture fish and waterfowl (Steenhof et al., 1980).

Increases in water turbidity that prevent bald eagles from being able to see fish in the water will cause bald eagles to turn to mammals and birds for food (Grubb, 1995, cited in Stinson et al., 2007). So long as mammal and bird prey is abundant, increased turbidity will not have an impact on the foraging success of bald eagles.

If siltation increases the amount of fresh sandbars, it may lead to an increase in cottonwood recruitment, which would benefit bald eagles.

Golden Eagle

The golden eagle is a species of Level II conservation priority in North Dakota.

These birds usually nest on cliffs, but will also nest in cottonwood or green ash trees (Hagen et al., 2005). They feed on small animals, primarily mammals (Hagen et al., 2005). Current understanding suggests that anthropogenic disturbance, caused by hunters, birders, and manmade structures, in addition to toxic chemicals, are the biggest threats to golden eagles. Habitat destruction is a problem not because it reduces suitable habitat for golden eagles, but because it limits access to food (Hagen et al., 2005).

If siltation increases the amount of cottonwood trees available by creating more riparian habitat, it will have a positive impact on golden eagles. Otherwise, it will not have a significant impact on these birds.

Least Tern

The least tern was listed as a federally-endangered species in 1985. In addition it is a species of Level II conservation priority in North Dakota.

The least tern adapted to colonial nesting on non-vegetated, shifting sandbars within large, alluvial rivers (USFWS, 1990; USFWS, 2003). Dam operations have reduced the availability of this habitat for least terns, due to the stabilizing effect on hydrology and their tendency to trap suspended sediment necessary for sandbar formation downstream (USFWS, 2003). According to USFWS (2000), the least tern's range in North Dakota does not extend into Lake Sakakawea, but is limited to the Garrison reach and Lake Oahe. Most research on least tern habitat has been conducted on the lower Missouri River, not in North Dakota (USACE, 2008).

Because the primary issue responsible for least tern decline is reduced habitat availability caused primarily by sediment retention behind dams, increased siltation would be a benefit for least terns only if it is able to increase the amount of sandbar habitat available. In the Garrison reach, which has a sediment deficit, increased siltation would be particularly beneficial to least terns if it is able to create sandbar habitat. Least terns require non-vegetated sandbar habitat, so if fresh sandbars became colonized by vegetation then they would be unsuitable for least tern use. This means that a one-time sediment release would not create suitable habitat for least terns. The generation of suitable sandbar habitat relies on the natural annual hydrologic peaks, in addition to an unhindered supply of sediment, occurring regularly as a constant flow through the system.

Piping Plover

The Northern Great Plains population of the piping plover (which includes the entire North Dakota population of the species) was listed as federally endangered in 1985. As of 2008, they had been changed from a federally endangered species to a federally threatened species. This bird is also a species of Level II conservation priority in North Dakota.

Plovers use beach-like habitat, including sandflats and gravel, with little vegetative cover (less than 20 percent). These habitats are often adjacent to rivers and reservoirs; they can also use natural islands that meet these characteristics (Haig, 1992). Northern Great Plains piping plovers in the pre-regulation Missouri River nested on sandbars and islands (Galat, 2005; Haig et al., 1994). They feed primarily on terrestrial invertebrates and benthic worms (Haig, 1992).

Siltation will benefit piping plovers if it occurs in high-velocity currents where it may aggrade to form sandbars and islands. As with the least tern, piping plovers require non-vegetated sandbars, and so any sandbar habitat that is formed will be unsuitable if it becomes colonized by vegetation. Siltation that does not generate sandbar habitat will not affect piping plovers. Thus, as with the least tern, a one-time release of sediment will not suffice to restore sandbar habitat suitable for piping plover. Sandbar habitat will require hydrologic peaks and flows that would transport sediment through the system.

Red-Headed Woodpecker

The red-headed woodpecker is a species of Level II conservation priority in the State of North Dakota.

Red-headed woodpeckers live in deciduous woodlands in the upland or floodplain habitats (Hagen et al., 2005). They make nests anywhere from 5 to 80 feet above ground level, in dead oak, ash, maple, elm, sycamore, cottonwood, or willow trees, or in utility poles (Hagen et al., 2005). Their diet is composed of insects found in decaying wood, corn, nuts, berries, and occasionally the eggs or young birds of other passerines (Hagen et al., 2005).

Siltation will not have an impact on red-headed woodpecker, unless it generates an increase in tree recruitment, which would have a positive impact.

5.1.3. OTHER CONSERVATION SPECIES

False Map Turtle

The false map turtle is a species of Level III conservation priority in North Dakota.

False map turtles rely primarily on large rivers and backwaters for their habitat (Bodie et al., 2000). Their decline has been attributed to the reduction and alteration of sandbar habitat in the mainstem Missouri River (Hagen et al., 2005). Therefore, siltation will benefit false map turtles if it generates new sandbar habitat. Recall from the discussions on least tern and piping plover that a one-time release of sediment will not suffice to this end.

Smooth Softshell Turtle

The smooth softshell turtle is a species of Level III conservation priority in North Dakota.

Smooth softshell turtles rely primarily on moderate to fast streams and rivers (Bodie et al., 2000). They are found in Lake Oahe, but have not been observed in Lake Sakakawea, nor have they been observed in the Garrison or Williston reaches of the river (Hagen et al., 2005).

North Dakota's 2005 Wildlife Action Plan suggests that reductions in sandbar habitat have been the primary cause of smooth softshell turtle declines. Therefore, siltation that results in the generation of sandbar habitat will be beneficial to these reptiles.

River Otter

The river otter is a species of Level II conservation priority in North Dakota.

River otters historically occurred throughout aquatic habitats in North Dakota, but their populations have declined due to the destruction or modification of riparian habitat, usually for the purposes of economic development of various kinds, including agricultural, residential, or others (Hagen et al., 2005). The current status of river otter populations in North Dakota is uncertain, and it is not clear whether a viable population exists within the State. However, we include river otters in our analysis because the Missouri River is an important waterway through which these animals might return to North Dakota from populations in other States (Hagen et al., 2005).

Increased siltation will only affect river otters if it generates riparian habitat, as they are known to use this habitat. Decline in riparian and wetland habitat was cited in Hagen et al. (2005) as a reason for river otter decline.

5.2 RECREATIONAL SPECIES

Walleye, channel catfish, sauger, northern pike, white bass, and Chinook salmon are the most important recreational fish species on the Missouri River in North Dakota. Of these six fish species, walleye are the most prized recreation fish. The fisheries for all of these species are thriving under the current sediment regime, although the particular impacts of siltation on the most popular species such as walleye, sauger, and northern pike remain unclear (Fred Ryckman,2008, personal communication). Trapping and hunting occurs for Canada goose, beaver, and muskrat (Steve Dyke, personal communication, 2008), so we include these animals as well. The methods used to estimate the populations of the recreational fish species are outlined in Brooks et al. (2007a, 2007b). Note that the margin of error is likely due to a small sample size.

Academic and government studies reveal that endemic recreational fish that were abundant in the pre-regulation Missouri River benefit from the increased turbidity brought about by siltation; these include the channel catfish and the sauger.

For those fish that were introduced or that were artificially made abundant, the effects of an increased sediment load and increased turbidity are negative; in this group are the northern pike, white bass, Chinook salmon, and walleye. Increases in sediment load are thought to be detrimental to these species for two reasons. First, these species are all visual predators, and their foraging success decreases in turbid waters. Second, their reproductive success requires a rocky or gravel substrate for laying eggs, and if this is coated with a layer of sediment, it becomes unsuitable. Highly-aggraded habitat is therefore unsuitable for them.

Fisheries for walleye exist in all four segments of the Missouri River mainstem in North Dakota. The considerable sedimentation that does occur in the inter-reservoir reaches presumably affects them, but successful fisheries exist nonetheless. The sediment-laden waters of the Williston reach deposit their sediment load in the 61-kilometer delta of Lake Sakakawea. The reservoir beyond the delta is relatively clear. Thus, increased siltation in the Williston reach or in the Lake Sakakawea delta will only affect the Lake Sakakawea fishery if it is of a volume sufficient to significantly increase the length of the delta or to increase the turbidity and siltation of the clear waters beyond the delta. For this reason, siltation in the inter-reservoir reaches will not have an impact on the fishery species unless it is severe. Recall, however, that much about the effects of siltation on fishery species remains uncertain (Fred Ryckman, 2008, personal communication); what is known is that the current conditions allow these species to thrive (Brooks et al., 2007a, 2007b; Fred Ryckman, 2008, personal communication).

Walleye

Walleye are a native fish in the Missouri River basin, although prior to the construction of dams, they were not abundant (Benson, 1968, cited in Bryan, 1995).

Today, walleye are the major constituent of the recreational fishery on the Missouri River in North Dakota. Eighty-two percent of the anglers on Lake Oahe in 2006 were found to fish primarily for walleye (Brooks et al., 2007a). Walleye accounted for 98 percent of boat angling and 68 percent of shore angling in 2006 on Lake Sakakawea (Brooks et al., 2007b). Total harvest of walleye from Lake Sakakawea during 2006 was between 993,482 and 285,871 fish caught by boat anglers, and between 476,051 and 181,468 fish caught by the shore anglers (Brooks et al., 2007b). In Lake Oahe, boat anglers caught between 141,951 and 48,719 individual walleyes, while shore anglers caught between 110,344 and 45,125 individuals (Brooks et al., 2007a).

Walleye are visual predators, and as such, high turbidity may impair their ability to see their prey and thus to forage successfully. They are also opportunistic predators that prey on a variety of fish species (Lyons and Magnuson, 1987, Vigg et al., 1991, Jackson, 1992, and Mero, 1992, cited in Bryan, 1995), and during portions of the year, their diet may consist primarily of aquatic insects (Kelso, 1973; Swenson, 1977, Johnson et al., 1988, and Mero, 1992, cited in Bryan, 1995). The most important prey fish are rainbow smelt, spottail shiner, and freshwater drum (Jackson, 1992, cited in Bryan, 1995). With the exception of freshwater drum, these species were introduced to the Missouri River system as forage for walleye and other game fish (Galat et al., 2004). They are not adapted to life in a turbid environment. Thus, increased turbidity in the clear waters of the reservoirs may have a negative impact on these fish, and these effects may carry over to walleye.

Siltation also has implications for walleye reproduction. This is because walleye are broadcast spawners, releasing fertilized eggs into the water column over a rocky surface so that they descend into the cracks between rocks and later hatch (Kerr et al., 1997, cited in Dustin and Jacobson, 2003). They have also been observed laying eggs over live vegetation (Dustin and Jacobson, 2003). Eggs that land on sand, silt, or muck experience high mortality (Johnson, 1961, and Priegel, 1970, cited in Dustin and Jacobson, 2003). Therefore, if the rocky surfaces that walleye rely on for reproduction become covered by sediment, this reduces their ability to reproduce successfully. Siltation of a level sufficient to prevent aquatic plant growth will also reduce walleyes' ability to reproduce successfully over vegetation.

Another way in which sediment will affect walleye is in its capacity to modify temperature. Temperature is an extremely important factor in walleye growth (Armour, 1993, cited in Bryan, 1995), and they cannot reproduce in waters colder than 6° C (Hokanson, 1977, cited in Bryan, 1995). If the suspended sediment load reduces the water temperature below this level during spawning, it will reduce their population.

The Williston and Garrison reaches have walleye fisheries, and these occur during late summer through spring, which are clear-water periods (NDGF, 1998a, 1998b).

Thus because of effects on foraging and reproduction, increased siltation is likely to have a negative effect on walleye populations. However, the walleye fishery in Lakes Sakakawea and Oahe is thriving. This is true of Lake Sakakawea despite the sediment load from the Williston reach and the delta at the headwaters. The effects of siltation on walleye in North Dakota are unclear (Fred Ryckman, 2008, personal communication). However, under current conditions their populations are not declining. Increased sediment loads are not likely to be a problem for walleye unless they result in increased turbidity in the clear waters of Lakes Sakakawea and/or Oahe.

Northern Pike

On Lake Sakakawea in 2006, northern pike accounted for less than 1 percent of all boat angling efforts, and 8 percent of all shore angling efforts, representing 7,799 (+/− 23,305) and 1,116 (+/− 6,737) individual fish, respectively (Brooks et al., 2007b). On Lake Oahe, northern pike accounted for less than 1 percent of all boat angling efforts, and 3 percent of all shore angling efforts (Brooks et al., 2007a). These totals (1,884 (+/− 4,674) and 636 (+/− 2,951), respectively) are for individual fish (Brooks et al., 2007a).

Northern pike thus constitute an important recreational species, and much of their life-cycle needs are similar to those of walleye. They are visual predators (Polyak, 1957, and Braekvelt, 1975, cited in Inskip, 1982), therefore increases in water turbidity affects their ability to detect prey and to forage successfully. Although northern pike will eat a variety of small mammals including invertebrates, waterfowl, and small mammals, they are mostly piscivorous,[4] with gizzard shad, alewife, yellow perch, and trout-perch comprising the bulk of their diet (Inskip, 1982). Ambush constitutes a major foraging strategy for northern pike; as such, they require aquatic plants for cover. Siltation reduces aquatic plant cover (by choking out young plants or by reducing light penetration); therefore, it will have a negative impact on northern pike.

Northern pike spawn over vegetation in areas of calm, shallow water (Williamson, 1942, and Clark, 1950, cited in Inskip, 1982). They can use flooded terrestrial vegetation for this purpose, although they have been observed using backwaters (McCarraher and Thomas, 1972, Jarvenpa, 1962a, and Frost and Kipling, 1967, cited in Inskip, 1982). Therefore, a reduction in submerged vegetation brought about by siltation reduces the northern pike's ability to spawn successfully.

The Williston and Garrison reaches have northern pike fisheries occurring during late summer through spring, which are clear-water periods (NDGF, 1998a, 1998b).

If siltation or turbidity increases occur in the clear waters of Lakes Sakakawea and/or Oahe, they will have a negative impact on northern pike populations due to adverse effects on foraging and reproduction. However, increased siltation in the Williston or Garrison reaches will not likely have an impact on northern pike, because unless it is severe, such siltation aggrades in the reservoir deltas once it reaches the reservoir from the inter-reservoir reach. This would leave ample clear-water areas in the reservoir for the northern pike fishery to remain.

Channel Catfish

In Lake Sakakawea during 2006, only 438 channel catfish were caught by shore and boat anglers (Brooks et al., 2007b). However, on Lake Oahe, channel catfish accounted for 3 percent of all boat angling efforts, and 39 percent of all shore angling efforts (Brooks et al., 2007a). Brooks et al. (2007a) estimate that 13,346 (+/− 16,857) channel catfish were caught by boat anglers, and 6,872 (+/− 13,571) channel catfish were caught by shore anglers.

Channel catfish are a native species throughout the Missouri River basin (Galat et al., 2004), and are substrate generalists (Pegg and Pierce, 2002). They use habitat in the mainstem, in the floodplain, and in reservoirs (Galat et al., 2004). They feed on insects and crustaceans (Walburg, 1975). Channel catfish in turbid water fisheries do not require stocking, and natural recruitment serves to maintain their population (Mosher et al., 2006), suggesting that they can successfully exist in turbid environments.

Because channel catfish are known to thrive in turbid environments, increases in turbidity are likely to have a positive impact on their populations in the Missouri River in North Dakota.

Chinook Salmon

Chinook salmon are a non-native species in the Missouri River system.

During 2006, Chinook salmon accounted for 1 percent of all boat angling, and 8 percent of all shore angling on Lake Sakakawea (Brooks et al., 2007a). The totals (4,199 (+/− 6,268) and 3,907 (+/− 5,806), respectively) are for individual fish (Brooks et al., 2007b). On Lake Oahe during 2006, only 1,121 Chinook salmon were caught (Brooks et al., 2007a).

Chinook salmon lay their eggs over a gravel substrate (Rice, 1960, cited in McCullough, 1999). Therefore gravel that becomes covered by sediment is unsuitable as spawning ground for Chinook salmon. However, Chinook salmon do not reproduce naturally in the Missouri River in North Dakota, and their population is entirely the result of stocking efforts; therefore, siltation will not affect their ability to reproduce. Additionally, turbidity has been shown to reduce the growth of the closely-related coho salmon (Sigler et al., 1984). As the Chinook salmon's popularity as a sport fish in Lake Sakakawea reflects a general abundance of this species in that reservoir, we may infer that the lack of siltation in Lake Sakakawea is favorable to Chinook salmon.

Thus, due to the limitations that it places on growth and on spawning, siltation is likely to have negative impacts on Chinook salmon. Increased siltation in the reservoirs is likely to have a negative impact on the species for the reasons outlined above. Increased siltation in the Williston reach is not likely to affect them unless it is severe enough to significantly increase the size of the delta or the turbidity of waters in Lake Sakakawea. Increased siltation in the Garrison reach is not likely to affect Chinook salmon in an appreciable way.

[4] A piscivore is a carnivorous animal which lives on eating fish.

Sauger

Sauger accounted for 2 percent of all boat angling and 4 percent of all shore angling on Lake Oahe during 2006, representing 3,940 (+/− 9,923) and 2,209 (+/− 7,031) individual fish, respectively (Brooks et al., 2007a). On Lake Sakakawea in 2006, sauger accounted for 1 percent of all boat angling and less than 1 percent of all shore angling, representing 8,363 (+/− 21,394) and 4,588 (+/− 12,654) individual fish, respectively (Brooks et al., 2007b). The Williston reach has a sauger fishery as well (NDGF, 1998a).

Sauger prefer habitat with high physical turbidity (Pflieger, 1975; Graeb, 2006). Therefore, other factors being equal, it is possible that increases in water turbidity will increase the likelihood of sauger presence. Little is known about sauger reproduction, and so siltation's effect thereupon cannot be estimated accurately here. However, it is known that sauger spawn successfully in the Lewis & Clark Lake delta of Nebraska. Therefore, it is possible that an increase in delta habitat brought about by siltation will have a positive impact on sauger reproduction (Graeb, 2006). Regardless, the current sediment regime allows for productive sauger fisheries throughout the Missouri River in North Dakota (NDGF, 1998a, 1998b; Brooks et al., 2007a, 2007b).

Gizzard shad are an important prey species for sauger (Graeb, 2006). Therefore, siltation will affect sauger in accordance with its effects upon gizzard shad. As gizzard shad are native to the Missouri River mainstem (Galat et al., 2004), it is unlikely that turbidity and high sediment loads have a negative effect upon their populations, so increases in siltation are not likely to affect them.

Siltation is likely to have a positive effect on sauger populations because is improves foraging habitat. However, the sauger fishery is currently thriving in the clear, silt-free waters of Lakes Sakakawea and Oahe.

White Bass

In 2006 on Lake Sakakawea, a total of 1,425 white bass were caught by boat and shore anglers (Brooks et al., 2007b). During the same year on Lake Oahe, white bass accounted for 1 percent of all boat angling efforts, and 4 percent of all shore angling efforts (Brooks et al., 2007a). The totals (2,308 (+/− 6,880) and 945 (+/ − 5,821), respectively) are for individual fish (Brooks et al., 2007a).

White bass were introduced into the Missouri River in 1959, 1960, and 1961 (Ploskey et al., 1994, cited in Beck, 1998). White bass are visual predators and feed on zooplankton in the early life stages and then their diet turns to fish and insects as growth progresses (Michaletz et al., 1977, cited in Beck, 1998). Juvenile white bass are prey for walleye, and have been known to seek cover from these fish in stands of aquatic vegetation (Beck, 1998).

Increased turbidity would have a negative impact on white bass because it would reduce their ability to forage successfully. Also, siltation that reduces aquatic vegetation will reduce the amount of cover available for juvenile white bass, so predation may increase, further reducing population size.

Canada Geese

Canada geese are opportunistic nest-builders, using whatever materials they can find, and build nests near open water with low banks (Dewey and Lutz, 2002). If no vegetation is present, Canada geese may construct nests in the open, simply by depressing the ground with their body weight and laying eggs into it (Dewey and Lutz, 2002). These birds feed on grasses, and can be quite flexible in their diet (Dewey and Lutz, 2002).

Siltation is not likely to affect Canada geese unless it reduces the amount of low-bank habitat, which is itself unlikely because silt deposition would create shallow-water habitat that suits Canada geese. Silt deposition might reduce herbaceous vegetation, reducing the food available for Canada geese.

Muskrat

Muskrats are present on the Missouri River system in North Dakota, and rely on riparian habitat for nesting and foraging (Smith, 1996). They create burrows in the river's banks, which can disturb sediment and result in increased turbidity (McMasters University, 2008). Muskrats feed primarily upon riparian plants, but consume mollusks and crustaceans occasionally (Natureserve, 2008).

Increased siltation of the mainstem Missouri River will not affect muskrats unless it significantly affects the amount of riparian vegetation that is available as food. As these animals naturally generate increases turbidity through their burrowing activities, it is not likely that increased turbidity brought about by large sediment loads will have a negative impact on them.

Beavers

Beavers are known for building their own stream impoundments, which can alter the riverine landscape; however, the Missouri River mainstem's large size and great depth prevents beavers from building impoundments on it, and so they instead burrow into the banks and create underwater food caches there (Collen and Gibson, 2001). While beaver dams may bring about a reduction in water velocity and thereby reduce the sediment carrying capacity of a stream, the absence of beaver dams on the Missouri River mainstem prevents this from happening. Beavers feed on riparian plants (Andersen and Cooper, 2000; Collen and Gibson, 2001).

Siltation will not affect beavers unless it affects the abundance of riparian plants that may constitute part of the beavers' forage base.

6.0 CONCLUSIONS

The results of our analysis are summarized below and in Table 1.

Increased sediment loads are likely to have a positive impact on channel catfish and sauger, which are known to inhabit turbid waters. These fish are not currently species of conservation priority, and the current sediment regime is allowing them to sustain populations.

Siltation will have no significant impact upon river otters and Canada geese. These animals are not directly affected by turbidity. Moreover, the reasons for the decline in river otter populations are the complete removal of habitat and changes in siltation will not significantly affect this factor. Canada geese are opportunistic in their habitat use; however, for the reasons noted in Section 6.2.1, Canada geese may be affected by increased siltation, although this is unlikely.

Siltation will have a positive impact on red-headed woodpeckers, golden eagles, and bald eagles only if it increases the amount of riparian forest habitat available, other wise it will have no impact. These birds all require riparian forests for their habitat. Siltation may contribute to riparian forest habitat by aggrading and creating new surfaces for colonization by cottonwoods and willows, but in the absence of natural hydrology this is unlikely to occur.

Increased sediment loading occurring in the clear waters of reservoirs will have a negative impact upon walleye, northern pike, Chinook salmon, and white bass. These species are all visual predators and gravel spawners, and increased turbidity and increased siltation has negative consequences for them. The current sediment regime does allow for an abundant fishery throughout the Missouri River in North Dakota. Note that inter-reservoir fisheries for these fish species exist only during clear-water seasons (late summer through spring; NDGF, 1998a, 1998b).

The pallid sturgeon, paddlefish, flathead chub, sicklefin chub, sturgeon chub, and blue sucker are adapted to thrive in a highly turbid environment, but cannot be expected to increase in abundance unless other environmental factors are satisfied also. The pallid sturgeon, as discussed above, is adapted to life in a turbid environment, however, they do not reproduce successfully in any reaches of the Missouri River, even the turbid Williston reach. It is hypothesized that their larval drift habits, which involve larvae drifting close to the river bottom, causes them to undergo widespread mortality after they reach deltas. The paddlefish can grow in the Missouri River, but do not reproduce successfully in any reach. It is known that chubs require turbid water for their survival, but it is unclear whether this is the only reason why they do not inhabit Lakes Sakakawea or Oahe. The blue sucker does indeed exist in the reservoirs, but primarily it inhabits the inter-reservoir reaches.

The least tern, piping plover, smooth softshell turtle, and false map turtle require sandbar habitat, and siltation that increases sandbar habitat will be of benefit to them. Sandbar habitat is more a result of hydrology than of sediment load. Therefore, NDGF (1998a, 1998b) recommends that flows be managed to allow more sandbar habitat to be created in the inter-reservoir reaches. NDGF, 1998a, suggests that "[i]n at least one year out of four, sustained flows of less than 28,000 but greater than 40,000 cfs in April, May, and June [would be] sufficient to create and/or scour sandbars for terns and plovers" (p. 3). Also, in order to be suitable habitat for terns and plovers, sandbars must be free of vegetation; USACE has not had complete success in managing sandbar habitat to be free of vegetation (USACE, 2008), although further research into feasible techniques is planned for the near future (USACE, 2008).

TABLE 6–1.—IMPACT OF SILTATION ON KEY SPECIES

	Positive impact	No significant impact	Positive impact if siltation increases riparian forest habitat; otherwise no impact	Negative impact	Siltation positive, but require other environmental factors as well	Positive impact if siltation increases sandbar habitat	River sections that the animal predominates in
Conservation Priority Level I:							
Blue sucker					X		Oahe and Garrison
Sturgeon chub					X		Williston only
Sicklefin chub					X		Williston only
Conservation Priority Level II:							
Bald eagle			X				N/A
Golden eagle			X				N/A
Least tern						X	N/A
Piping plover						X	N/A
Red-headed woodpecker			X				N/A
River otter		X					N/A
Flathead chub					X		Williston Reach only
Paddlefish					X		Williston, Sakakawea, Oahe
Pallid sturgeon					X		Yellowstone River and Williston
Conservation Priority Level III:							
Smooth softshell turtle						X	N/A
False map turtle						X	N/A
Flathead catfish					X		Oahe only
Recreational Species:							
Beaver							N/A
Canada goose		X					N/A
Channel catfish	X						Oahe
Chinook salmon				X			Sakakawea
Muskrat							N/A
Northern pike				X			Sakakawea
Sauger	X						Sakakawea, Oahe
Walleye				X			Sakakawea, Oahe
White bass				X			Sakakawea, Oahe

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APPENDIX F—IMPACT OF SILTATION ON FLOOD CONTROL MISSOURI RIVER, NORTH DAKOTA

1.0 INTRODUCTION

The Louis Berger Group, Inc. (Berger) was tasked by the U.S. Army Corps of Engineers (USACE) to assess the potential impacts of sedimentation in the Missouri River within the State of North Dakota. The assessment was to be based on review of relevant existing data and information. The study area was defined by the USACE to include the watershed of the mainstem of the Missouri River from the North Dakota/South Dakota border on the downstream end to the Montana/North Dakota border on the upstream end. This section of the report analyzes the potential impacts of sedimentation on flood control.

The Garrison and Oahe Dams and their respective reservoirs are part of the Missouri River Mainstem System consisting of six dams in total. The Garrison and Oahe Dams were authorized by the Flood Control Act and serve as the main mechanisms for flood control along the Missouri River in the State of North Dakota.

1.1 Principal Flood Problems

Principal flood problems were identified in the 2005 Flood Insurance Study (FIS) prepared by the Federal Emergency Management Agency (FEMA) for the Bismarck, North Dakota area. The FIS attributes the following four conditions as the causes or contributing factors to flooding in the area: (1) open-water season flooding from Garrison Dam operations; (2) open-water season flooding from tributaries, and other residual drainage areas below Garrison Dam, combined with releases from Garrison Dam; (3) flooding, resulting from ice jams and ice conditions; and (4) flooding caused by aggradation in the upper reaches of the Lake Oahe.

Major flooding along the Missouri River occurred in 1881, 1887, 1910, 1917, 1938, 1939, 1943, 1947, 1950 and 1952. As a result of the completion of Garrison Dam in 1953, floods of the magnitudes experienced during these events would have a recurrence interval greater than 500 years.

The maximum peak discharge that has occurred since 1953 on the Missouri River was 68,900 cubic feet per second (cfs) at the USGS stream gage at the city of Bismarck. This occurred on July 13, 1975, with an estimated recurrence interval of 75 years. A more recent flood of record occurred in May 1980, with a peak discharge of 18,900 cfs.

The highest record of flooding at the Bismarck stream gage since completion of the Garrison Dam was 14.8 feet, which occurred on January 13, 1983, because of ice conditions and ice jams. A discharge of 59,500 cfs was recorded on July 25, 1997. These conditions are typical of an event with a recurrence interval of approximately 10 years.

1.2 Flood Storage Capacity Losses in Reservoirs

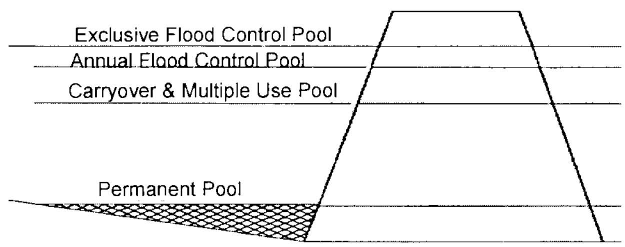
The Garrison and Oahe Reservoirs have defined zones for flood control, multiple uses, and permanent pool. These zones are defined as follows and are shown on Figure 1–1:

—*Exclusive Flood Control Zone.*—This zone is the total upper volume of the mainstem lakes maintained exclusively for flood control. Water is released from this zone as quickly as downstream channel conditions permit so that sufficient storage remains available for capturing future inflows.

—*Annual Flood Control and Multiple Use Zone.*—This zone is used to store the high annual spring and summer inflows to the reservoirs. Later in the year, water stored in this zone is released for riverine uses so that the zone is evacuated by the beginning of the next flood season on March 1. Evacuation is accomplished mainly during the summer and fall navigation season.

—*Carryover Multiple Use Zone.*—This zone is designed to provide water for all uses during drought periods. The zone is operated so that it remains full during periods of normal inflow but is gradually drawn down during drought periods.

—*Permanent Pool.*—The permanent pool provides the minimal water level necessary to allow the hydropower plants to operate and to provide reserved space for sediment storage. It also serves as a minimum pool for recreation and for fish and wildlife habitat and as an ensured minimum level for pump diversion of water from the reservoirs.



Source: Aggradation, Degradation and Water Quality Conditions, USACE 1993.

FIGURE 1–1.—*Reservoir Storage Zones*

The Garrison Reservoir has lost 907,000 acre-feet of total storage capacity due to accumulated sediments from the time it began operation in 1953 until 1988. The Oahe Reservoir has lost 614,000 acre-feet of total storage capacity from the time it began operation in 1958 until 1989. Table 1–1 and Figure 1–2 show the storage loss by zone.

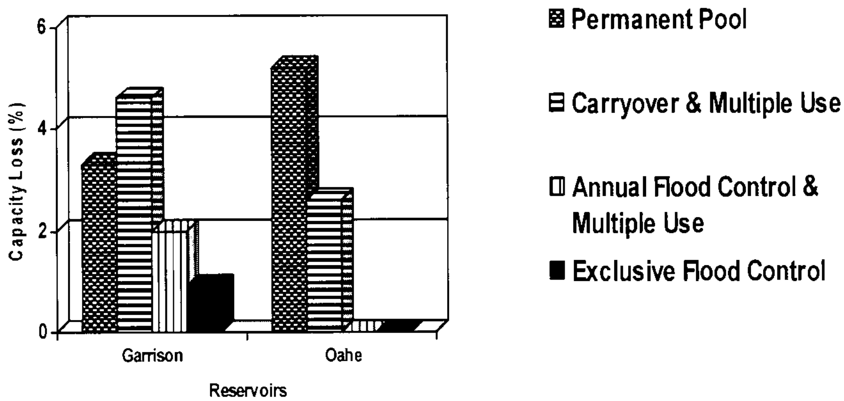


FIGURE 1–2.—*Reservoir Storage Losses By Zone*

TABLE 1–1.—RESERVOIR STORAGE LOSSES BY ZONE

Year	Total Storage Below the Pool Elevation (1,000 acre-feet)				Storage Change Over Time (percent)						
	Excl. Flood Control	Flood Control & Multiple Use	Carry-over & Multiple Use	Perm. Pool	Excl. Flood Control	Flood Control & Multiple Use	Carry-over & Multiple Use	Perm. Pool	Total Storage Loss 1,000 acre-ft	Total Storage Loss (percent)	Annual Loss (percent)
Garrison Reservoir:											
Pool Elev	1,854	1,850	1,837.5	1,775	1,854	1,850	1,837.5	1,775	....	....	....
1953	24,728	23,225	18,917	5,152	....	....	....	....	....	....	....
1958	24,504	23,000	18,694	5,004	−0.1	....	0.5	2.9	224	0.9	0.18
1959	24,477	22,973	18,670	4,989	−0.1	0.1	0.6	3.2	251	1.0	0.17
1964	24,355	22,846	18,517	4,981	−0.4	−0.5	1.7	3.3	373	1.5	0.14
1969	24,137	22,635	18,348	4,976	0.1	0.5	2.9	3.4	591	2.4	0.15
1979	23,923	22,439	18,209	4,990	0.6	2.0	4.0	3.1	805	3.3	0.13
1988	23,821	22,332	18,110	4,980	0.9	2.0	4.6	3.3	907	3.7	0.11
Oahe Reservoir:											
Pool Elev	1,620	1,617	1,607.5	1,540	1,620	1,617	1,607.5	1,540	....	....	....
1958	23,751	22,649	19,490	5,665	....	....	....	....	....	....	....
1963	23,647	22,545	19,386	5,575	....	....	0.1	1.6	104	0.4	0.09
1968	23,507	22,416	19,239	5,521	1.0	−0.6	0.8	2.5	244	1.0	0.10
1976	23,337	22,240	19,054	5,451	0.5	−0.9	1.6	3.8	414	1.7	0.10
1989	23,137	22,035	1,883	5,373	....	−1.3	2.6	5.2	614	2.6	0.08

Source: Aggradation, Degradation and Water Quality Conditions, USACE 1993.
Data taken from Plate 7, "Summary of Reservoir Surveys and Associated Storage Loss by Zone".

2.0 LITERATURE AND DATA COLLECTION METHODOLOGY

Jeff Klein of the North Dakota State Water Commission (NDSWC) was contacted to obtain data used to develop the Missouri River hydraulic model, particularly channel profile data. Mr. Klein responded by providing components of the hydraulic model in Burleigh and Morton Counties.

Nancy Steinberger, the Regional Engineer for FEMA was contacted to obtain historic flood plain mapping and historic hydraulic modeling of the river, particularly the channel profiles from the model input data set. Ms. Steinberger indicated that the channel profiles of the river would best be obtained from the Omaha District of the USACE, who was responsible for the hydraulic modeling. Ms. Steinberger further indicated that historic flood mapping of the Missouri River in North Dakota could be obtained through FEMA but only three counties, Morton, Burleigh, and a small portion of Williams, have been updated in recent years. She noted that the Williams County update was underway and had not been published yet. Morton, Burleigh and Williams County (in the vicinity of the town of Williston) were updated because they contain population centers; the other counties along the Missouri River within the State of North Dakota did not have populations high enough to warrant updating the FEMA mapping.

Due to the lack of new flood data all along the Missouri River, analysis in this report was limited to the areas where historic and current flood data was available, particularly the areas surrounding the City of Bismarck. The analysis can be expanded to include Williams County in the vicinity of the town of Williston once the updated flood data becomes available.

3.0 POTENTIAL SILTATION IMPACTS ON FLOOD CONTROL

During the design and construction of a reservoir, siltation rates are one of the many factors that are considered when determining the expected life of a reservoir. Excessive siltation rates are those considered above what is expected when a reservoir is constructed. When excessive siltation occurs, the storage capacity of a flood control reservoir is significantly and rapidly decreased. The two most common impacts associated with excessive siltation are: less water available for domestic and agricultural use; and decreased flood protection. The most common causes for excessive siltation are accelerated erosion and increased runoff associated with change in land use activities throughout the watershed.

The decrease in storage potential of a reservoir due to siltation can cause increased downstream flood risks. Increases in probability and intensity of flood events can result from increased upland erosion, which causes a decrease in hydraulic capacity of a channel due to sedimentation. Changes in land use of upland areas may also generate more runoff in a shorter period and potentially increase flood intensity. Agricultural and recreational uses may be impacted by the increased flooding and sediment transport. There may also be an increase in water treatment costs where water treatment plants draw raw water from the impacted impoundments, streams and rivers.

There were two FISs prepared by FEMA for Bismarck, North Dakota and the surrounding area. The 1988 FIS for the city of Bismarck and Burleigh County Unincorporated areas was compared to the 2005 FIS for Burleigh County and Unincorporated Areas. The 1988 FIS used an older version of the Hydrologic Engineering Centers analysis software (HEC–2) and the 2005 FIS used the HEC River Analysis System software (HEC–RAS). The models, which were provided by the NDSWC and Houston Engineering, Inc., were run to simulate the 50-year, 100-year, and 500-year storm event scenarios. The results of the models were then compared to the data within the associated report for verification.

The flood profiles from the two models were then compared at key milestones along the river to determine the change in elevation (Table 3–1). It was found that for the 50-year design storm, flood water surface elevations had risen by approximately 1.2 feet at the downstream station and by as much as 1.8 feet within the reach. For the 100-year storm, flood elevations had risen by approximately 1.3 feet at the downstream station and as much as 1.4 feet within the reach. The model results also yielded that for the 500-year storm, flood elevations had risen as much as 1.1 feet at the downstream station. Although these model simulations provided verification of the water surface elevation change, they did not provide an explanation for the increase.

Compilation and review of data from previous studies prepared by the USACE indicates that sediment is accumulating at various locations within the main channel of the Missouri River. Table 3–2 shows the segments of river that have experienced documented sedimentation. The highlighted segments are located within the reach analyzed in the Bismarck FIS or downstream from this reach. The sedimentation occurring in these segments could be impacting the flood elevations in the Bismarck area. It should be noted that only two of the segments, identified in bold text in Table 3–2, fall within the reach bounded by the key milestones identified in Table 3–1.

TABLE 3–1.—FLOOD ELEVATION COMPARISON

Key Milestone	River Station	Flood Elevations, (feet) NAVD						Changes in Flood Elevations from 1988 to 2005 (feet)		
		1988 Flood Data			2005 Flood Data					
		50 yr	100 yr	500 yr	50 yr	100 yr	500 yr	50 yr	100 yr	500 yr
Confluence Apple Creek	1300.21	1626.7	1627.7	1631.0	1627.9	1629.0	1632.1	1.2	1.3	1.1
Confluence Little Heart River	1302.22	1628.3	1629.3	1632.8	1629.6	1630.7	1633.8	1.3	1.4	1.0
Confluence Heart River	1310.72	1633.7	1634.9	1638.3	1634.5	1635.7	1638.8	0.8	0.9	0.5
Bismarck Expressway	1313.41	1635.1	1636.3	1639.8	1636.0	1637.3	1640.4	0.9	1.0	0.6
Memorial Bridge	1314.21	1635.4	1636.5	1640.0	1636.3	1637.5	1640.8	0.9	1.0	0.7
Railroad	1314.99	1635.9	1637.0	1640.5	1637.7	1637.9	1641.2	1.8	0.9	0.7
Interstate 94	1315.49	1636.1	1637.3	1640.7	1636.9	1638.1	1641.5	0.8	0.9	0.8
City of Bismarck Limits	1317.42	1637.7	1638.9	1642.9	1638.2	1639.6	1643.6	0.5	0.7	0.6
Confluence Burnt Creek	1319.88	1638.9	1640.0	1643.9	1639.5	1640.8	1644.6	0.6	0.8	0.8
Burleigh County Limits	1328.64	1644.0	1645.0	1648.5	1643.7	1644.8	1648.4	−0.3	−0.2	−0.1

Source.—Elevations are from HEC–2 data and HEC–RAS data from the 1988 and 2005 Flood Insurance Studies, respectively.

TABLE 3–2.—RIVER SEGMENTS WITH SEDIMENTATION

STARTING RIVER MILE	ENDING RIVER MILE	MILES WITHIN SEGMENT	LEVEL OF SEDIMENTATION
1564	1548	16	Low
1548	1534	14	Moderate
1534	1521	13	High
1521	1489	32	Moderate
1489	1470	19	Low
1457	1453	4	Low
1438	1436	2	Low
1362	1352	10	Moderate
1303	1301	2	Low
1301	1297	4	Moderate
1297	1290	7	High
1290	1288	2	Moderate
1288	1285	3	Low
1285	1282	3	Moderate
1282	1270	12	Low
1270	1248	22	Moderate
1248	1232	16	Low

River miles within the Bismarck FIS boundary with sedimentation.
River miles downstream of the Bismarck FIS boundary with sedimentation.
Source.—Data taken from Berger Aggradations Area Map; October 2008.

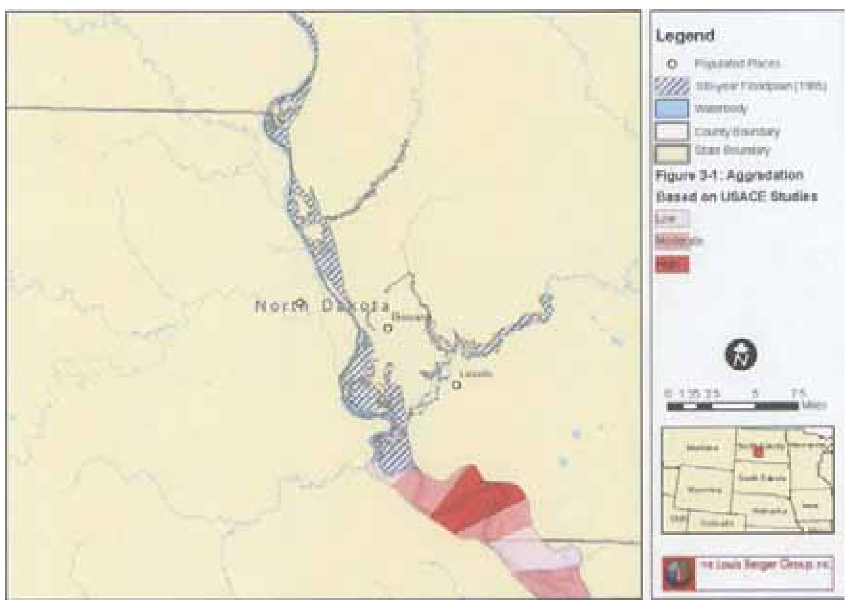


FIGURE 3–1—*Aggradation Based on USACE Studies*

4.0 FLOOD CONTROL MEASURES

Siltation in the reach between the Garrison Dam and Lake Oahe has resulted in increased risk of flooding in the downstream reach between the dam and the headwater of Lake Oahe. Because of this sediment aggradation, the impact of ice dams on seasonal flooding is increasing. As a means to counter this impact, careful sequenced water releases during the winter months are made to prevent flooding caused by ice dams.

The Missouri River typically freezes in December, and remains frozen until the thaw which occurs in March and April. Ice dams can form during freeze-up as well as during ice break-up. Initial forming of ice (ice-in) starts at the headwaters of

Lake Oahe and moves upstream towards Garrison Dam. Ice dams formed during break-up are most common downstream of the confluence between the Missouri River and the Heart River (river station 1311). According to FEMA (2005), the higher flows in the Heart River during snowmelt or spring rains cause the formation of ice dams on the still-frozen Missouri River. With the siltation causing a higher river bed elevation and resulting higher ice sheet elevation, flooding impacts are exacerbated as a result.

The USACE releases water at the Garrison Dam in a controlled manner over the winter months to reduce the ice-in and ice-out risk to flooding in the Bismarck/Mandan area. The ice break-up which occurs in March and April can cause ice dams which block the flow of water. This issue is compounded when spring thaw and rainfall increases the discharge flow from tributaries into the Missouri River. Proper management of water releases is able to help control downstream flooding, but reduced flow during winter months can impact the production of electrical hydropower.

5.0 CHANNEL GEOMETRY ANALYSIS

As discussed in Section 3.0, Berger compared the output data from the models associated with the 1988 and 2005 FIS reports and found a trend for higher water surface elevations and lower minimum channel bed elevations. Ten river stations, which were selected based on their proximity to key milestones identified in the aforementioned FIS reports, were selected for a more detailed analysis. The stations and their associated water surface and minimum channel elevations are shown in Table 5–1 and the differences between the values of the two models are shown in Table 5–2.

TABLE 5–1.—RIVER STATIONS AND ELEVATIONS

River Station	1988 FIS DATA		2005 FIS DATA	
	Water Surface NAVD 88 (feet)	Minimum Channel NAVD 88 (feet)	Water Surface NAVD 88 (feet)	Minimum Channel NAVD 88 (feet)
1300.21	1627.72	1598.40	1629.04	1603.40
1302.22	1629.31	1601.50	1630.70	1596.10
1310.72	1634.85	1611.30	1635.71	1607.70
1313.41	1636.27	1608.60	1637.27	1606.30
1314.21	1636.53	1602.30	1637.54	1601.50
1314.99	1637.00	1605.00	1637.91	1601.90
1315.49	1637.25	1602.60	1638.12	1598.00
1317.42	1638.90	1610.20	1639.56	1612.60
1319.88	1640.02	1612.90	1640.80	1609.50
1328.64	1645.00	1616.40	1644.82	1617.10

As demonstrated in Table 5–2, the majority of the river stations evaluated indicated an increase in water surface elevation. However, a trend for the minimum channel elevation could not be established. Because channel geometry and flow characteristics are inherently related and constantly changing, Berger then compared the cross-sectional area for each of the 10 river stations to evaluate the channel geometry to determine if excessive erosion or sedimentation occurred between the two model years. Changes in the channel geometry will affect water velocity, assuming a constant discharge, which in turn influences a river's ability to transport sediment as bed load, material in contact with the river bed having a diameter larger than fine sand; or as suspended load, fine materials such as clay and silt that are held in suspension in the water and carried without contact with the river bed.

As the velocity of the water in a channel increases, the more capacity the water has for erosion and transportation of sediment in the channel. In other words, the sediment transportation power, or the kinetic energy, of the water is directly proportional to the increased velocity. When discharge is held constant and width decreases, the velocity increases and the channel will tend to deepen by eroding the channel bed, which is referred to as scouring. Kinetic energy is decreased as water erodes the river channel or moves sediments along the river bed. In addition, some of the kinetic energy is lost through turbulence and friction. Once sufficient kinetic energy has been expended or lost, the deposition of the sediment load will occur.

TABLE 5–2.—COMPARISON OF ELEVATIONS

River Station	Water Surface NAVD 88 (feet)	Minimum Channel NAVD 88 (feet)
1300.21	1.32	5.00
1302.22	1.39	−5.40
1310.72	0.86	−3.60
1313.41	1.00	−2.30
1314.21	1.01	−0.80
1314.99	0.91	−3.10
1315.49	0.87	−4.60
1317.42	0.66	2.40
1319.88	0.78	−3.40
1328.64	−0.18	0.70

Studies have demonstrated that for any given discharge, the river channel bed will adjust to a quasi-equilibrium condition governed by the kinetic energy transfer between channel flows and the local resistance associated with the geometry of the river channel, which directly influences sediment transport. The greater the ratio of the cross-sectional area of the channel is to the wetted perimeter, the less the local resistance will be as there is proportionately less water within the friction zone of the channel (near the sides and bed). In other words, the channel geometry will stabilize once the water has reached its maximum sediment load for a given discharge.

One example of particular interest is that water flowing over a spillway will have very little sediment as most of it will have settled out upstream of the dam. This water then has a lot of kinetic energy and is capable of transporting a large amount of sediment. For this reason, channels immediately downstream of impoundments are particularly susceptible to the effects associated with erosion.

The gross cross-sectional areas of the 10 river stations were compared (see Table 5–3) for the HEC–RAS data for both the 1988 and 2005 FIS models. All sections indicate a net increase in cross-sectional area. These values include both the main channel and the overbank areas. Detailed analysis of the channel geometry required evaluation of the main channel cross-section.

The cross-sections of the 10 river stations were plotted with the output from the HEC–RAS models. The two cross-sections of the main channel from the 1998 and 2005 FIS models were then visually compared for each of the river stations. The results of this analysis are illustrated in Figures 5–1 through 5–10.

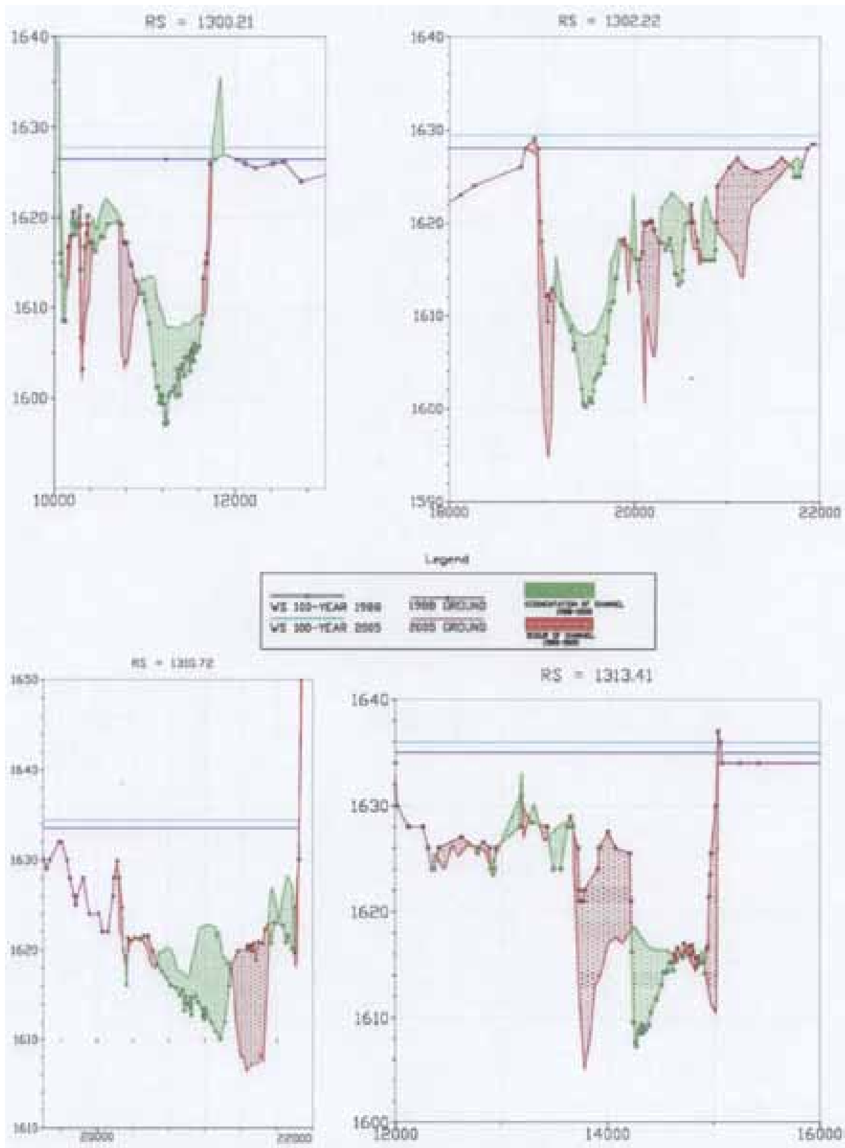
TABLE 5–3.—RIVER STATIONS AND GROSS CROSS-SECTIONAL AREA

River Station	1988 FIS Area (square feet)	2005 FIS Area (square feet)	Change in Area (square feet)
1300.21	24,685.40	24,936.13	250.73
1302.22	25,136.57	27,422.00	2,285.43
1310.72	30,438.93	31,333.79	894.86
1313.41	21,768.87	28,165.79	6,396.92
1314.21	23,065.15	26,082.67	3,017.52
1314.99	17,418.97	19,355.91	1,936.94
1315.49	14,456.52	15,614.66	1,158.14
1317.42	35,911.24	38,000.80	2,089.56
1319.88	24,774.47	27,718.37	2,943.90
1328.64	19,530.14	20,203.27	673.13

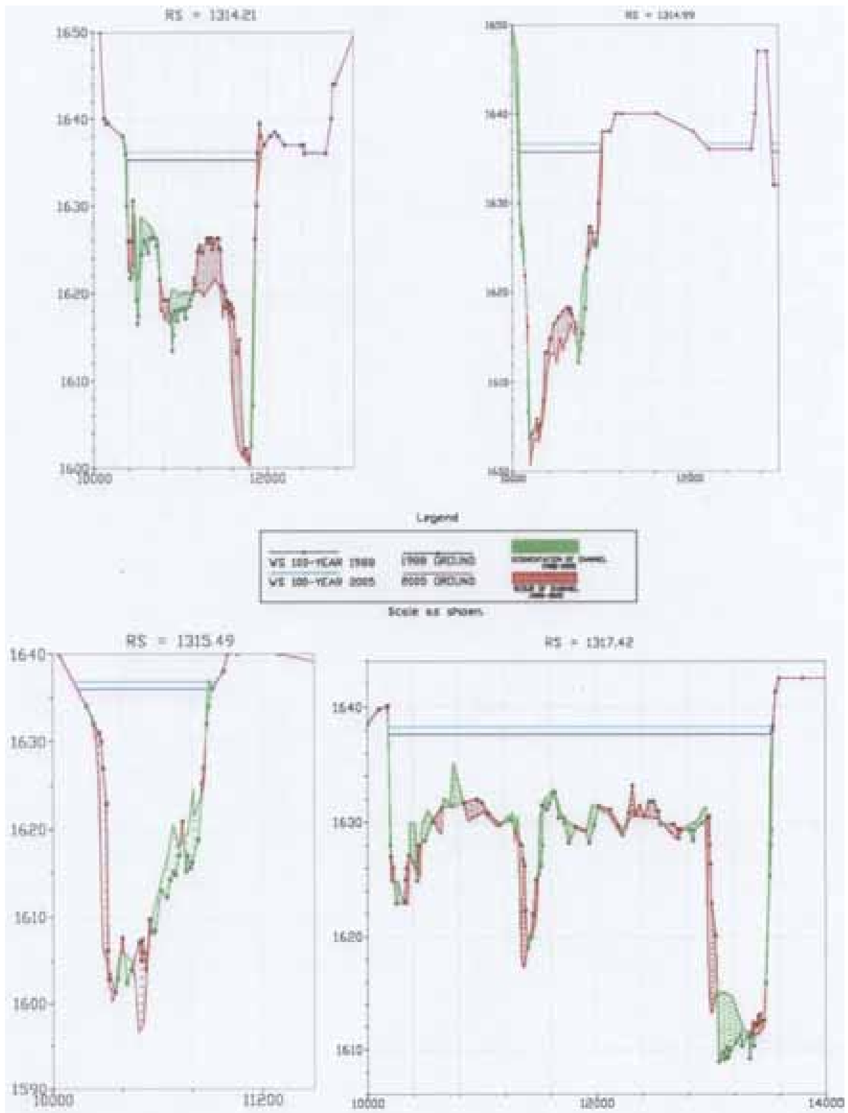
Based on the results of the analysis, 7 of the 10 river stations show a net increase in cross-sectional area within the main channel. Likewise, 8 of the 10 stations show signs that significant scouring and sloughing has occurred. Both scour and sloughing are a normal part of a river's natural erosion processes. Scour of a river channel can occur due to an increased discharge rate, as mentioned previously, when the channel geometry is reduced thus increasing the velocity through that section. These influences can be temporary, such as an increase in discharge associated with a storm event or a decrease in channel area caused by debris or ice dams. Sloughing, also commonly referred to as slumping, is a form of channel bank erosion where the sides of a channel collapse and are deposited to the bottom of a channel. The main cause of sloughing is saturation of soil associated with a rise in the water surface elevation, often followed by a sudden decrease of the same water elevation. As the water surface falls, it creates a pressure imbalance within the saturated soil and the resulting forces cause the soil to erode into the channel bed. The soils that collapse into the channel bed are often comprised of fine silts and sands and are therefore more susceptible to scouring. Two of the three areas identified as having a net decrease in main channel cross-sectional area are preceded by river stations where sloughing appeared to have occurred.

There is a significant increase in water surface elevation from the 1988 FIS report and the 2005 FIS report at the downstream river station. This increase, approximately 1.32 feet, slowly decreases in subsequent upstream river stations until in the vicinity of river station 1300.21. However, this does not appear to be attributable to a channel geometry based on the 10 river sections analyzed. In fact, the majority of the cross-sections indicated an increase in the area of the main channel, either through scouring or sloughing, which would lend itself to a fall in the water surface elevation. The data suggest that the water surface elevation is either being influenced by a downstream source or an increased initial water surface elevation used in the 2005 model.

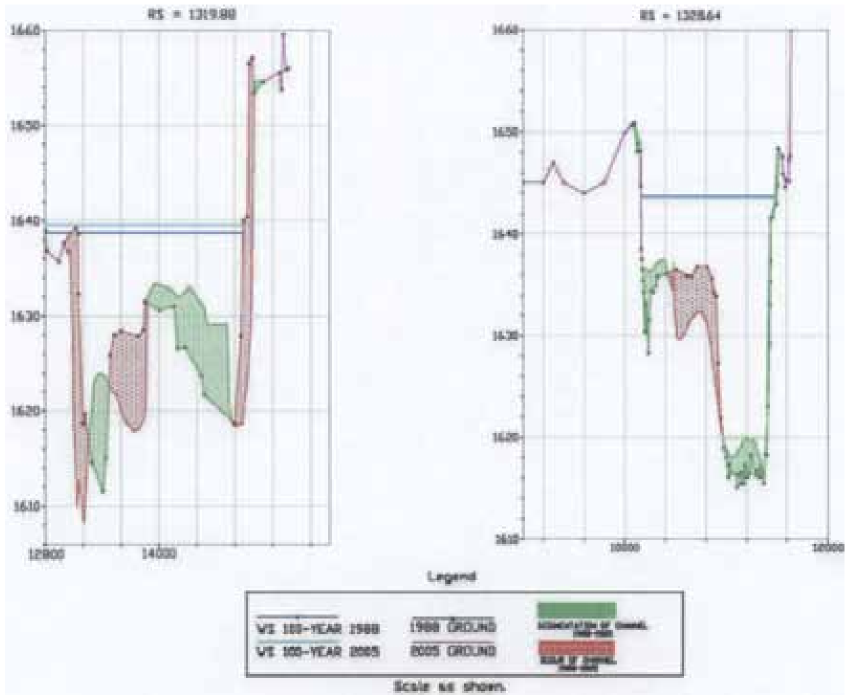
It is important to note that this analysis has a finite study area and is limited by the accuracy of the data and the HEC–RAS models provided. It should also be noted that common industry belief is that this HEC–RAS model, albeit a highly versatile tool, is not able to accurately model all dynamics of flood events, especially in a highly urbanized watershed.



FIGURES 5–1 TO 5–4.—*River Station Cross-Sections*



FIGURES 5–5 TO 5–8.—*River Station Cross-Sections*



FIGURES 5–9 TO 5–10.—*River Station Cross-Sections*

6.0 CHANNEL STABILITY ANALYSIS

Channel and bank stability on the Missouri River is a continual concern as a potential source of sedimentation. Section 33 of the Water Resources Development Act of 1988 authorized the USACE to alleviate bank erosion and related problems along the Missouri River from Fort Peck Dam, Montana to Ponca State Park, Nebraska. The act stated that both structural and nonstructural measures could be used to address bank erosion on the river. As a consequence, the stabilization projects constructed along the river have created concern about the overall cumulative impacts of bank stabilization on river issues such as fish and wildlife resources, which resulted in the USACE preparing a report entitled "Missouri River—Fort Peck Dam to Ponca State Park Geomorphological Assessment Related to Bank Stabilization" (December 2001). The report was prepared as a joint effort by the U.S. Army Engineer Research and Development Center, University of Nottingham and Colorado State University (Biedenharn et al). The report studied the potential geomorphic impacts of the bank stabilization program on wildlife habit within the Missouri River system with a particular emphasis on the formation and persistence of habitat bars.

There is a general scarcity of research literature regarding the effect of further bank stabilization measures on the sediment supply to the river channel and how this affects the bar and island morphology. According to Biedenharn et al. (2001), the upper Missouri River contains numerous bars and islands composed primarily of material from eroding banks. A report prepared for the USACE by Pokrefke, T.J., Abraham, D.A., Hoffman, P.H., Thomas, W.A., Darby, S.E. and Thorne, C.R. entitled "Cumulative Erosion Impacts Analysis for the Missouri River Master Water Control Manual Review and Update Study" (July 1998), attempted to predict how any future increases in bank stabilization would affect erosion rates in the four reaches (Fort Peck, Garrison, Fort Randall and Gavins Point) on the Missouri River. Of these four, the Garrison Reach is the only reach set solely in the State of North Dakota. The Pokrefke et al. (1998) report predicted that an exponential relationship exists between increasing amounts of bank stabilization and decreasing rates of bank erosion in the three upriver reaches (Fort Peck, Garrison and Fort Randall), primarily due to the fact that the upriver reaches are close to a position of dynamic equilibrium and are stabilizing naturally. By comparison, the Gavins Point Reach, which is further downriver, has a linear relationship between increasing bank stabilization and decreasing bank erosion.

The Garrison study reach extends from river station 1390 just downstream of the Garrison Dam to river station 1311, located just south of Bismarck where the Heart River connects to the Missouri River. The reach is regulated by the Garrison Dam. The Biedenharn et al. (2001) report states that the bed material in the reach is predominantly sand with occasional outcrops of gravel. The channel in the Garrison reach is relatively straight, with a moderate to high degree of braiding with numerous bars and islands. The channel width ranges from about 430 feet to 4,400 feet, with an average width of about 2,100 feet. Bank heights within the Garrison Reach generally range from about 10 feet to 43 feet, with an average bank height of about 17 feet. The bank material contains approximately 29 percent fines (silts and clays), with the remainder sands (upper limit approximately 1 mm in size).

The Biedenharn et al. (2001) report studied the Garrison Reach using specific gauge sections to study the degradational trend of the reach. Historically, this reach followed a degradational pattern after the dam construction was completed in 1953, but this degradational trend began to subside in the mid 1970s to early 1980s. The report notes that the gauge records suggest that this reach of the river has been approaching a state of dynamic equilibrium since the mid 1980s. This is not to say that the reach has achieved dynamic equilibrium, as active processes such as widening of the active channel continue to occur, but it is evident that the rate of change in degradation is declining.

The Biedenharn et al. (2001) report investigated the relationship between channel widths and the formations of bars and islands by comparing the cumulative distribution for two time periods, 1975 and 1997. In general for the Garrison Reach, the channel width in the range of 2,070 feet appeared to be the threshold zone below which it is unlikely that bars will exist. Using the collected information for bars and island formation in the Garrison Reach, the report attempted to determine a relationship between the percent bank stabilization and the bar and island density, but found no obvious trends.

A follow-up report, built upon the work presented in the Pokrefke (1998) and Biedenharn (2001) reports, was prepared under contract to the USACE by HDR Engineering, IIHR-Hydro science & Engineering, Mussetter Engineering and WEST Consultants, entitled “Bank Stabilization Cumulative Impact Analysis Final Technical Report—Fort Peck, Garrison, Fort Randall, and Gavins Point Study Reaches” (March 2008). The HDR report draws on the USACE’s 1999 Cumulative Environmental Impact Statement (CEIS) for on-going bank stabilization within the Missouri River from Fort Peck Dam to Ponca, Nebraska. The CEIS was intended to evaluate the cumulative environmental impacts of past and future banks stabilization construction on the Missouri River. The HDR report, formed from the draft Appendix C of the CEIS, evaluates the amount of bank stabilization over two time periods and the potential relationship between increased bank stabilization and sandbar habitat formation in the Missouri River within the four study reaches. The HDR report concluded that there is no correlation between past bank stabilization construction and evaluated habitat features. As a result, the USACE declared that there is no geomorphologic basis on which to alter the rate or amount of bank stabilization currently being permitted in the Missouri River and postponed the preparation of the CEIS. Figure 6–1 (HDR, 2008) shows the vicinity map for the Garrison reach studied in the Biedenharn (2001), Pokrefke (1998) and HDR (2008) reports.

In studying the Garrison Reach, the HDR (2008) report utilized data recorded from five stream gauge locations, two sets of aerial photography taken 17 years apart, channel cross-section survey data, and HEC–RAS model data. The planform analysis performed in the study took into account variables such as channel top width, annual flow, bank material, channel bed material to determine the river trends within each study reach.

The HDR (2008) report presented a table (Table 1–7, Revetment by Study Reach) showing the miles of revetment installed for each study reach and the time periods during which the revetment was installed. The information was based upon a revetment inventory performed as part of the HDR study, using a database of bank stabilization constructed by USACE and authorized by USACE under section 404 of the Clean Water Act, supplemented by videotape observations of bank stabilization of both banks of each study reach. The table summarized the percentage of bankline protected, which is interpreted in the report as the amount of historic channel high bank stabilized. The historic channel high banks are stated in the report to be the outer boundaries of a developing, new flood plain. The report recognizes that the remnant river has a much smaller main channel which generally migrates within the banks of the historic channel. The historic or pre-dam river changed significantly with construction and operation of the mainstem dams. The revetment identified in the HDR report for the Garrison Reach is shown in Table 6–1 below.

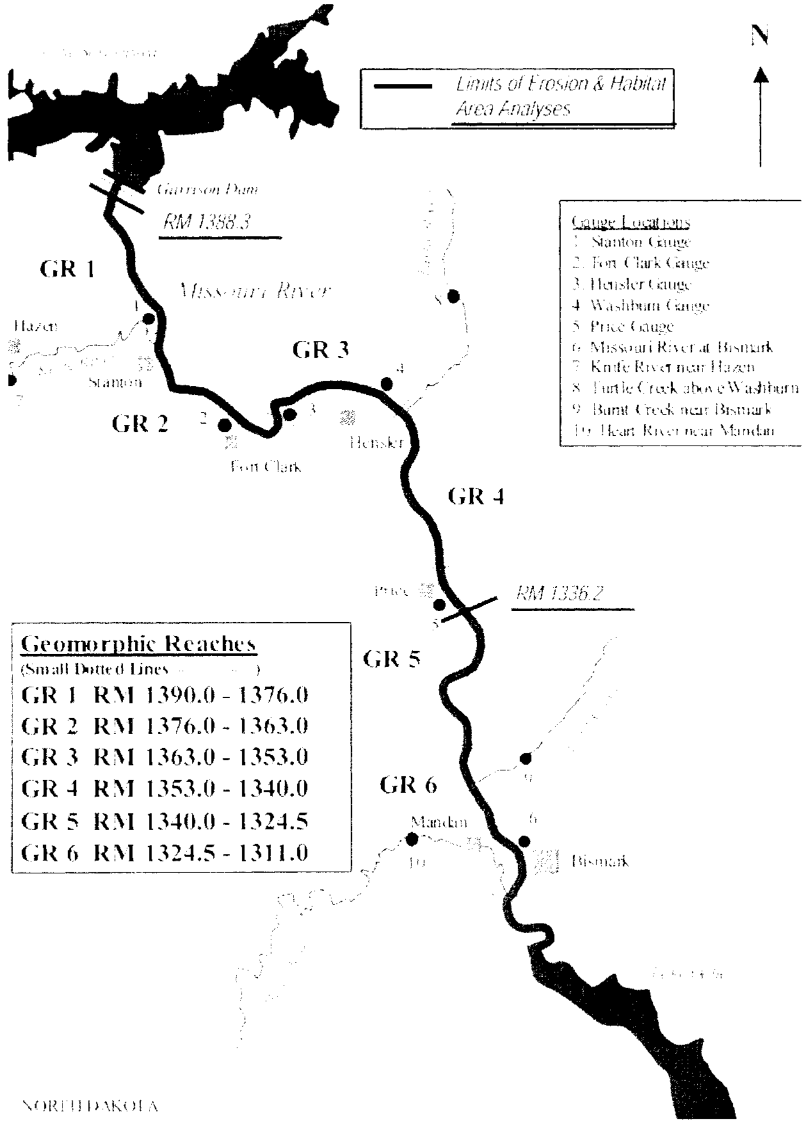


FIGURE 6–1.—*Vicinity Map for Garrison Study Reach (HDR, 2008)*

TABLE 6–1.—REVETMENT, GARRISON REACH

Study Reach	Revetment (miles) [1]	Year Installed	Total Study Reach River Miles, Both Banks	Bankline Protected (percent) [2]
Garrison [3 4]	24.0	1976–1985	104.2	[2] 23.0
	5.6	1985–1999	104.2	5.4

Source: Table 1–7, HDR Report (2008).

[1] The amount of revetment is the amount that exists within the geomorphic reaches, not the total stabilization that may exist within the total reach as some areas outside the geomorphic study reach have been stabilized.
[2] The percent of bankline protected reflects the total amount on high bank that is stabilized. Some of this bankline is no longer adjacent to the active flow channel.
[3] There were approximately 8 miles of bank stabilization constructed in the Garrison Study Reach prior to 1976, during what is considered the pre-revetment study period.
[4] The 8 miles of bank stabilization completed prior to 1976 represent about 8 percent of the bankline in the Garrison Study Reach, which means that 15 percent of the bankline was actually stabilized between 1976 and 1985.

The analysis in the HDR (2008) report measures total flood plain erosion. Some of this erosion is degradation of the new main channel (particularly immediately downstream of a dam); some erosion is where the new channel is widening within its new flood plain, and some erosion is where the new channel is widening its new flood plain via erosion of the historic channel bank.

The nature of the Missouri River and its channel planform is that of a meandering stream, as opposed to a braided stream. The difference between meandering and braided is shown in Figure 6–2 (HDR, 2008). The terms are defined in a USACE report by E.W. Lane entitled "A Study of the Shape of Channels Formed by Natural Streams Flowing in Erodible Material M.R.D. Sediment Report Series 9" (1957) as follows: "a braided stream is characterized by having a number of alluvial channels with bars or islands between meeting and dividing again, and presenting from the air the intertwining effect of a braid" and "a meandering stream is one whose channel alignment consists principally of pronounced bends, the shapes of which have not been determined predominantly by the varying nature of the terrain through which the channel passes." It is important to note that the Lane report indicated that, prior to construction of the five lower mainstem dams, the Missouri River exhibited characteristics closer to a meandering stream. This conclusion was based upon plotting a number of U.S. rivers to determine the relationship between slope and mean discharge and a stream's tendency to exhibit a braided or meandering planform. The HDR (2008) report points out the popular misconception held by many that the pre-dam construction Missouri River was a braided river due to the numerous sandbars and shallow water habitat.

Thus, the Missouri River which flows today is classified as a meandering steam, but has changed from its original meandering stream nature before the dam construction. The Missouri River floodplains of today are primarily confined to the historic channel, which is several thousand feet wide compared to the several-mile-wide historic floodplain. The HDR report presents a floodplain analysis which demonstrates that flows in excess of the 500-year discharge flow are needed to produce overbank flooding of the historic floodplain in the study reaches where degradation has occurred. The dams have, in effect, completely eliminated vast flooding of the historic flood plain. Post-dam construction degradation has effectively eliminated inundation of this new flood plain in the Garrison Reach, except during very high flow periods, such as those experienced in the late 1990s.

Analysis of the placement of bank stabilization on the Missouri River was assumed to be only where the river, as defined by the main channel, would come in contact with the outside edge of the new, developing flood plain boundary (historic channel bank). As such, the main channel is free to meander within the new flood plain which is the new natural process related to post-dam construction conditions. Figure 6–3 (HDR, 2008) shows an aerial view of the Missouri River floodplain along the Garrison Reach at river station 1351.7. The new floodplain is shown within the historic channel with the historic floodplain displayed outside of the new floodplain.

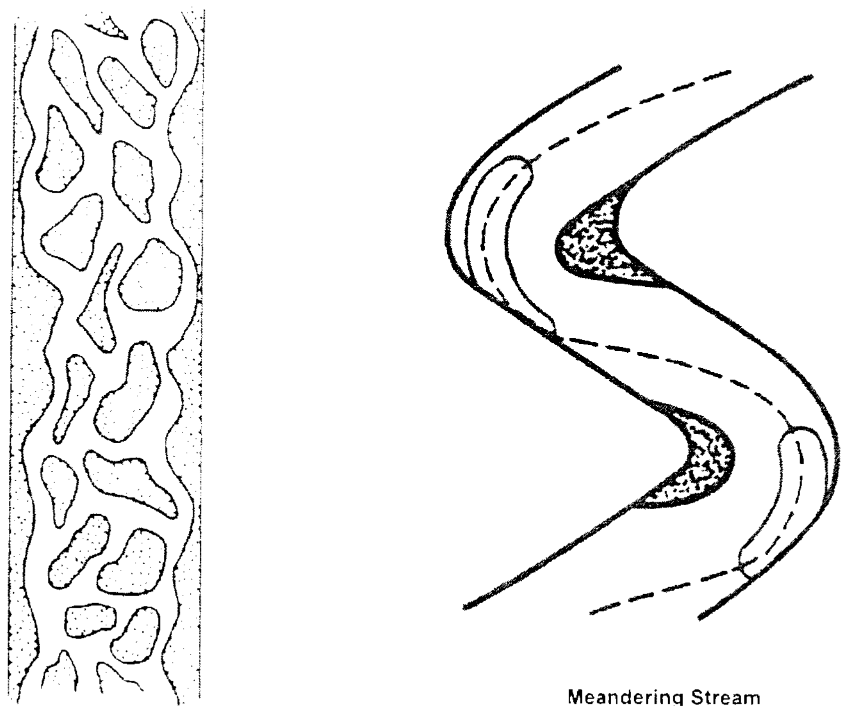


FIGURE 6–2.—*Types of Channel Planform (HDR, 2008)*

A cross-section view of the Missouri River along the Garrison Reach at river station 1362.7 is shown in Figure 6–4 (HDR, 2008). The vertical scale depicts the elevation of the channel and the new high banks and compares the cross-section from two study periods, 1976 and 1999. It demonstrates the changes which take place between 1976 and 1999, showing the main channel migrating from one side of the flood plain to the other. Degradation with the bank station is also seen in Figure 6–4, as well as limited erosion on the channel banks. Figures 6–3 and 6–4 support the concept that stabilizing the high bank of the old channel still allows the river to migrate within the high banks of the old channel. This allows the sandbars, islands and attached habitat within the historic high banks to erode, with eroded material then deposited downstream. The HDR report states that although analysis is unable to measure how this stabilization might affect the trend toward dynamic equilibrium, the local effect of this stabilization is eliminated when the main channel migrates away from the stabilization location.

Erosion of the bank and bed was analyzed for the Garrison Reach by Biedenharn et al. (2001). The erosion rate was estimated by summing the left and right bank erosion rates for each geomorphic reach length. Bank erosion rates were estimated based upon measurement of the area of bankline eroded as evidenced by aerial photographs or through analysis of channel cross-section surveys. From analysis of the erosion rates presented in Biedenharn (2001), the report published in Environmental Conservation in 2000 by F.D. Shields, A. Simon and L.J. Steffen entitled “Reservoir Effects on Downstream River Channel Migration,” concluded that the mean erosion rate in the Garrison Reach has decreased more than fourfold since the closure of Garrison Dam. The Shields et al. (2000) report also stated that much of the reach has experienced net channel widening and deposition rates of alluvial material to form islands and bars have decreased from 408 to 3.2 acres/year. The effect of the Garrison Dam has been to a reduction in magnitude of the Missouri River high flows in this reach as well as a change in timing (from April to July pre-dam to February to March post-dam). The resulting control by the dam in reducing higher flows has acted to reduce overbank flows. The HDR (2008) report concluded that channel changes must occur as a result of processes acting only on the banks, including a loss of sedimentation by mass wasting due to a lack of prolonged periods of high-stage saturated banks.

The HDR (2008) report assessed the impact of increased bank stabilization within the Garrison Reach. The upstream and downstream controls (mainstem dams) provide upstream clear-water release and a downstream backwater. This results in scouring and lowering of the degradation zone portion of the channel in the upstream reaches and an aggradational effect in the lower portion of the reach. The elevation of the channel bed is raised in the aggradation zone and the channel begins to display braided characteristics within a meandering regime as it becomes wider and shallower, a result of the backwater condition and delta formation at the headwater of Lake Oahe.

The banks along the Garrison Reach generally are composed of fine sands, while the channel bed is composed of coarser sands and cobbles. The channel bed has changed since the construction of the mainstem dams, as the channel bed material in the degradation zone has become coarser. This increase is a result of sediment-free releases from the Garrison Dam removing the fines and leaving the coarser material to remain, in order to maintain the river's sediment load. Further downstream, this condition becomes less prevalent as the river carries more sediment. Upon reaching the depositional zone, the channel beds are comprised of increasingly finer material.

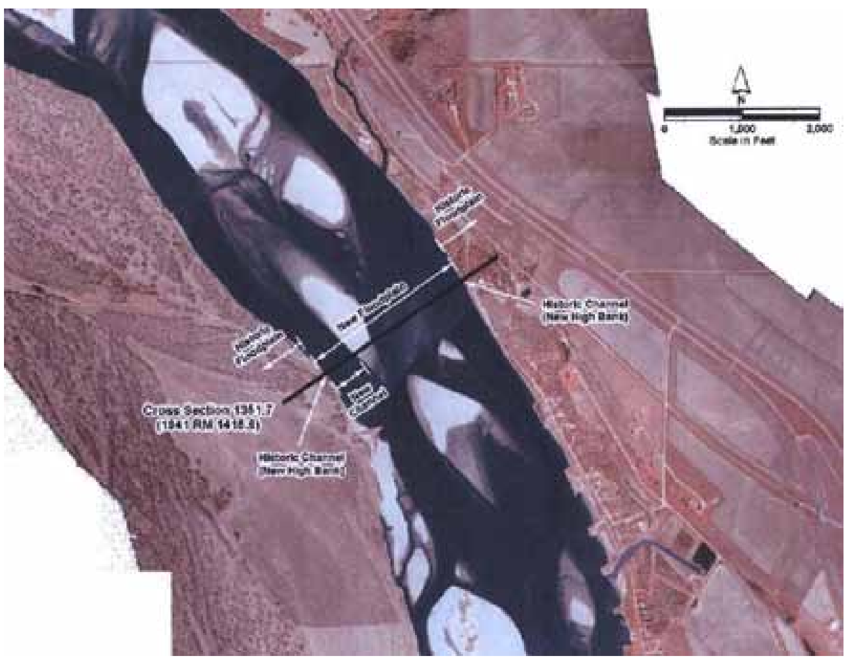


FIGURE 6–3.—*Missouri River Floodplain, Garrison Study Reach (HDR, 2008)*

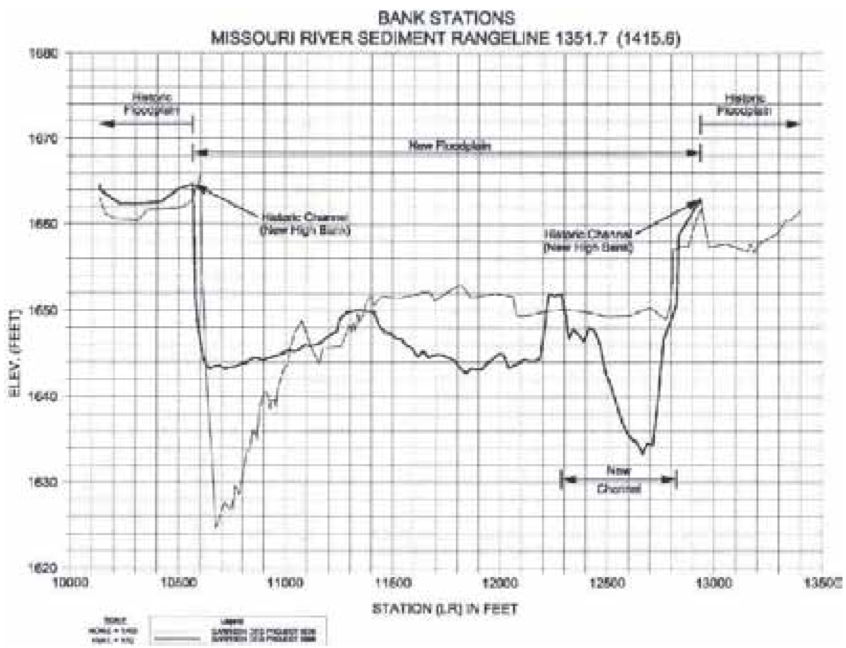


FIGURE 6–4.—*Cross-Section at River Station 1362.7, Garrison Study Reach (HDR, 2008)*

The bank stabilization features along the Garrison Reach were constructed to prevent bank failure and as a result, serve to limit the bank materials from entering the river. The HDR (2008) report states that, in general, placing rock or other stabilization features may not totally prevent movement of bank materials. The effectiveness of the bank stabilization features depends on the structure's construction. It is possible that fines may be "piped" through the stabilization structure or that rock may be undersized and move as result from river flow impacting it. Also, stabilization features may be outflanked or undercut by the river flow. Rock that may have been initially sized properly during installation may become undersized due to freeze-thaw action and aging. However, HDR (2008) does acknowledge that, in general, most bank stabilization structures tend to prevent most bank erosion and can be considered effective for their intended purpose.

The HDR (2008) report concludes that bank and channels may experience erosion immediately downstream of bank stabilization structures through several mechanisms. Bank stabilization structures immediately downstream of the dam may prevent the erosive, sediment-free dam discharge from removing bank material in this location, resulting in an increased channel erosion pressure and relocating the bank erosion zone further downstream. Generally, this is most pronounced in the first geomorphic reach below the dam.

Bank stabilization structures prevent the widening of the channel. This prevents the reduction in stream power and relief of shear stress on the channel bed from taking place if the channel were allowed to widen. However, because bank stabilization has been constructed only where the new main channel of the river is in contact with historic high banks of the river, the new channel is free to migrate away from the stabilized bank.

A hardened outer bank may induce secondary currents, potentially causing erosion or scouring along the toe of the outer bank and increasing erosion at the end, or flank, of the hardened bank. Further, a hardened bank may also induce erosion immediately downstream as a result of changes in either the roughness or the current direction.

The HDR (2008) report summarizes that the channel will tend to stabilize over time in the erosion-related mechanisms discussed above. The Garrison Reach contains approximately 29 percent bank stabilization coverage and the bank erosion rate within this reach is in a decreasing trend.

7.0 ADDITIONAL ANALYSIS

The FEMA floodplain mapping and HEC–RAS model output were analyzed to compare limits of current versus historic flood inundation for the 100-year storm event. This comparison was conducted for the river's extent within Burleigh County as well as within just the Bismarck city limits. Table 7–1 compares the areas of the 100-year flood inundation between the 1985 FIS to the 2005 FIS.

TABLE 7–1.—FLOODPLAIN AREA COMPARISON

Burleigh County	Bismarck City Limits
1985 100-year Floodplain—28 mi^2	1985 100-year Floodplain—2.7 mi^2
2005 100-year Floodplain—36 mi^2	2005 100-year Floodplain—3.6 mi^2

mi^2 = square miles

The area of the 100-year floodplain has increased by nearly 28.6 percent within Burleigh County from the 1985 FIS to the 2005 FIS. The floodplain area within the Bismarck city limits has increased by approximately 18.5 percent and accounts for approximately 6.3 percent of the net increase within the county. This is of particular concern to property owners whose property now lies within the floodplain. Two of the potential impacts for property owners associated with this are devaluation of the property and the requirement to purchase flood insurance. Homes, businesses, and agricultural land are among the types of properties most heavily affected by the floodplain area increase.

As discussed in the previous sections, increased water surface elevations and increased floodplain area could be the result of areas with high aggradation and/or the natural morphology of the river changing and/or restricting the channel's ability to convey the flow associated with a particular storm event.

8.0 SUMMARY AND RECOMMENDATIONS

This report assesses the potential impacts of siltation in the Missouri River Basin within the State of North Dakota on flood control. The report incorporates the review of relevant existing data and information from prior studies and research programs. As defined by the U.S. Army Corps of Engineers (USACE), the study area includes the watershed of the mainstem of the Missouri River border from the North Dakota/South Dakota border on the downsteam end and the Montana/North Dakota border on the upstream end. Included with this study area are the Garrison and Oahe dams and the reservoirs associated with each dam, Lake Sakakawea and Lake Oahe, respectively.

The Garrison and Oahe Reservoirs have defined zones for flood control, multiple uses, and permanent pool. These zones are utilized to control flow on the Missouri River and meet multiple and potentially conflicting goals.

Flood control issues within the Missouri River for the Bismarck, North Dakota area are caused or affected by: (1) open-water season flooding from Garrison Dam operations; (2) open-water season flooding from tributaries, and other residual drainage areas below Garrison Dam, combined with releases from Garrison Dam; (3) flooding, resulting from ice jams and ice conditions; and (4) flooding caused by aggradation in the upper reaches of Lake Oahe.

This report reviews Flood Insurance Studies (FIS) prepared by the Federal Emergency Management Agency (FEMA) for the Bismarck, North Dakota area to analyze changes in water surface elevation and its affects on flooding.

Siltation in the reach between the Garrison Dam and Lake Oahe has resulted in increased risk of flooding in the downstream reach between the dam and the headwater of Lake Oahe. Because of this sediment aggradation, the impact of ice dams on seasonal flooding is increased. As a means to counter this impact, careful sequenced water releases during the winter months are made to prevent flooding caused by ice dams. Water release from the Garrison Dam is also used to provide flood control during other seasons as well.

Evaluation of the data from the 1998 and 2005 FIS reports indicates that the water surface elevation has increased. Analysis of the channel geometry was conducted at ten river stations, which revealed that the net cross-sectional area of the river channel has increased at most of the river sections from the 1998 model to the 2005 model. This is likely the result of erosion in the form of scour and sloughing.

The changes in channel geometry are likely not the cause of the increase in the water surface elevation. The data suggest that the water surface elevation is either being influenced by a downstream source or an increased initial water surface elevation used in the 2005 model.

Channel and bank stability on the Missouri River is a concern as a potential source of sedimentation. Stabilization projects, including structural and non-structural measures, constructed along the river for the purposes of alleviating bank erosion (authorized by section 33 of the Water Resources Development Act of 1988), have created concern about the overall cumulative impacts of bank stabilization on river issues, such as fish and wildlife, recreation usage, and flood zone control.

Within the Garrison Reach, the upstream and downstream controls (mainstem dams) provide upstream clear-water release and a downstream backwater. This results in scouring and lowering of the degradation zone portion of the channel in the upstream reaches and an aggradational effect in the lower portion of the reach. The elevation of the channel bed is raised in the aggradation zone and the channel begins to display braided characteristics within a meandering regime as it becomes wider and shallower, a result of the backwater condition and delta formation at the headwater of Lake Oahe.

The impact of increased bank stabilization within the Garrison Reach appears to result in a decreasing rate of bank erosion within the reach. The Garrison Reach contains approximately 29 percent bank stabilization coverage.

Table 8–1 summarizes the impacts evaluated in this report and provides recommendations on how to address these impacts related to sedimentation.

TABLE 8–1.—IMPACT SUMMARY AND RECOMMENDATIONS

Impact	Significance	Timeline	Recommendation
Reduced storage capacity in Oahe and Garrison Reservoirs	Significant	Near term (1 to 5 years)	Continue to study potential methods to reduce aggradation upstream of reservoirs
Aggradation of sediment within main channel	Significant	Near term	Study impacts of dredging and identify specific sections of channel downstream of Bismark which could benefit from limited dredging program
Aggradation of sediment raises impact of ice dams on seasonal flooding.	Significant in some areas.	Near term	Continue sequenced water release during winter months and identify when ineffective to make necessary corrections
Cumulative effects of stabilization projects on river issues	Minor Significance	Long term	Continue to study cumulative effects of bank stabilization on fish and wildlife, new or on-going stabilization projects to include eco-friendly design techniques
Channel stability/geometry	Possibly Significant	Near term	Additional study needed to determine reaches most impacted from sloughing and slumping
Channel stability	Possibly Significant	Near term	Identify reaches where eco-friendly bank stabilization techniques can be applied and will achieve reduction of aggradation downstream

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Contacts

Jeff Klein, State NFIP Coordinator North Dakota State Water Commission jklein@nd.gov 701–328–4898

Bruce Englehardt, Investigations Section Chief North Dakota State Water Commission bengelhardt@nd.gov 701–328–4958

Nancy Steinberger, Regional Engineer FEMA in Denver nancy.steinberger@dhs.gov 303–235–4992

Gregg Thielman, P.E. Houston Engineering Inc. gthiel@houstonengineeringinc.com 701–237–5065

APPENDIX G—IMPACTS OF SILTATION OF THE MISSOURI RIVER ON INDIAN AND NON-INDIAN HISTORICAL AND CULTURAL SITES IN NORTH DAKOTA

1.0 INTRODUCTION

Berger was tasked by the U.S. Army Corps of Engineers (USACE) to assess the potential impacts of sedimentation in the Missouri River within the State of North Dakota. This assessment is intended to meet the level of effort defined in the Missouri River Protection and Improvement Act. The assessment was to be based on review of relevant existing data and information. The study area was defined by the USACE to include the watershed of the mainstem of the Missouri River from the North Dakota/South Dakota border on the downstream end to the Montana/North Dakota border on the upstream end (Figure 1–1). This report analyzes the potential impacts of sedimentation on Indian and non-Indian historical and cultural sites.

This appendix is a brief report that describes the potential impacts to Indian and non-Indian cultural resource sites. It provides a summary of the types and locations of the records that were consulted and a description of the qualifying properties within the project area. The project area is considered the areas of potential aggradation or siltation (Figure 1–2 through Figure 1–5). The area possessing the potential for Indian and non-Indian sites is known as the area of potential effects (APE). For this assessment, the APE is considered to be the area between the historic low water mark in 2007 and the ordinary high water mark at Lake Sakakawea (1,850.0 feet above mean sea level—msl) (USACE 2006a) and Lake Oahe (1,620 feet msl) (USACE 2004a).[1] However, the research conducted by USACE includes all sites within the footprint of Lake Oahe and Lake Sakakawea, and are not separated into the portion of the shoreline between the low and high water marks.

The report identifies the impacts to cultural resources that should be monitored and/or mitigated as a result of siltation along waterways and reservoir margins to comply with various statutes, regulations, and USACE policies. Such impacts include deposition of sediments on extant Indian and non-Indian historical and cultural sites. In some cases, a layer of sediment covering a cultural site is beneficial because it protects the site from weathering, erosion, and intentional or unintentional human actions. For standing structures, the impact may be considered adverse because moisture and sediments can destroy foundations and walls. Along reservoir margins, siltation followed by fluctuation in water levels tends to cause more damage to sites because of newly created cut banks and erosion. The integrity of sites is damaged and much cultural and scientific data are lost.

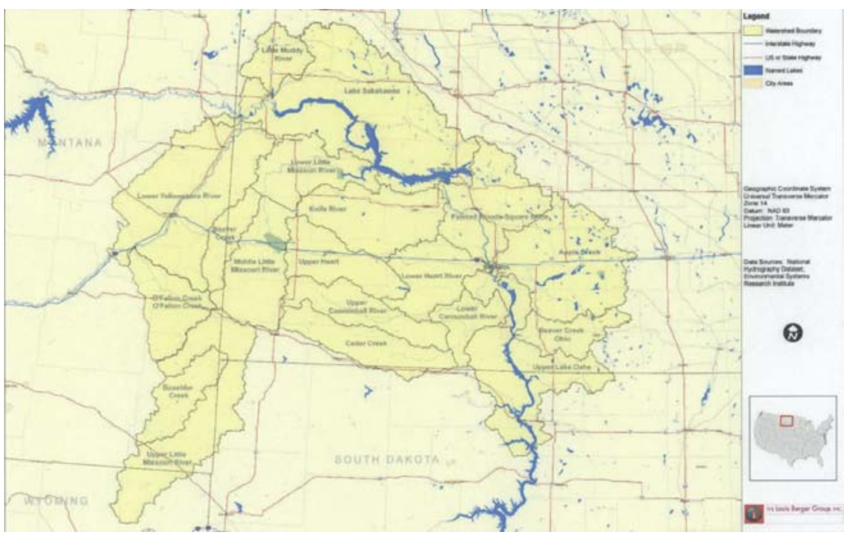

FIGURE 1–1.—*Location of Study Area*

[1] To protect the cultural resources, location information is not included.

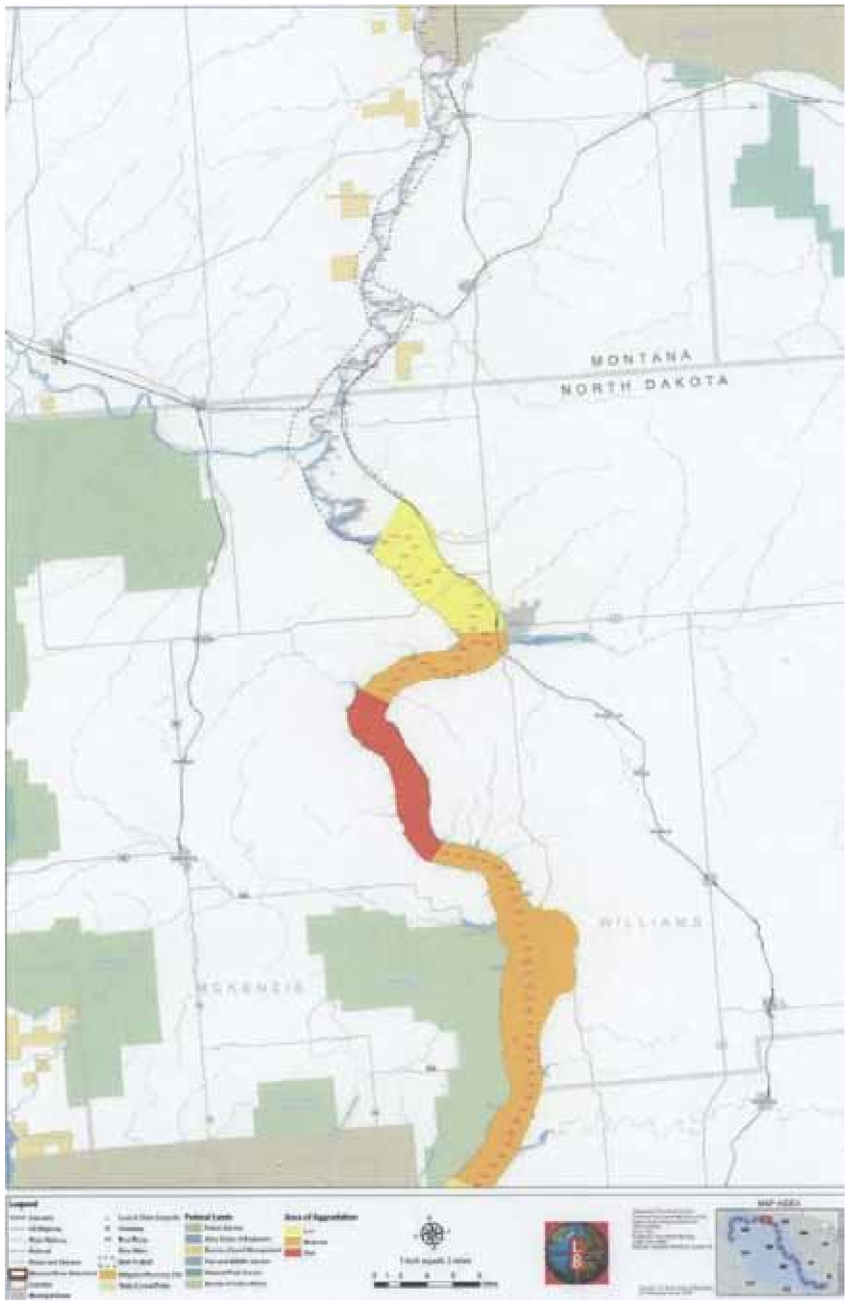

FIGURE 1–2.—*Aggradation Area Map 1*

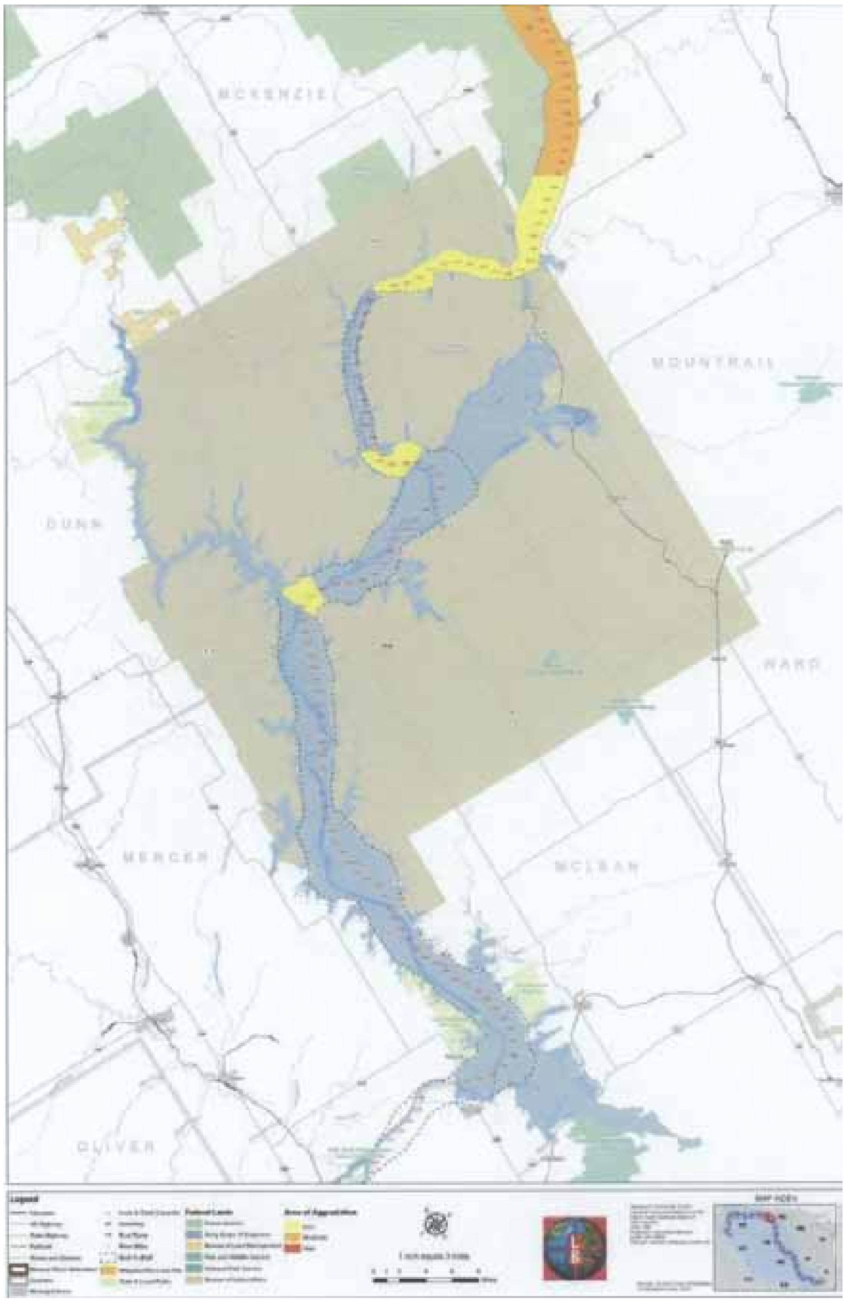

FIGURE 1–3.—*Aggradation Area Map 2*

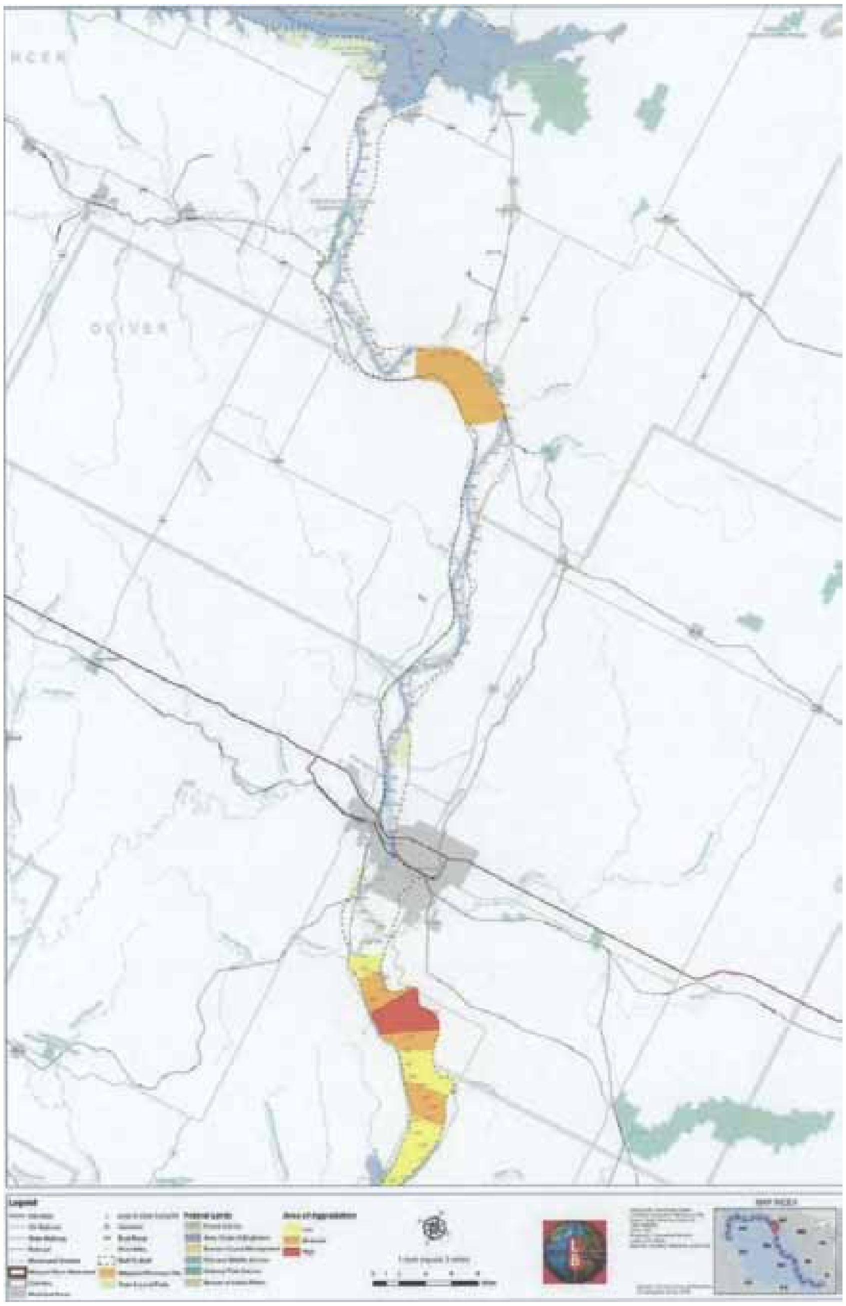

FIGURE 1–4.—*Aggradation Area Map 3*

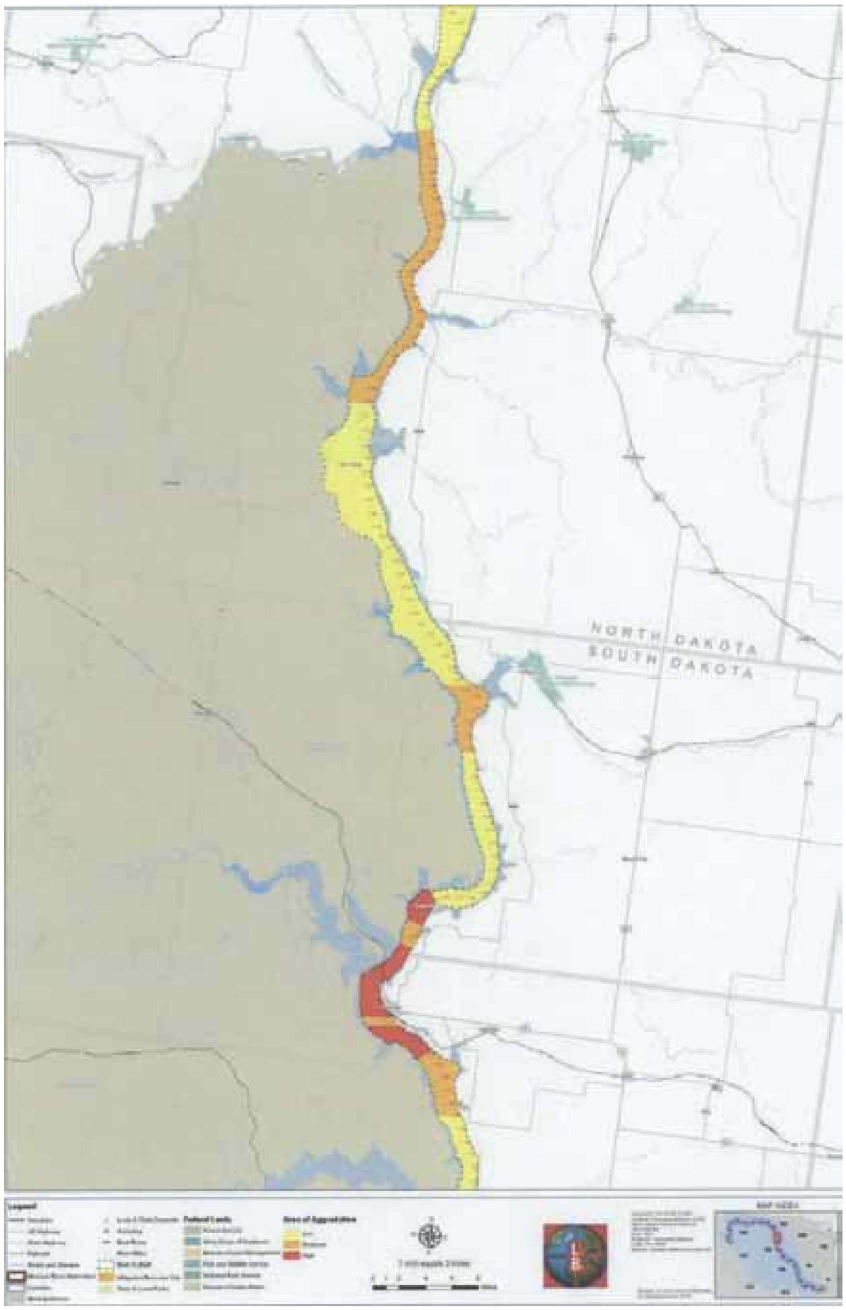

FIGURE 1–5.—*Aggradation Area Map 4*

2.0 METHODOLOGY

2.1 Literature and Data Search

To identify data on cultural resources, Berger performed a review of the records on file at the following agencies and repositories, as available:

—USACE records repository (provided by USACE personnel)

—North Dakota State Historic Preservation Office (NDSHPO)

—Appropriate Tribal Historic Preservation Officers (THPO)

Berger entered information on all properties located within the APE into a database, including all properties listed in the National Register of Historic Places (National Register); properties determined eligible for listing by the Keeper of the National Register; properties in the process of being nominated to the National Register; properties determined eligible by consensus determination by the SHPO; and properties identified in the SHPO inventory as meeting the National Register criteria.

2.2 Analysis

The potential impacts on and relationships to Indian and non-Indian historical and cultural sites were analyzed in terms of duration (short-term versus long-term) and magnitude of effects to significant resources. Significant resources are those determined to meet specific evaluation criteria contained in 36 Code of Federal Regulations (CFR) 60.4—Criteria for Evaluation: (a) that are associated with events that have made a significant contribution to the broad patterns of our history; or (b) that are associated with the lives of persons significant in our past; or (c) that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or (d) that have yielded, or may be likely to yield, information important in prehistory or history.

Sites that meet at least one of the criteria are considered eligible for inclusion in the National Register and are afforded a level of protection by Federal and State agencies.

The report also contains recommendations for solutions to siltation with respect to cultural resource sites.

3.0 BACKGROUND AND CULTURE HISTORY

3.1 Prehistoric Period

The prehistory of the Great Plains is divided into five general time periods consisting of: the Paleo-Indian, Plains Archaic, Plains Woodland, Plains Village, and the Historic (NDSHPO 2003; USACE 2004b; USACE 2006b). The project area may either contain the physical remains of prehistoric properties or the potential to harbor such properties. The physical remains of past human occupation occurring within the project area are identified as sites. The contents of a site and its component parts are described as artifacts or features. An artifact is defined as an object than can be carried off such as a projectile point or pottery sherd and a feature is defined as an object that is non-removable without mechanical means, such as a structure or rock art panel. The manner in which ancient people manufactured tools, constructed shelters, or domesticated wild plants is an important aspect of understanding a cultural group's development through time.

The Missouri River watershed within central North Dakota contains a diverse and in-depth cultural history. Numerous American Indian tribes containing extensive oral traditions have identified properties within, and in close proximity to, the project area. These properties consist of places where events significant to the development of their culture have occurred and are referred to as traditional cultural properties (TCPs). Through the examination of these oral traditions, in conjunction with linguistic and archaeological studies, we can gain a better insight to which native cultural group(s) may potentially be affiliated with the prehistoric properties within the project area.

The Division of Historic Preservation of the State Historical Society of North Dakota published Historic Preservation in North Dakota, II: A Statewide Comprehensive Plan, which divides the State into 13 study units for archaeological research. The Missouri River and associated reservoirs fall primarily within the Garrison, Souris River, and Bismarck Study Units. The Division separates the cultural prehistory of North Dakota into five distinct themes based on a cultural chronology spanning approximately 11,500 years (NDSHPO 2003). The Cultural Resource Management Plans (CRMPs) for Lake Sakakawea and Lake Oahe developed by USACE also define five prehistoric periods that differ slightly from the Division of Historic

Preservation (USACE 2004b; USACE 2006b). The categories of both the NDSHPO and USACE are shown in Table 3–1.

TABLE 3–1.—PREHISTORIC CHRONOLOGIES OF NORTH DAKOTA

Cultural Period	NDSHPO Chronology	USACE Chronology
Pre-Clovis	N/A	Prior to 13,000 B.C.
Paleo-Indian	9,500–5,500 B.C.	13,000–9,500 B.C.
Plains Archaic	5,500–400 B.C.	9,500 B.C.–A.D. 1
Plains Woodland	400 B.C.–A.D. 1850	500 B.C.–A.D. 1000
Plains Village	A.D. 1000–1850	A.D. 900–1750
Equestrian Nomadic	Mid A.D. 1700–1851	N/A

The following sections contain excerpts from the USACE CRMPs for Lake Oahe and Lake Sakakawea and is provided with the approval of USACE. These CRMPs are not accessible to the public in compliance with a Programmatic Agreement (PA) among the USACE and participating tribes to protect site location information. Therefore, the indented text in each section is provided as information to the reader that would not otherwise be available.

Pre-Clovis

Although no evidence exists for pre-Clovis occupation within the project area, the potential exists for the area to harbor deeply buried subsurface intact pre-Clovis evidence. The most convincing pre-Clovis evidence in North America may come from the Meadowcroft rock-shelter site in Pennsylvania (Adovasio et al. 1977, 1978, 1980). Additional possible associated sites containing a pre-Clovis horizon are Pendejo Cave, New Mexico (Chrisman et al. 1996:357–376), Selby/Dutton and Lamb Springs, Colorado (Stanford 1979; Stanford et al. 1981), and the Big Eddy Site, Missouri (Ray 1997). While none of these sites are unequivocal, their existence lends credence to some oral tradition stories describing a gradual development in tool making as people adapted to their changing environment (USACE 2004b).

Paleo-Indian

The Paleo-Indian tradition is characterized by hunting and gathering adaptation, primarily of now extinct big game animals. Diagnostic artifacts or sites in North Dakota are typically attributed to the Clovis, Goshen, Folsom, Hell Gap-Agate Basin, Cody, Parallel Oblique Flaked, Pryor Stemmed, and Caribou Lake projectile points manufactured by the Paleo-Indian complexes.

Sites identified as Clovis are generally kill sites and processing stations containing fossilized mega-fauna remains, but there have been a few campsites, quarry sites and base sites associated with Paleo-Indian occupation (Fiedel: 1987). Other Paleo-Indian sites in the West include the Anzick site, Montana (Lahren & Bonnichsen: 1974), and the Drake site, Colorado (Stanford: 1991). Evidence from Anzick suggests tool caches may be related to the burial practices of Clovis people. Clovis is the earliest recognizable culture complex—a complex which occurs repeatedly, in patterned and predictable contexts, in the Great Plains (Wood: 1980).

Plains Archaic

The Plains Archaic complexes recognized in North Dakota include Oxbow, McKean Lanceolate, Duncan, Hanna, Pelican Lake, and Yonkee as determined by the projectile point style. This tradition subsumes hunting and gathering adaptation to essentially modern flora and fauna. The atlatl was developed during this period and became the new hunting instrument of choice. The Plains Archaic people maintained a nomadic hunter/gatherer lifestyle and continued to hunt the larger mammals of the plains to include bison, elk, deer, and antelope.

Early Archaic.—The Early Plains Archaic period is most commonly associated with the Folsom Complex whose significant diagnostic artifact is the Folsom deep fluted projectile point. In Lakota this point is identified as hist'o'la bla'ha, "tapered without barbs" (Mesteth & Charging Eagle: 2000). Their tool technology was advanced and the archaeological evidence of early Folsom people consists of artifacts such as channel flakes, end scrapers, side scrapers, bifacial knives, burins, gravers, drill tools, choppers, ground stone abraders, bone awls, eye needles, tubular bone beads, and bone disks (Gunnerson: 1987). Folsom sites in this region are the Moe (Schneider: 1975), Lake Ilo and Winter sites (Haug: 1982) in North Dakota, and the Agate Basin (Frison & Stanford: 1982), Hell Gap (Irwin-Williams et al. 1973) and Carter Kerr/McGee Sites (Frison: 1984) in Wyoming.

Middle Archaic.—The Middle Archaic people continue to live as nomadic hunter/gatherers, but climate conditions were changing and the last remaining megafauna in North America he'halo'ǧeca iyéceca, "longhorn buffalo—Bison Antiquus" becomes extinct. This extinction forced people to alter their subsistence patterns and dependence upon smaller mammals, birds, fish, shellfish, and plants brought about a change in their tool making technology and their cultural development. Foraging for food plants takes on a greater importance during this period and archaeologists have become aware that foraging could be the basis for developing quite complex societies (Fiedel: 1987).

As groups settled into more localized hunting territories an increased reliance upon local lithic resources occurred. The long thin lanceolate point tradition began to disappear and replacing them were side-notched projectile point types such as Hawken, Logan Creek, Oxbow, Bitterroot, Pahaska Side-notched, and Blackwater Side-notched points (Frison et al. 1996; Gregg et al. 1996). The use of local lithic material and more sparse use of exotic material in archaeological assemblages dated to this period seem to support this conclusion (Gregg et al. 1996; Fiedel: 1987). Modern bison remained the principle game for native people living across the Plains and this is demonstrated in the Hawken site in Wyoming (Frison et al. 1976), the Head-Smashed-In site (Reeves: 1978) in Alberta, Canada, the Smilden-Rostberg site (Larson & Penny: 1991) in North Dakota and the Granite Falls site (Dobbs & Christianson: 1991) in Minnesota. A number of habitation sites for this period have been discovered in the Big Horn Mountains of Wyoming, the Black Hills of South Dakota, and the Pryor Mountains of Montana. There are two important complexes identified in the Northern Plains for this period, Oxbow and McKean (Dahlberg and Whitehurst 1990:80; Frison et al. 1996).

Terminal Archaic.—Terminal Archaic people are much more diverse culturally and linguistically. On the northern plains the Pelican Lake Complex manifests itself and spreads across Alberta, Saskatchewan, Manitoba, Montana, North and South Dakota, Idaho, Wyoming, Northern Colorado and Nebraska (Peterson et al. 1996). The diagnostic artifact is a thin, corner notched projectile point with wide, deep-notched corners or barbs on it (Frison: 1991). Sites attributed to Pelican Lake are the Head-Smashed-In (Reeves: 1978) site in Alberta Canada, and the Kobold (Davis & Stallcop: 1965) and Keaster (Frison: 1991) sites in Wyoming. Tool kits include scrapers, chisels, bifaces, choppers, drills and a variety of multi-purpose flake tools. The bone tool assemblage for Pelican Lake people consists of awls, beamers, hide-grainers, scrapers and antler tine flakers (Greg, et al. 1996).

Known Archaic property types include animal kill sites, camps, Knife River flint quarry sites, lithic workshops, and burial sites (NDSHPO 2003).

Plains Woodland

The Plains Woodland culture continued the hunting and gathering adaptations, but can be characterized by increased sedentism, expansion of regional trade networks the practice of elaborate mound burials, production of ceramic vessels, and the intensified use of horticultural through indigenous seedy plants and grasses for supplemental food (Griffin 1967). During this period the bow and arrow replaced the atlatl at approximately A.D. 600.

Early Plains Woodland.—The Early Plains Woodland period is generally associated with the development of ceramic technology (pottery), generally stone-tempered with cordmarked exteriors (Montet-White: 1968; Adair: 1996). The bow and arrow was introduced (Adair: 1996) replacing the throwing darts used by Archaic people. This period on the Dakotas is poorly understood and the Naze site (Gregg: 1987) was one of first to be excavated. The information from Naze and other sites in the region basically identifies Early Plains Woodland sites as seasonal use sites (Benn 1990). Applicable traditions for this period describe the establishment of a distinct Dakota language cultural group inhabiting portions of the Ohio River valley. These Dakota speakers are the direct descendants of the Indian Knoll cultural group (Terrell: 1974).

Middle Plains Woodland.—The Middle Plains Woodland is best characterized by the widespread manufacture of pottery, constructing permanent village sites, and the establishment of well-organized trade relations between different cultural groups specifically centered on the Hopewell culture. In the Midwest material resources and ornate objects were widely distributed as a result of these trading relationships and in Hopewell sites archaeologists have discovered obsidian from the Black Hills and Rockies, copper from the Great Lakes, shells from the Atlantic and Gulf coasts, mica from the Appalachians, silver from Canada, and alligator skulls from Florida (Waldman: 1985). Middle Plains Woodland people did have contact with Hopewellian people. Knife River flint artifacts have been found in a few Early and Middle Plains Woodland sites in Iowa (Benn: 1983). The location of Middle

Woodland sites suggests the gradual adaptation to more sedentary lifestyles. Settlement patterns among these people involved permanent to semi-permanent base camps typically situated at the base of bluffs or on side streams within the bluffs of large valleys (Fortier: 1984; Roper: 1979).

Late Plains Woodland.—Late Plains Woodland is a time when mound building cultures faded out and people living in the Midwest began reverting to more nomadic, possibly less rigorously structured societies as major population centers were abandoned and people dispersed and spread out. There are important cultural changes taking place during this period that set the stage for the development of the Plains Village stage (Ford: 1977). Some noticeable changes are modification of ceramic technology and the development of an agricultural economy. An increase in the importance of maze is noted throughout the Midwest during this period (Ford: 1977; Kelly 1984). Settlements were widely spread across the landscape and this was probably due to population growth. Habitation sites became more and more common above floodplain terraces along the Missouri River and its tributaries (Ludwickson et al. 1987).

The North Dakota Plains Woodland complexes include Sonota/Besant, Laurel, Avonlea, Blackduck, Mortlach, Old Women's, and Sandy Lake sites. Typical Plains Woodland property types include burial mounds and other burial sites, occupations, camps, quarries and lithic procurement areas, and bison kill sites (NDSHPO 2003).

Plains Village

The Plains Village tradition consisted of horticulturalists, as well as hunters and gatherers. The Plains villages dominated the North Dakota cultural scene from as early as A.D. 1000 until 1780 and included contact with European trappers and early settlers. Much of the later Plains Villages were decimated by the contraction of European diseases. One of the key elements in Plains Village adaptive strategies was the development of a dependable, storable surplus food supply primarily in the form of dried corn. Stored food facilities are indicative of the Plains Village period.

The Plains Indian Village period is a time when the people inhabiting the Missouri River basin began establishing permanent village sites along the Missouri River and its tributaries. Plains village dwellers learned to plant the seeds traded to them from the Indians of the mound and temple building cultures in small garden plots they cultivated next to their villages. As people settle down and move farther and farther away from the nomadic lifestyles of their ancestors, they learned how to build earth lodges surrounded by protective wooden palisades or ditches. Gradually as villages grow larger in size small garden plots become tilled fields. Annual crops of corn, beans, squash, and sunflowers were raised and stored as winter food surpluses. Manufacturing pottery became wide spread among the tribes as they developed regional trading centers located throughout the plains. The Plains Village period may be divided into two variants, but both periods overlap each other and share cultural traits. The variants are the Middle Missouri Tradition (A.D. 900—A.D. 1200) and the Coalescent Tradition (A.D. 1200—A.D. 1740) (USACE 2006b).

Middle Missouri Tradition.—Middle Missouri Tradition represents the first sedentary village occupations of the Missouri River and its tributaries occurring where agriculture becomes more important than bison hunting (Winham & Calabrese: 1998:278). When corn was introduced tending to the crops during growing season forced people to remain in place for part of the year. This brought about a much more sedentary lifestyle that also required people to carefully choose a good location for establishing a village site where an ample supply of water, wild game, and wild plants could be easily obtained to sustain them until the crops were ready for harvesting (Zimmerman: 1985). Growing an abundance of crops allowed population levels to increase. Subsequently, when bands divided among themselves to occupy and settle new areas they could take their main food source with them. This meant that pottery became more important because it was used to store and cook the plants people are growing (Zimmerman: 1985).

At the end of the period a variant complex within Middle Missouri called the Extended Middle Missouri Variant (EMM) began to appear. Sites attributed to the EMM are located along the Missouri River in the area of the Bad and Cheyenne Rivers, and are labeled as the Bad River phase (Winham & Calabrese: 1998). The Bad River phase is linked to the historic Arikara occupation of the area. Another variant complex, the Terminal Middle Missouri Variant (TMM), is believed directly related to EMM. The people of the TMM variant are considered ancestral to the Mandan (Johnson: 1996).

Coalescent Tradition.—The Coalescent Tradition is best described as a time when massive population migrations were taking place. No one has ever been able to establish how the Coalescent Tradition developed; some claim the Middle Missouri Tradition people and Central Plains Tradition people basically joined together and hence the term Coalescent. It is thought that people coming in gradually blended with groups already living along the Missouri River. Ceramics and lodges within the villages reflect this view as houses of the period were constructed in a square manner which is a trait associated with people from the Central Plains Tradition, and in a circular manner which is a trait associated with people from the Middle Missouri Tradition (Zimmerman: 1985).

The Coalescent Tradition brought about the emergence of the Mandan, Cheyenne, Dakota, Arikara, Kiowa, Siouan Ponca, and Omaha tribes and traditions.

The Mandan.—At a point probably towards the end of the period, a portion of the Miwa′t′aŋni began moving north up the Missouri River eventually reaching the mouth of the Little Missouri River where the group splits apart (Terrell: 1974). One group called Psa′loka, "Crow Indians," moved southwest and settled in lands lying below the Rocky Mountains. The other group returned to the Knife River area and returning as they did the Miwa′t′aŋni begin calling them Mini′tari′, "Crossed the River." The Mini′tari′ are historically identified as the Hidatsa. The Hidatsa and Crow kept their kin relation with each other and Crow trading parties helped the Hidatsa people establish numerous village sites in the Little Missouri and Yellowstone River valleys (Terrill: 1974).

The Cheyenne.—One of the tribes sharing lands with the Dakota in Minnesota was the Sahi′yela, "Red Talkers/Cheyenne Indians." They are an Algonquian speaking people that migrated to the Minnesota River valley after abandoning their homelands above Lake Superior to the Chippewa (Grinnell: 1972) and established themselves along the Minnesota River and the Yellow Medicine River. Their earth lodge village at the Yellow Medicine River is called Sahi′yela na wo′jupi, "Where the Cheyenne Plant" by the Dakota (Grinnell: 1972). When a war between the Chippewa and Dakota broke out the Cheyenne began a westward movement and ultimately abandoned their Minnesota and Yellow Medicine river village sites. Dakota traditions about the Cheyenne never indicate that warfare between the two tribes ever took place, but there are recordings attributed to Stephan Riggs, and Lewis and Clark, that indicate the Cheyenne were driven from the Minnesota River and the Yellow Medicine River valley by the Dakota and the Chippewa (Grinnell: 1972). One element of the Cheyenne eventually settled along the south bend of the Sheyenne River in the area of Lisbon, North Dakota (Grinnell: 1972).

The Cheyenne villages in North Dakota were fortified and the people grew crops and hunted bison. Their lodges were circular in form with extended entryways usually facing southeast (Moore: 1996). The basic floor plan of the lodge was similar to the other lodges constructed by the Missouri River tribes. They were large circular structures enclosing a central fire pit and built around four central support posts (Grinnell: 1972). Other Cheyenne groups were nomadic hunters after leaving Minnesota. They hunted and traded with the Mandan and contrary to reports from Maximilian during the Missouri River travels who claimed the two tribes engaged in a war, the Cheyenne and Mandan people entered into and maintained friendly relations (Grinnell: 1972). In the last part of the 18th and in the early part of the 19th century, the Cheyenne were dispersed over a wide territory extending from west of the Black Hills to the Missouri River, and from the Little Missouri River towards its mouth, and as far south as the Arkansas river (Grinnell: 1972). This wide dispersal was rewarding for the Mandan, Arikara, and the Ti′toŋ′waŋ because the Cheyenne are the people that brought horses into the Northern Plains (USACE 2004b).

The Dakota.—Circa A.D. 1500 to A.D. 1600, the Dakota at Bde′ Wakaŋ′ were engaging the Chippewa in a war for control of the marshy wild rice lands lying between the Lake of the Woods in Canada and Lake Superior and Lake Michigan. In the east the Iroquois began a period of territorial expansion and conquest that drove the Chippewa into the Dakota (Warren: 1984). The conflict between the tribes was a bloody one with each side winning and losing numerous battles. At the time of the war the Dakota were living as seven related bands, the Bde′ Wakaŋ′toŋ′waŋ, "Spirit Lake Village People;" the Ti′toŋ′waŋ, "Dwellers of the Plains;" the Sisi′toŋwaŋ, "Slimy Ones;" the Wahpetoŋwaŋ, "Leaf Village People;" the Wahpe′ kute, "Leaf Shooters;" the Ihaŋ′ktoŋwaŋ′, "Camps on the End;" and the Ihaŋ′ktoŋwaŋla, "Little Camps on the End." To hold their lands the Dakota formed an alliance known as the Oce′ti Sako′wiŋ, "Seven Council Fires," to defeat the Chippewa (Walker: 1982) and for a time they remained in control of the wild rice producing lands, but the formation of the alliance eventually impacted all of the tribes occupying the Missouri River (USACE 2004b).

The Arikara.—Throughout the 17th century the Arikara continued to move up the Missouri River. The villages they constructed were earth lodges encircling a central plaza and typically there was a large ceremonial lodge facing the plaza area (Gilmore: 1930). Their lodges were circular structures containing central hearths and large sub-floor cache pits. Many of the villages had fortified palisades or ditch entrenchments boarding them for protection (Ludwickson et al. 1987). Lakota and Dakota traditions describe the Arikara occupation of the Missouri River as expansive (LeBeau: 1994). Historically they may be known as traders, but to the Lakota they were a powerful enemy who were once considered relatives (Rice: 1994). They were the power in the Missouri River basin until massive epidemics of diseases ravaged and reduced their population after they came into contact with White people (USACE 2004b).

The Kiowa.—The Kiowa are thought to have entered the Black Hills region circa 1700 (Mayhill: 1971). They were a buffalo hunting people and never developed an earthlodge farming culture. They did establish trading relations with tribes in the area, primarily the Sc′ili, Pawnee and they often traveled along the Cheyenne and the Bad Rivers to trade with the Arikara. When the first Ogla′la and Sican′gu hunting bands entered the Black Hills country, the Kiowa began fighting with them over land and resources. A constant state of warfare between them and the Lakota continued until the late 1700's when one of their sub-bands were wiped out near the headwaters of the Cheyenne River by a large Ogla′la war party (Mooney: 1898). This defeat forced the remaining Kiowa to leave the region and move south into the southern plains (USACE 2004).

The Ponca and Omaha.—The Siouan Ponca and Omaha are thought to have entered the Missouri River region in the early part of the 18th century. Near the mouth of the White River they established a camp circa 1715 (Howard: 1995). The Ponca then moved on to the Black Hills and traded with the Kiowa for a time, but for unknown reasons they eventually migrated back to the White River camp and rejoined the Omaha. Both tribes followed the river back to the south, returning to the area around the mouth of the Niobrara River where they finally established a permanent presence (Howard: 1995).

Typical Plains Village property types include occupations (fortified and unfortified earthlodge villages), winter villages, camps (hunting), flint quarries, eagle trapping sites and conical timber lodges, burials, lithic workshops, bison kill sites, and rock art sites (NDSHPO 2003).

Equestrian Nomadic

The Equestrian Nomadic tradition subsumes those lifeways that were dependent upon horses during protohistoric and early historic times in the Northern Plains. The introduction of the horse brought about significant changes in subsistence strategies, demographics, social organization, and settlement patterns. Known property types include camps, battle sites, and animal kill sites (NDSHPO 2003).

3.2 Historic Period

The Historic period on the Missouri River is defined as the period of first contact with non-Indians. During this period the Lakota were the preeminent power in the project area until they were removed, along with all of the tribes associated to the river basin area, to various reservations in North Dakota and South Dakota. The Historic Period consists of two parts: A.D. 1740 to 1804, the phase when the Lakota rise to power within the Missouri River basin and displace the Arikara, and A.D. 1804 to 1890, the phase when Indians lose control of the land and are relocated to reservations.

The first portion of the historic period represents a time when life along the Missouri River was in constant flux as the Lakota started crossing the river in the middle of the 17th century. The Arikara, the Mandan, and the Hidatsa have a well-established self-sufficient, surplus-abundant trading system operating throughout the Upper and Middle Missouri River region. The Mandan-Hidatsa villages below the Knife River in North Dakota were visited annually by the Cheyenne, Cree, Crow, Gros Ventre, and Yanktonai people who exchanged tanned buffalo, deer and elk hides for agricultural goods and material resources such as Knife River flint. The Arikara villages located at the mouth of the Grand, Cheyenne, Bad, and White Rivers were visited annually by the Cheyenne, Pawnee, Lakota and Dakota. The trade intercourse throughout the plains revolved around these trading centers and goods from the southwest, southeast, northwest, and northeast were traded regularly between the tribes (Bowers: 1950; Wood & Thiessen: 1985).

By the 1790's the Lakota were roaming over a vast hunting territory on both sides of the Missouri River as nomadic buffalo hunters. Traditions state that once the Ogla′la drove the Kiowa out of the Black Hills region the Lakota bands came together to hold a great council at Bear Butte. During this council they formed their own tribal alliance, which is also called the Oce′ti Sako′wiŋ, "Seven Council Fires" (Plenty Chief: 1985). As the dominate power throughout the region, the Lakota and their Dakota cousins in Minnesota quickly gained control over a vast territory that stretched to the Teton Mountains in the west, to the Minnesota River valley in the east. They maintained an almost constant state of warfare with the Pawnee, Shoshone, Crow, Blackfeet, Arikara, Mandan, Hidatsa, Cree and Plains Chippewa. By the turn of the century in 1800 the Lakota controlled all of the lands below the mouth of the Grand River that lie within the project area. The Ita′zipco and the Mniko′woju bands were occupying the area between the Bad and Cheyenne Rivers. The Huŋ′kpapa were in the area between the Moreau and Grand Rivers, and the Siha′ Sa′pa and the Oo′henuŋpa were in the area between the Cheyenne and Moreau Rivers (Hassrick: 1988). All along the Missouri River bottoms the various bands erected seasonal winter encampments, hunting camps and temporary trading camps where they traded with each other. The Lakota became regular visitors to the Big Bend area, holding councils with the Kul Wica′śa and Yankton bands who lived in the area. In the area around the Little Bend all of the Lakota bands, several Yankton bands, and various Sisseton and Santee Dakota bands held annual spiritual ceremonies and conducted individual spiritual activities on a regular basis (LeBeau: 1994; 2002). Farther up river in the area of Medicine Rock near the Little Cheyenne River, the Lakota visited the site for ceremonial purposes, but it is also considered an area where people could meet to trade with each other (LeBeau: 1994).

The first eyewitness report recording contact occurring between the Indians and non-Indians within the project area took place in 1743 when the Verendrye brothers, Chevalier and Louis, entered the area and traveled along the Cheyenne and Bel Fourche Rivers by canoe in an attempt to find an overland route to the Pacific Ocean (Chittenden: 1986). In March of that year they returned to the area of the mouth of the Bad River where they camped with a band of Arikara headed by Chief Little Cherry. On March 30, 1743 the Verendryes went to a hill at the junction of the Bad River with the Missouri and claimed the region for France, and planted a lead plate as evidence of the claim (Schuler: 1990).

The second portion of the historic period consists of the interaction between the first non-native people and the local tribes as recorded by the early explorers, trappers, traders, military personnel, and settlers.

In 1800 with the Louisiana Purchase the United States authorized a series of official U.S. Army expeditions to explore their newly acquired territory. In 1804 the Lewis and Clark Expedition entered the area seeking to discover a water route leading to the Pacific Ocean. The expedition sketched a map of the river attempting to list intersecting rivers, creeks, streams, and physical features such as prominent hills and buttes, Indian village sites, and expedition camping sites (USACE 2004b).

In 1812 Fort Manuel was constructed along the west bank of the Missouri River, 10 miles south of the present day North Dakota/South Dakota border (Schuler 1990). The fort named after Manuel Lisa, a fur trader from St. Louis, was the first trading post operating within the project area. The fur trading business was booming and new forts were erected to meet the need for trading with the local tribes. The success of the fur trade operations along the upper Missouri created a need for additional manufactured good to be traded to the local tribes for furs.

The establishment of the fur trade and the construction of trading posts in the project area helped open up the territory to settlement by homesteaders. By the time the fur trade was in full force the primary occupants of the territory were the Lakota and Dakota Indians (Schuler: 1990). Once the settlers began entering the region conflicts between them and the local native populations were inevitable. The Indian tribes wanted white trade goods, but they did not want the white settlers. Relations between the Indian tribes, specifically the Lakota and Dakota, and the United States began deteriorating in the late 1820's and early 1830's.

Due to the influx of outsiders to the region new diseases spread among the tribes decimating their populations. In 1837 a smallpox outbreak on the Northern Plains reduced the Indian population by half including seven-eighths of the Mandan and over 50 percent of the Arikara populations (Dollar 1977). These disease outbreaks greatly reduced the fur trade with the local indigenous people.

To secure trading rights with various Indian tribes the United States Government began making treaties with the tribes as the westward expansion into the Northern Plains took place. Invariably the treaty processes also attempted to establish territorial limits for individual Indian tribes and get them to acknowledge that the United States had supremacy over them. Stipulations to protect the tribes from depredations committed upon them by non-Indians not legally authorized to enter their country for the purposes of trade or other views were also included in the treaties that were made during this period. By the 1850's government treaties with the tribes in the Great Plains began including additional language that dealt with the right of the United States Government to establish roads, military and other posts within a tribe's respective territory, as well as delineate a set boundary for that territory (LeBeau: 1997). The United States failed to maintain its treaty obligations with the tribes to keep non-Indians out of Indian land and this failure more than any other factor is what caused conflicts to break out that eventually resulted in the Missouri River tribes being removed to permanent Indian reservations (LeBeau: 1997).

In 1851 the first Treaty of Fort Laramie was made by the United States Government with the Sioux, Cheyenne, Arapaho, Crow, Assiniboine, Gros Ventre, Mandan and Arikara tribes. This was an important event because this treaty impacted all of the Indian tribes who resided in the Missouri River basin running through the Dakotas. Under Article 5 in the treaty, physical boundaries delineating the territories of each tribe are described and these physical descriptions provide indications where tribal populations were located in 1851. In 1868 as a result of Red Clouds War, a second Fort Laramie Treaty was made with the Sioux, which established the Great Sioux Reservation and delineated its physical boundaries. Again the descriptions provide an indication of where tribal populations were located.

It was not just treaties the United States Government entered into with Indian tribes living along the Missouri River. Agreements between the Government and Indian tribes were also made, and in 1866 the United States made the Fort Berthold Agreement with the Arikara, Mandan and Hidatsa, which ceded land to the Government. In 1882–1883 the Agreement with the Sioux of Various Tribes was made, and this agreement broke up the Great Sioux Reservation and established 5 separate reservations for the Sioux; those are Pine Ridge, Rosebud, Standing Rock, Cheyenne River, and Lower Brule (USACE 2004).

The first military post in the region, Fort Pierre, was purchased by the U.S. Army in 1855, but later abandoned in 1857 due to lack of surrounding resources. In 1863 a second military installation, Fort Sully, was established along the left bank of the Missouri River, 6 miles below Pierre, South Dakota. Fort Sully served as headquarters for military troops stationed in the area, but was abandoned in 1866 and relocated 34 miles upstream of the Missouri River approximately 30 miles below the confluence with the Cheyenne River (Frazer 1965). Several additional military installations sprang up along the Plains of the Missouri River drainages over the next few decades to include Fort Rice in 1864, Fort Bennett in 1870, Fort Abraham Lincoln in 1872, and Fort Yates in 1874 which remained a military post until 1903 (Frazer 1965).

In order to supply the military installations and trading posts, steamboats were used to navigate the Missouri River. The steamboat era was one of booming commerce, with many ships plying the major rivers of the West. Steam operated wheel boats were used on the Missouri River as early as late 1850s. By 1859 steamboats started to visit Fort Benton on a regular basis. During the 1850s, Government contracts were issued to companies willing to navigate the Missouri River to deliver annuities to various Indian Tribes as required by treaty (Chittenden 1936; Schuler 1990).

Steamboat travel was risky and dangerous since many of the inland rivers were shallow during the summer, fall, and winter months. Paddle wheelers were subject to accidents that could damage a cargo or destroy the vessel. The Missouri River was especially dangerous due to its shallow waters, swift currents, and narrow navigable channel. Many paddle steamers perched their paddle-wheels on submerged sand bars, often stranding the ship until high water returned the following spring. In addition to the sandbars, numerous dead trees and snags washed down stream within the channel and could puncture the bottom of boats. By 1897 over 295 steamboat wrecks were recorded along the Missouri River corridor; 193 of these wrecks were caused by dead trees and snags (Chittenden 1897). Chittenden reports 11 steamboat wrecks occurred along the North Dakota segment of the Missouri River alone (Table 3–2).

TABLE 3–2.—SHIP WRECKS ALONG THE MISSOURI RIVER IN NORTH DAKOTA

Name of Ship	Year of Wreck	Location of Wreck
Abner O'Neal	1892	Painted Woods, North Dakota
Amelia Poe	1868	Near Little Porcupine Creek
Assinniboine	1835	Head of Sibley Island, North Dakota
Behan	1884	Bismarck, North Dakota
Black Hills	1884	Bismarck, North Dakota
Colonel McCloud	1879	Bismarck, North Dakota
Denver No. 2	1880	Fort Lincoln, North Dakota
Emily No. 3	1885	North of Bismarck, North Dakota
Ida Stockdale	1871	Bismarck, North Dakota

TABLE 3–2.—SHIP WRECKS ALONG THE MISSOURI RIVER IN NORTH DAKOTA—Continued

Name of Ship	Year of Wreck	Location of Wreck
Island City	1864	Below Fort Buford, North Dakota
Rose Bud	1896	Bismarck, North Dakota

Source: Captain H. M. Chittenden's Report of the Chief of Engineers, U.S. Army (1897).

By the mid 1880s, steamboat traffic ceased to exist. The completion of the transcontinental railroad and subsequent railroad branches replaced river traffic.

The early pioneer settlement of the Dakotas was directly influenced by the construction of the railroads. The Dakota Central branch of the Chicago & North Western Railroad built a track from Tracy, Minnesota to Pierre, South Dakota during 1879 and 1880. In the 1880s during the Great Dakota Boom (Robinson 1974) emigrants from Norway, Germany, Russia, along with Midwestern groups in the United States, flooded into Dakota Territory and the non-Indian population exploded with these settlers coming in (USACE 2004b). New towns, farms, and rail lines cropped up. The State's main economic base was primarily tied to agriculture.

The last major event to occur that directly impacted the Native and non-Native population living along the Missouri River was the construction of the Pick-Sloan Reservoirs. The contemporary Missouri River in North Dakota is highly modified from its natural character due to the Flood Control Act of 1944. The Flood Control Act was Federal legislation that led to the establishment of the Pick-Sloan Plan to construct six large dams on the Missouri River main stem from Nebraska to Montana. Closure of the Garrison Dam in 1953 and the Oahe Dam in 1958 and flooding the river bottom displaced thousands of people from their homes. The cultural effects on the people that lived on the river have never been adequately researched (LeBeau 1994).

Some of the historical and cultural sites that are open to tourists include Fort Union Trading Post National Historic Site, Fort Buford State Historic Site, Knife River Indian Villages National Historic Site, Fort Clark State Historic Site, Double Ditch Indian Village State Historic Site, and On-A-Slant Indian Village State Historic Site.

4.0 RESOURCE EVALUATION

4.1 Site Types and Known Resources

Berger assessed the potential types of cultural resources within Burleigh, Emmons, Mclean, Morton, Oliver, Williams, Dunn, McKenzie, Mercer, Mountrail, and Sioux Counties. The areas included USACE jurisdiction areas at Lake Oahe and Lake Sakakawea, the Standing Rock Sioux and Fort Berthold Reservations, as well as designated aggregation areas of the Missouri River corridor. File searches were conducted by USACE. File searches for private land along the main stem near the town of Washburn were conducted through the State Historical Society of North Dakota between January and March 2009. The list of legal locations encompassed by the files and literature search is included in Exhibit 1.

It should be noted that, while previous investigations have been conducted, there are portions of the project area where no surveys have been completed, particularly on private or tribal lands. Site types encountered during the records search include prehistoric sites, historic sites, multi-component sites (sites with both prehistoric and historic materials), and sites that cannot be assigned to a specific time period ("unknown").

The research conducted by USACE revealed that prior investigations have been undertaken within the aggradation areas; 148 sites have been recorded within the Lake Oahe portion of the project area, and 1,216 sites have been previously recorded within the Lake Sakakawea portion of the project area. The sites at Lake Oahe consist of 90 prehistoric, 31 historic, 17 multi-component, and 10 unknown sites. The sites at Lake Sakakawea consist of 835 prehistoric, 120 historic, 54 multi-component, 246 paleontological, and 205 unknown sites. The site information for Lake Oahe is summarized in Table 4-1. The site information for Lake Sakakawea is summarized in Table 4–2. To assist the reader, a glossary of common archaeological terms in included in Exhibit 2.

TABLE 4–1.—SITE TYPES WITH U.S. ARMY CORPS OF ENGINEERS JURISDICTION AT LAKE OAHE

Site Type	Historic	Prehistoric	Unknown	Number
Artifact Scatter			X	32
Buffalo Jump		X		1

TABLE 4–1.—SITE TYPES WITH U.S. ARMY CORPS OF ENGINEERS JURISDICTION AT LAKE OAHE—Continued

Site Type	Historic	Prehistoric	Unknown	Number
Grave Sites	....	X	X	2
Buried Bone Bed	....	X	....	3
Camp/Ceramic Site	....	X	....	1
Dam	X	....	....	1
Dugout	X	....	....	1
Earthlodge Village	....	X	....	42
Hearth/Lodge	....	X	....	13
Homestead	X	....	....	19
Military Post	X	....	....	2
Mounds	....	X	....	9
Rock Cairns	....	....	X	1
Town site	....	X	....	1
Community Center	X	....	....	1
Unknown	....	....	X	15
TOTAL	....	....	....	144

Of the 144 sites recorded at Lake Oahe, 123 sites are eligible for inclusion in the National Register, and 21 sites remain unevaluated for eligibility for the National Register.

TABLE 4–2.—SITE TYPES WITH U.S. ARMY CORPS OF ENGINEERS JURISDICTION AT LAKE SAKAKAWEA

Site Type	Historic	Prehistoric	Unknown	Number
Artifact Scatter	X	X	X	187
Buffalo Jump	....	X	....	3
Grave/Burial Sites	X	X	X	18
Buried Bone Bed	....	X	....	2
Camp/Ceramic Site	....	X	....	2
Bridge	X	....	....	2
Dugout	X	....	....	39
Earthlodge Village	....	X	....	14
Hearth/Lodge	....	X	....	2
Homestead	X	....	....	46
Military Post	X	....	....	2
Mounds	....	X	....	2
Rock Cairns	....	X	X	160
Town site	....	X	....	8
Community Center	X	....	....	1
Cemetery	X	....	....	13
Ceramic/Lithic Scatter	....	X	....	8
Church	X	....	....	1
Eagle Trap	....	X	....	31
Quarry/mine	X	....	....	4
Trail	X	....	....	1
Indian Agency	X	....	....	1
Isolated Finds	....	....	X	71
Lithic Scatter	....	X	....	249
Mission	X	....	....	1
Paleontological Localities	....	....	....	246
Post Office	X	....	....	1
Railroad Roundhouse Grade	X	....	....	1
Ranch	X	....	....	3
Sacred Object	....	X	....	1
School	X	....	....	3
Stone Circles	....	X	....	200
Stone Alignments	....	X	....	12
Teepee Rings	....	X	....	52
Trading Posts	X	....	....	3
Unknown	....	....	X	70

TABLE 4–2.—SITE TYPES WITH U.S. ARMY CORPS OF ENGINEERS JURISDICTION AT LAKE SAKAKAWEA—Continued

Site Type	Historic	Prehistoric	Unknown	Number
TOTAL				1,460

Of all sites recorded at Lake Sakakawea, the number of sites eligible for inclusion in the National Register is 22. The number of sites unevaluated for inclusion in the National Register is 1,194. (Paleontological localities are not included in the numbers.)

The Three Affiliated Tribes (Mandan, Arikara, Hidatsa) at the Fort Berthold Reservation currently does not maintain a database of sites that could be searched. Therefore, there are no numbers available to add to the site types.

The research conducted by the NDSHPO revealed that more than 70 sites have been previously recorded on private land portions subject to aggradation along the main stem of the river within the project area. This information is summarized in Table 4–3 below.

TABLE 4–3.—SITE TYPES PREVIOUSLY LOCATED WITHIN AGGRADATION AREAS ON PRIVATE LAND

Site Type	Historic	Prehistoric	Unknown	Number
Post Office	X			4
School	X			2
Church	X			2
Farmstead	X			11
Unknown Foundation	X			1
Unknown			X	4
Trading Post	X			1
Artifact (Trash) Scatter	X			4
Pump House	X			1
Bridge	X			6
Coal Mine	X			1
Stone Circles		X		5
Earthlodge Villages		X		5
Burials		X		3
Artifact Scatters		X		26
TOTAL				76

Of the 76 sites, 4 sites are eligible for inclusion in the National Register; 4 sites are ineligible for inclusion in the National Register; and 68 sites are unevaluated.

The NDSHPO lists 32 historic period context themes in the Statewide Comprehensive Plan (NDSHPO 2003). Of the 32, at least 24 are pertinent to projects that could be conducted by USACE to address siltation and erosion, as well as other projects, along the Missouri River. Historic site types, as defined by the NDSHPO (2003) that could be encountered are:

—*Bridges.*—Relates to historical and/or design, engineering and/or architectural values of bridges, grade separations, and trestles.

—*Colonization.*—Relates to the planned and organized immigration, settlement and/or resettlement of groups to, into, or within North Dakota from other areas. Groups may be religious, social, ethnic, or others, such as a Hutterite colony. Typical property types may include: towns, colonies, settlements, reservations, businesses, residences, and farms.

—*Commerce.*—Relates to the establishment, growth, and operations of the sale or exchange of goods, including banking and financial support services. Typical property types may include: trading posts, retail stores, wholesale stores, general stores, banks, savings and loan institutions, brokerage houses, mail order houses, shipping and transportation facilities, and the homes of prominent merchants, bankers.

—*Communications.*—Relates to the transmission of messages and information. Typical property types may include: pow wow sites, traditional cultural properties, newspaper offices, telegraph and telephone facilities, post offices and mail stations, post roads, radio, T.V. and microwave stations and towers.

—*Depression—The Great.*—Relates to the causes, effects of, conditions during, and/or relief and recovery from the Great Depression, 1929–1940. Typical property types may include: abandoned farms, banks, business buildings, city parks, civic improvements, relief facilities, WPA projects, Civilian Conservation Corps (CCC) camps and project sites.

—*Education.*—Relates to the organized transmission of formal knowledge, training and skills. Typical property types may include: schools, boarding schools, colleges, universities, business schools, trade schools, campuses, campus living quarters, administration buildings, and homes of prominent educators.

—*Energy Development.*—Relates to the establishment, development and use of mechanical, hydro- and electrical power sources, their generation, distribution and use. Typical property types may include: water wheels, steam and/or electrical generating and transmission facilities, dams, and power stations. This context should not include coal or petroleum production facilities.

—*Exploration.*—Relates to the exploration, discovery, recording and dissemination of information about the characteristics, attributes, and values of the State. Typical property types may include: trails, camp sites, camps, forts, battlefields, storage yards, and the residences of prominent explorers.

—*Farming.*—Relates to the establishment and operation of farms. Typical property types may include single or multiple dwellings, barns, corrals, privies, dumps, grain storage, animal shelters, indoor and outdoor storage facilities, and water sources.

—*Fur Trade.*—Relates to the establishment, operation and adaptations of the fur trade industry in North Dakota, particularly (although not exclusively) from the late 18th to the late 19th centuries. Typical property types may include, fur trading posts and forts, trails, loading and shipping facilities, trapping, trading and hunting grounds, camps and camp sites, steamboat docks, stores, dwellings, warehouses, and residences of prominent fur trade participants.

—*Government—National.*—Relates to the establishment and operation of U.S. authority over, control of, and services to the area within North Dakota's current boundaries. Typical property types will generally include: Federal Government office buildings, Federal courthouses, border stations, reservation headquarters, customs houses, and post offices, but may also occasionally include: mail stations, forts, trails, roads, highways, camps, camp sites, and dwellings.

—*Irrigation and Conservation.*—Relates to the conservation and planned use of land and water resources. Typical property types may include: historically significant shelter belts, conservation-oriented farming sites, pumping stations, water pipelines, dams, reservoirs, canals, and flumes.

—*Military.*—Relates to all aspects of the military presence in the State. Typical property types may include: forts, cantonments, posts, Air Force installations, armories, battlefields, trails, roads, bridges, fords, mail stations, cemeteries, villages, camps, camp sites, dumps, defensive works, corrals, barns, storage areas, and dwellings and residences.

—*Railroads.*—Relates to the establishment and operation of the railroad industry in North Dakota. Typical property types may include: railroad grades, bridges and trestles, depots, freight yards, switch yards, barracks, dormitories, construction yards, section houses, roundhouses, loading facilities, construction camps, trails, camps, camp sites, office buildings, warehouses, dumps, and signal devices.

—*Ranching—Fee Simple.*—Although similar to "Open Range Ranching" in general activities and products, important differences separate this context from the other. Fee Simple Ranching is characterized by the widespread use of privately owned, fenced land. Usually intended to be permanent occupants of limited space, these ranches were oriented towards continual re-use of the natural resources, perpetuation and improvement of smaller herds, were usually locally owned and financed, tended to operate on a smaller scale and remain a part of the State's agricultural economy. Typical property types may include: single and multiple unit dwellings, barns, corrals, feed lots, equipment storage yards and buildings, and wells.

—*Religion.*—Relates to the establishment and operations of religious groups and institutions. Typical property types may include: colonies, traditional cultural properties, shrines, holy places, churches, synagogues, rectories, parsonages, church schools and colleges, convents, and monasteries.

—*Roads, Trails, and Highways.*—Relates to the development and use of overland transportation systems (excluding railroads) including trails, roads, highways, automobile and truck traffic, stagecoach and bus traffic and wagon routes. Typical property types may include: trails, historically significant roads and highways, bridges, fords, stage stations, rest stops, auto dealerships, gasoline stations, freight yards, barns, relay stations, maintenance shops, dwellings, repair shops, bus depots, bus barns, and possibly camps, campsites, motels, inns, and diners.

—*Rural Settlement.*—Relates to factors that influenced (or were influenced by) settlement in rural areas including rural institutions, rural industries (except farming and ranching), ethnicity, colonization, and social institutions. Typical property types may include: churches, factories, assembly plants, brick making factories, roads-trails-highways, fords, ferries, and river crossings, cemeteries, social gathering places, rural schools, township halls, mills, forts, and railroad properties.

—*Water Navigation.*—Relates to the commercial use of North Dakota's lakes and rivers for transportation of goods and people. While focusing on the steamboat industry, the context is intended to include other forms of commercial water navigation, but to generally exclude recreational boating. Typical property types may include: steamboat docks, wharfs, piers, wood yards, ferries, storage yards, freight yards, loading facilities, wrecks or wreckage, boatyards, and dry docks.

5.0 DESCRIPTION OF IMPACTS

5.1 Current Land Use

The jurisdictional boundary of USACE is considered the shoreline along Lake Oahe and Lake Sakakawea shown in Figure 1–1. The land use around the reservoirs is primarily for USACE operations and maintenance and public recreation. Between the two reservoirs is private and tribal land. The land uses on the most of that reach of the river is agricultural, ranching, recreation, and some community facilities (e.g., Washburn).

5.2 Sources and Deposit Locations of Erosion and Sedimentation

For purposes of this assessment, the main stem of the Missouri River is divided into four segments, each of which has the potential to be affected by sedimentation and subsequent erosion. From north to south, the segments are described below.

Williston Reach

The Missouri River between the Montana border and the upstream end of Lake Sakakawea is generally referred to as the Williston reach. This approximately 60-mile section of the Missouri River is not inundated by a reservoir and the confluence with the Yellowstone River is within this reach. When this sediment load meets the slow-moving headwaters of Lake Sakakawea, it settles out and forms a delta.

Lake Sakakawea

Lake Sakakawea is a reservoir of approximately 286 kilometers in length (Galat et al., 1996). It has a delta that is 61 kilometers in length, formed by the deposition of sediment from the Williston reach (Galat et al. 2005). Sakakawea's waters are colder, clearer, deeper, and more hydrologically stable than what they would have been prior to the construction of the dam.

Garrison Reach

Aside from the Williston reach, the Garrison reach, is the only other section of the river in North Dakota that is not inundated by a reservoir. However, this approximately 80-mile reach is controlled by releases from Garrison Dam. The Garrison reach between Garrison Dam and the headwaters of Lake Oahe is relatively deprived of sediment because of the retention of sediment in Lake Sakakawea. Major sources of sediment in this reach come from tributaries, not from the upstream segments; among these tributaries, the Heart River is the most important contributor of sediment (MacekRowland 2000).

Lake Oahe

Lake Oahe, formed by the Oahe Dam in South Dakota, is the longest of the six Pick-Sloan Reservoirs, 372 kilometers in length (Galat et al. 1996). Sediment import from the Garrison reach forms a delta 103 kilometers in length (Galat et al. 2005). Only a third of Lake Oahe is located within North Dakota, with the remainder in South Dakota. Recent drought conditions have changed the upstream reservoir sections from flat water (typically at elevations above 1,600 to 1,608 feet msl) to riverine characteristics that could affect cultural resource sites that are exposed from falling water levels.

In the *Identification of Sources and Deposits and Locations of Erosion and Sedimentation* report prepared for the USACE, Berger (2008) found that:

—The majority of the identified aggradation areas were located upstream of Lake Sakakawea in the close vicinity to the Montana/North Dakota border and in the vicinity of watersheds that showed large amounts of delivered land-based sediments. It appears that the largest delivered sediment load originates from Montana. The area between Garrison Dam and Lake Oahe showed only one aggradation area. Potential sources for sediment deposition were sediment erosion from upstream and surrounding watersheds that have high potential of delivering sediments.

—Areas that showed little or no aggradation were generally located within the center of lakes (Lake Sakakawea and Lake Oahe), the majority of the section between Garrison Dam and Lake Oahe, and in the vicinity of watersheds that delivered considerable less sediment.

5.3 Impacts on Indian and Non-Indian Sites

According to USACE and NDSHPO records of known Indian and non-Indian sites along the reservoirs and main stem of the river within potential areas of aggradation and erosion, USACE and other researchers have recorded erosion, inundation, bioturbation, and effects of farming, construction, and vandalism. Table lists observations of impacts at Lake Oahe, and Table lists observations at Lake Sakakawea.

TABLE 5–1.—IMPACTS OCCURRING ON SITES AT LAKE OAHE

Impacts	Number of Sites Impacted
Cut bank Erosion	34
Unspecified Erosion	7
Shoreline Erosion	7
Complete Inundation	10
Partial Inundation	7
Periodic Inundation	8
Decay/weathering	2
Razed	10
Cultivation	22
Bioturbation	1
Recreation	2
Railroad Construction	2
Vandalism/unauthorized Collection	3
Vehicular Movement	8
Unknown	7
TOTAL	130

TABLE 5–2.—IMPACTS OCCURRING ON SITES AT LAKE SAKAKAWEA

Impacts	Number of Sites Impacted
Cut bank Erosion	74
Unspecified Erosion	111
Shoreline Erosion	108
Complete Inundation	85
Partial Inundation	8
Periodic Inundation	12
Siltation/buried	59
General Disturbance	19
Absent	139
Authorized Archaeological Collection	22
Grazing	51
Deflation	8
Development	1
Decay/weathering	29
Razed	14
Cultivation	68
Landscape Construction	11
Military Activity	7
Moved	3
Overgrown	23
Bioturbation	24
Recreation	95
Railroad Construction	15
Vandalism/Unauthorized Collection	13
Vehicular Movement	83

TABLE 5–2.—IMPACTS OCCURRING ON SITES AT LAKE SAKAKAWEA—Continued

Impacts	Number of Sites Impacted
Other	28
Unknown	93
TOTAL	1,203

Natural or human-caused impacts to Indian and non-Indian sites can be direct or indirect.

Direct Impacts.—Those impacts that would be caused by deposition of silt and sediment, flooding, erosion caused by waves or changes in reservoir levels, and ground surface disturbance during construction projects associated with siltation remediation (such as rip-rap placement).

Indirect Impacts.—Those impacts that would be caused by factors associated with increased agency, tribal, or public access to site locations. These could include inadvertent ground disturbance, vandalism, or changes to the viewshed.

Several studies of the effects of reservoir construction and inundation of cultural resources have been conducted (e.g., Carrell et al. 1976; Adivasio 1980; Lenihan et al. 1981a, 1981b; Fairley 2003). There are four basic reservoir areas that are important to understanding effects to cultural resources (USACE 2002): (1) The Inundation Zone—the main body of water making up a reservoir excluding its lateral edges; (2) Zone of Fluctuation—the reservoir area where water levels range between high water to low water marks and includes land not always under water; (3) Zone of Direct Impact—the reservoir area where cultural resources are located and potentially in contact with water levels; and (4) Zone of Indirect Impact—the land adjacent to a reservoir that is not exposed to inundation.

The impacts of siltation and erosion on cultural resources occur in the Inundation Zone, Zone of Fluctuation, and Zone of Direct Impact, while (as expected) indirect impacts occur most frequently in the Zone of Indirect Impact.

While siltation can effectively and beneficially protect and preserve some sites, such as subsurface archaeological sites, often the subsequent wind or water erosion is destructive. Recent drought conditions have resulted in lower than normal lake levels in Lake Oahe changing the upstream character of the reservoir from a reservoir to that of riverine character. Of particular concern is cut bank erosion. Archaeological sites and historic structures along reservoir and river banks can slowly or drastically erode away as the shoreline erodes. Indian and other ethnic group traditional use or ceremonial areas, also known as TCPs, can be affected by both siltation (covering the resource or area) and erosion (depleting the resource or area). Other factors potentially destructive to cultural resources are agricultural and grazing leases close to the USACE jurisdictional boundary (Gilbert personal communication 2009). Because Indian and non-Indian sites resources are non-renewable resources, almost all impacts as a result of siltation and erosion are considered adverse or negative. In cultural resource terms, the integrity, or composition and cohesiveness, of a site is crucial to a site's significance and intrinsic value to understanding our history or prehistory. The magnitude of the impact to the integrity of a site can vary from minor (e.g., artifact displacement resulting from sediment movement) to substantial (e.g., complete removal of a stone circle, stone cairn, or structural foundation resulting from an erosion event).

6.0 SUMMARY AND RECOMMENDATIONS

Cultural resources are considered a non-renewable resource that can be lost forever when destroyed. For Indian and non-Indian historical and cultural sites, the primary recommendation is to provide mitigation of impacts resulting from the cycle of siltation and erosion. Mitigation is defined as avoiding or lessening impacts to significant resources. Mitigation measures for the types of adverse impacts listed in Section 5.3 can range from cultural resource inventories, to regular periodic monitoring of known sites, to full-scale excavation and data recovery. Measures to be taken would depend on the type, context, character, setting, size, complexity, and other characteristics of the individual resources. Cultural resource inventory projects identifying surface sites, features, and standing structures are usually considered short-term measures, although pedestrian surveys may need to be repeated as environmental or site conditions change over time. Other more long-term measures can consist of fencing for avoidance, monitoring during ground-disturbing activities, and stabilization of stream banks or building foundations.

Long-term, periodic monitoring of the condition of surface and subsurface cultural resources should be done by prehistoric or historical archeologists. Monitoring of standing structures should be done by architectural historians. Should full-scale excavation be needed to retrieve scientific data that are in danger of being lost from development or fluctuation of water levels, the duration would depend on the surface extent and depth of the cultural material; in other words, how big is the site and how deep does it extend below the ground surface? This would be considered a short-term project compared to monitoring. All work should be performed by specialists whose credentials meet or exceed the Secretary of Interior's Professional Qualifications Standards.

Table 6–1 and Table 6–2 list future actions and mitigation measures recommended in the USACE site database for known Indian and non-Indian sites at Lake Oahe and Lake Sakakawea.

TABLE 6–1.—RECOMMENDATIONS BY THE U.S. ARMY CORPS OF ENGINEERS AT LAKE OAHE

Recommendation	Number of Sites
Monitor at Low Water Levels	4
More Research Required	1
Test for NRHP Eligibility	62
Re-evaluate Site	9
No Further Work Needed—Completely Inundated	10
No Recommendation Available	18
Other (Unspecified)	17

TABLE 6–2.—RECOMMENDATIONS BY THE U.S. ARMY CORPS OF ENGINEERS AT LAKE SAKAKAWEA

Recommendation	Number of Sites
Monitor at Low Water Levels	2
Monitor for Erosion and Vandalism	35
More Research Required	3
Protect or Mitigate	39
Test for NRHP Eligibility	140
Re-evaluate Site	840
No Further Work Needed—Completely Inundated	79
No Recommendation Available	64
Other (Unspecified)	14

A further recommendation would be to prepare a regional research design for the study of cultural resources as was done for the Colorado River in Arizona (Fairley 2003). The purpose of the design would be to guide future research at Indian and non-Indian historical and cultural sites affected by the Missouri River in North Dakota. The objective would be to provide a framework for management and treatment of cultural resources under the jurisdiction of USACE.

Table 6–3 contains a summary of impacts, a timeline, and recommendations for managing Indian and non-Indian sites along the Missouri River in North Dakota.

Some of the recommendations can be implemented by various parties of the Task Force. For example, the State of North Dakota can conduct public education on the importance of preservation of historical and other cultural sites, which can help prevent intentional and unintentional vandalism. Local and private recreational entities can construct and operate facilities with respect for historical and cultural sites along the river. The Standing Rock Sioux Tribe and the Three Affiliated Tribes can continue to monitor archaeological sites and other sensitive areas that are in danger from siltation and erosion. The USACE can limit the range of agricultural and grazing leases to avoid sensitive areas.

These recommendations can be promoted by all members of the Task Force. Appreciation and understanding of the non-renewable nature of cultural resources is the key to managing cultural resources. All parties can be included as stakeholders in the development of a research design and plan for the treatment of Indian and non-Indian historical and cultural sites.

TABLE 6–3.—SUMMARY OF IMPACTS AND RECOMMENDATIONS

Impact	Significance	Timeline	Recommendation
Inundation (partial, periodic, complete)	Substantial	Long-term—for life of jurisdiction	Monitorat low water levels; data recovery as needed
Erosion (cut bank, shoreline, general)	Substantial	Long-term—for life of jurisdiction	Monitor for erosion; stabilize if needed; data recovery as needed
General Disturbance	Moderate	Long-term—for life of jurisdiction	Monitor; data recovery as needed
Agriculture	Minor—Moderate	Long-term—for life of lease	Protect or mitigate with fencing, testing, or data recovery
Grazing	Minor—Moderate	Long-term—for life of lease	Protect or mitigate with fencing, testing, or data recovery
Construction	Substantial	Short-term—up to 1 year as project progresses	Protect or mitigate with fencing, testing, or data recovery
Recreation	Moderate	Long-term—for life of jurisdiction	Monitor for activity and vandalism; fence as needed
Vandalism	Moderate	Long-term—for life of jurisdiction	Monitor for activity and vandalism; fence as needed
All	Minor—Substantial	Short-term (1 to 5 years)	Prepare research design for cultural resources along the Missouri River in North Dakota

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EXHIBIT 1—LEGAL SECTIONS IN FILES AND LITERATURE SEARCH

The research area search encompasses all or parts of the following sections:
Township 130N Range 80W Sections 1, 3, 10–15, 22–26
Township 130N Range 79W Sections 19, 30, 31
Township 137N Range 80W Sections 16, 17
Township 137N Range 79W Sections 7, 8, 18
Township 134N Range 79W Sections 2, 11
Township 153N Range 102W Sections 9–30, 33–36
Township 152N Range 102W Sections 5, 6
Township 153N Range 103W Sections 24
Township 154N Range 101W Sections 21–24, 28, 29
Township 153N Range 102W Sections 12, 13, 24, 25, 36
Township 153N Range 101W Sections 18, 19, 30
Township 154N Range 100W Sections 19, 29
Township 154N Range 97W Sections 2, 3, 10, 11, 14, 15
Township 155N Range 96W Sections 31, 32
Township 154N Range 96W Sections 2–10, 15–18, 20
Township 154N Range 97W Sections 1, 2, 11–14
Township 155N Range 97W Sections 36
Township 154N Range 96W Sections 1–3, 11–13
Township 154N Range 95W Sections 18
Township 154N Range 94W Sections 32–35
Township 154N Range 94W Sections 36
Township 144N Range 83W Sections 13, 14, 22–27, 34, 35
Township 144N Range 82W Sections 8, 9, 18–30, 33–36
Township 143N Range 82W Sections 1, 2
Township 144N Range 81W Sections 29–32
Township 143N Range 81W Sections 6
Township 134N Range 79W Sections 14, 15, 23, 26, 35, 36
Township 133N Range 79W Sections 1, 2, 12, 13, 24–26, 34, 35
Township 132N Range 79W Sections 4, 5, 9, 16
Township 131N Range 79W Sections 7, 18
Township 131N Range 80W Sections 12–14, 23–25, 35, 36
Township 132N Range 79W Sections 15, 16, 28, 32, 33
Township 131N Range 79W Sections 5, 7, 8, 18
Township 131N Range 80W Sections 35, 36
Township 130N Range 80W Sections 1–3, 10–15, 22–26, 36
Township 130N Range 79W Sections 6, 7, 18, 19, 30, 31
Township 129N Range 80W Sections 1
Township 129N Range 79W Sections 4–6, 8–10, 14, 15, 22, 23, 25–27, 35, 36
Township 152N Range 93W Sections 9, 11, 14–16, 20–23, 27–33
Township 151N Range 93W Sections 5–8, 16–20, 30, 31
Township 151N Range 94W Sections 25, 26, 35, 36
Township 151N Range 93W Sections 30, 31
Township 150N Range 92W Sections 13, 14, 23–26, 35, 36
Township 150N Range 91W Sections 18, 19, 30–32
Township 149N Range 92W Sections 1, 2
Township 149N Range 91W Sections 6
Township 148N Range 91W Sections 14–17, 20–23
Township 148N Range 90W Sections 20–23, 27–29

EXHIBIT 2—GLOSSARY OF ARCHAEOLOGICAL TERMS

Analysis.—The process of studying and classifying artifacts, usually conducted in a laboratory after excavation has been completed.

Archaeology/archeology.—The scientific study of past human cultures by analyzing the material remains (sites and artifacts) that people left behind.

Archaeological Site.—A place where human activity occurred and material remains were deposited.

Artifact.—Any object made, modified, or used by people.

Assemblage.—Artifacts that are found together and that presumably were used at the same time or for similar or related tasks.

Attribute.—A characteristic or property of an object, such as weight, size, or color.

B.P.—Years before present; as a convention, 1950 is the year from which B.P. dates are calculated.

Ceramic.—Pottery, fired clay.

Chronology.—An arrangement of events in the order in which they occurred.

Classification.—A systematic arrangement in groups or categories according to criteria.

Context.—The relationship of artifacts and other cultural remains to each other and the situation in which they are found.

Culture.—A set of learned beliefs, values and behaviors—the way of life—shared by the members of a society.

Debitage.—The by-products or waste materials left over from the manufacture of stone tools.

Diagnostic Artifact.—An item that is indicative of a particular time period and/or cultural group.

Excavation.—The systematic digging and recording of an archaeological site.

Experimental Archaeology.—Scientific studies designed to discover processes that produced and/or modified artifacts and sites.

Feature.—A type of material remain that cannot be removed from a site such as roasting pits, fire hearths, house floors or post molds.

Grid.—A network of uniformly spaced squares that divides a site into units; used to measure and record an object's position in space.

In Situ.—In the original place.

Level.—An excavation layer, which may correspond to natural strata. Levels are numbered from the top to bottom of the excavation unit, with the uppermost level being Level 1.

Lithic.—Stone, or made of stone.

Material Remains.—Artifacts, features and other items such as plant and animal remains that indicate human activity.

Midden.—An area used for trash disposal.

Post Mold/Post Hole.—A type of feature; a circular stain left in the ground after a wooden post has decayed; usually indicates the former existence of a house or fence.

Pot Sherd.—A piece of broken pottery.

Prehistoric.—The period of time before written records; the absolute date for the prehistoric period varies from place to place.

Projectile Point.—A general term for stone points that were hafted to darts, spears or arrows; often erroneously called "arrowheads".

Rock Art.—A general term for pecked, incised, or painted figures on rock.

Site.—A place where human activity occurred and material remains were deposited.

Site Steward.—A volunteer who visits a site and helps protect it form vandalism and looting.

Strata.—Many layers of earth or levels in an archaeological site (singular stratum).

Stratigraphy.—The layering of deposits in archaeological sites. Cultural remains and natural sediments become buried over time, forming strata.

Survey.—The systematic examination of the ground surface in search of archaeological sites.

Test pit.—A small excavation unit dug to learn what the depth and character of the stratum might be, and to determine more precisely which strata contain artifacts and other material remains.

EXHIBIT 3—ENVIRONMENTAL COMPLIANCE REQUIREMENTS

There are several statutes, regulations, executive orders, and Department of Defense regulations, USACE policies and procedures that require USACE to take into account the effects of a proposed action or program on cultural resources. These include, but are not limited to:

—National Historic Preservation Act (NHPA), 1966
—Advisory Council on Historic Preservation (ACHP)—Protection of Historic Properties—36 CFR 800
—Native American Graves Protection and Repatriation Act (NAGPRA), 1990
—American Indian Religious Freedom Act (AIRFA), 1978
—Archeological Resources Protection Act (ARPA), 1979
—Executive Order 11593—Protection and Enhancement of the Cultural Environment, 1971
—Executive Order 13007—Sacred Sites, 1996
—Executive Order 13175—Consultation and Coordination with Indian Tribal Governments, 2000
—National Environmental Policy Act of 1969 (NEPA)
—Archeological and Historic Preservation Act of 1974 (AHPA), amending Reservoir Salvage Act of 1960
—Abandoned Shipwreck Act of 1987
—Army Regulation (AR) 200–4 Cultural Resources Management
—USACE Rules and Regulations Governing Public Use of Water Resources Development Projects—36 CFR 327

Compliance with the above listed items ranges from inventory and consideration of cultural resources (Indian and non-Indian) by Federal agencies in project planning to monetary fines for destruction, theft, or vandalism of cultural sites.

Mr. GUNSCH. Just a couple following examples taken from this report and tables are attached to my testimony.

Table 2.13, the Flood Plain Area Comparison, the difference between the 1985 and the 2005 mapping which showed an increase in flooding within the Bismarck city limits from 2.7 to 3.6 square miles. And within Burleigh County it increased from 28 to 36 square miles which is an increase of 28.6 percent. That is concerning.

Appendix F is impacts of siltation on flood control.

Table 3.1 Flood Elevation Comparison, that goes back to the elevations I discussed earlier on the increases in elevations which in the Fox Island area between that 17 year period was about a foot. So the base flood elevations have increased significantly.

The question at this point is what can be done? Interestingly enough there's been a review of the Berger Report. Table 7 includes recommendations for addressing sedimentation impacts along the Missouri River in North Dakota under flood risks. In the Bismarck/Mandan area there are four key items.

I have listed them.

Their tradeoff analysis of the flood control is basically development restrictions or flow restrictions.

No. 2, study impacts of sedimentations of flood risk when the Oahe reservoir is full.

Three is develop strategies for mitigating ice affected flooding exacerbated by sediment deposition at the headwaters of Lake Oahe.

Four is conducting debris and snag removal in the Heart River confluence area.

The timeframe to complete these project study items ranges from short term to 3 to 5 years with a total cost combined for all of them is between $2 and $4.2 million. These are not inclusive of the elements that are currently being reviewed by the Water Resource Districts. Therefore additional costs remain to be identified.

The fourth item on that particular table study list had to do with the conducting removal of debris and tree or dead fall trees in the Heart River area. The remnants from that 2009 flood will become increasingly more difficult to remove once they're entrapped by additional river sediments. A flood hazard mitigation grant was filed or an application was filed with the North Dakota division of Emergency Management in July 2009. And the estimated costs of that work was about $430,000. We've included a copy of the risk assessment for that particular project as part of our testimony.

[The information follows:]

MISSOURI RIVER FLOOD HAZARD MITIGATION—BISMARCK/MANDAN PROJECT SUMMARY AND RISK ASSESSMENT—DEADFALL TREE REMOVAL GRANT APPLICATION

PROJECT DESCRIPTION

The deposition of fallen trees (deadfall) within the bed and along the banks of the Missouri River, during the April 2009 flood event, represents a significant increase in the potential flood hazard in this reach. These trees were carried into and deposited within the river channel as a result of significant bank erosion, channel shifts and ice flows. They range from 18 inches to 48 inches in diameter and from 20 to 60 feet in length. The number of deadfall trees varies by location, but they are heaviest on the upstream edge of existing or newly formed sandbars, along the eroded river banks lined with native forest, and along the shallower channel areas.

In addition to the deposition of the deadfall trees the 2009 flood resulted in the deposition of a significant amount of sediment generated by the Heart River, bed and banks of the Missouri River and other upstream tributaries. Some of these sand bars represent new deposition, while existing sandbars were increased in both elevation and width.

Since the deadfall trees are large and numerous, given projected river flows as well as the high Oahe Reservoir elevation, it is unlikely they will be transported downstream by normal runoff. As a result they represent a considerable and avoidable risk for the continued accumulation of sediments downstream from the Heart River confluence. This is commonly referred to as the Oahe Delta and was the location of the 2009 ice jam that flooded South Bismarck, Fox Island and areas with the city of Mandan. The net effect of these trees is much like that of a snow fence as waters continue to flow around them and sediment deposition increases. Once these trees are submerged by sediment they become entrapped, semi permanent and will not move downstream without significant shifts in the river channel. In addition the sediments they collect will also not be flushed downstream into the Oahe Reservoir.

Additional depths from 2 to 3 feet are anticipated to occur within these areas, which will result in a measurable reduction in the available floodway conveyance within the Missouri River channel. This additional deposition will eventually convert the character of the new sand bars from unvegetated to vegetated, and then from vegetated to vegetated, with extended trees and brush. This sandbar growth, which again is part of the Oahe Delta formation, will then further restrict open channel conveyance thus creating shallower areas. During winter and spring flows this significantly increases the risk for ice jams resulting in potential for backwater flooding and bank erosion.

The location of the Oahe Delta within the Missouri River Floodway creates a number of primary flood hazards. The first is a continuing increase in the Base Flood Elevation (BFE) on the Missouri River and the associated flood risks in South Bismarck, Fox Island Area and the city of Mandan. The increase in BFE from 0.8 to 1.0 foot between the 1985 and 2005 FIRM's documents this situation and raises significant concern. The additional sediment deposited by the 2009 flood has compounded this increase, though an evaluation of the extent of this impact remains to be quantified.

A second significant hazard is the blocking of the Heart River's confluence into the Missouri River and the increased risk for localized ice jams in this area. Such ice jams pose a risk not only to create upstream backwater flooding, but also impacts to and the potential failure of the Heart River levee system protecting the city of Mandan. While the risk of a given event occurring during the current blockage by sediment and trees might be probability based it cannot be taken lightly given recent events. Subsequently, proactive action is necessary to alleviate and mitigate this known flood hazard.

A third hazard is the substantial growth of new and existing sandbars within the Missouri River channel and floodway that restrict not only the flow of open water, but increase the risk for ice jams. The 2009 ice jam occurred within the first 2 miles south of the Heart River confluence and was caused by a combination of factors.

One was the restriction of flows within the Missouri River channel due to existing sandbars and new sediment deposited by the event itself. Any additional restriction of the channel conveyance by trees and further sediment deposition needs to be addressed in a timely manner.

After reviewing the extent and nature of the debris deadfall trees and sediment deposition within the bed of the Missouri River south of the Heart River Confluence consideration was given to the need to remove and dispose of these trees. The future removal of the prior and recent sediment deposition within this area is being addressed separately and is not included in nor part of this application.

When considering the project scope several factors had to be weighed as they relate to direct or indirect impacts and flood hazards. Generally the primary impact area for deadfall trees is located within a few miles of the Heart River confluence, Missouri River Mile 1311.5 to 1307. The deadfall in this reach has the greatest potential to increase the risk and frequency of ice jams and backwater flooding. Areas further south, while having an impact on the overall growth and expansion of the Oahe Delta, were not deemed as critical as this southern area is located more in the headwaters of the Oahe Reservoir. In addition deadfall trees located along the eroded shoreline were excluded from the proposed removal project as they are presently acting as a buffer and natural stabilization measure to limit future bank line losses.

PROJECT PURPOSE

The proposed project is located entirely within the Missouri River floodway. Its purpose is to prevent the future deterioration and loss of flow conveyance associated with the deadfall trees and future sediment accumulations. The project requires the collection, cutting, loading, hauling and disposal of deadfall trees at an offsite location. The removal process requires the contractor to use several barges and a tug boat to haul equipment along the river channel and onto the sandbars to collect, cut, load and haul deadfall trees to an area where they would be transported to a disposal site. The deadfall trees within the river would be loaded by crane onto the barge or towed upstream using the tugboat to an off load point along the river bank. The larger deadfall on the sandbars would be cut into sections suitable for collection then loaded onto the barge for transport and disposal.

Both aerial and ground photos were taken to document the approximate location and extend of deadfall trees within and along the river. A ground survey was then completed to document the location and general size distribution of the deadfall trees and provide an indication as to the approximate number that need to be removed, which is necessary to determine the opinion of probable cost. A photo record of the areas of concern and typical situations is included in this project summary.

OPINION OF PROBABLE COST

The Opinion of Probable Cost (OPC) to remove the deadfall trees was determined based on the number of trees to be removed, their location and the equipment and time required. Based line cost data was gathered from various contractors who have completed similar work. This cost opinion was then completed using the best available data at the time this application was prepared. Bidding and contracting for this work has the probability of resulting in either higher or lower costs depending upon a number of factors including, but not limited to, economic conditions, time of work, and contractor availability. The OPC for this project is approximately $430,100 or roughly an average of $3,162 per deadfall tree.

BENEFIT—COST RATIO DETERMINATION

The development of a benefit to cost ratio to justify the mitigation funds required a certain amount of generalization and estimation of present values. First, the risk for ice jams varies from year to year and is based on a number of climatic factors and the probability for various stream flows. Since the probability for such an event exists in any given year it is assumed that flood flows can and will occur, therefore waiting to mitigate avoidable damages is not an acceptable option.

The basis for benefits provided by the deadfall tree removal is measured in two separate ways, which are cumulative. First, is to avoid further losses in channel conveyance associated with the accumulation of sediments over, around and downstream from the deadfall trees. Second, is to avoid the expenditure of public and private resources to fight an ice jam flood event resulting from this additional sediment accumulation.

The continued sediment accumulation increases the potential frequency for ice jam and higher flood events. The cost to remove these deadfall trees also increases dramatically if they are covered or entrapped in future sediment deposition. These additional sediments would have to be removed to access these trees; therefore removal of these materials is necessary not only to access the trees to prevent future deposition but to restore the lost channel conveyance. The value of not having to remove these sediments in the future is deemed a present value benefit of the removal project. The removal costs are based on the use of a hydraulic dredge to avoid the placement or relocation of fill materials within the Missouri River Floodway. Discharge, disposal and storage of these materials most likely would occur on the left bank on properties owned by the State of North Dakota.

The present value benefit associated with the deadfall tree removal was determined based on the projected cost to hydraulically dredge the projected accumulated sediments associated with the tree's location within the river. Utilizing an approximation of the aerial extent and depth of sediment deposition over, around and downstream from an average size tree it was determined that from 300 to 400 Cubic Yards of material would be captured by each. While this could occur in 1 year or over a period of years the net accumulation was totaled for removal based on a present day cost per cubic yard. The benefit is provided by the removal of the deadfall trees before these sediments accumulate. The present value cost is based on a projection of approximately 125 sites, 350 CY per site, and $17 per cubic yard for sediment removal.

Sediment Removal Benefit—$743,750

A 10-year event is used to define the present value cost to defend the communities against an ice jam flood, which is a flow rate of 68,500 cfs on the Missouri River below the Heart River confluence. Estimates of the actual 2009 flood flow vary, but likely ranged from 80,000 cfs to 90,000 cfs. It is projected that currently a major ice jam during the 10 year flood event could result in similar impacts, or the expenditure of resources as the 2009 flood. The cost to defend against an ice jam event flood varies dependent upon its location, nature, extent and duration. For the purposes of this assessment it is deemed that the general preparedness and resources necessary to battle a similar event are a reasonable basis for projecting the present value cost for the flood hazard. It is not specifically known if the ice jamb event could result from existing sediment deposition without the removal project; however, the additional accumulation will measurably increase the current flood hazard. A current conditions analysis is unavailable.

Based on contacts with the city of Bismarck, city of Mandan, the Burleigh and Morton County Emergency Managers, and the North Dakota National Guard we were able to obtain the following estimated public costs associated with the 2009 flood event. The figures provided are for reimbursable expenses only and do not include employee or staff time, or private property financial impacts.

PUBLIC RESOURCE COST—2009 FLOOD EVENT

	Amount
City of Bismarck—Tabulation of FEMA Reimbursable Expenses	$464,000
City of Mandan (estimated)	200,000
North Dakota National Guard—Ice Jam Demolition	80,000
Total	744,000

The private cost to defend against the 2009 event or damages incurred were not readily available, from the sources contacted, at the time this application was completed.

Private Costs (Undetermined)—$ Unknown

Both the Public and Private costs are additive utilizing a 10-year timeframe the probability of a 10 year event occurring within the next 10 years is approximately 39 percent. Therefore, the following is the projected present value benefit of the project:

Public resource Benefit—$744,000 × 0.39 = $290,160

BENEFIT—COST SUMMARY

	Amount
Total Present Value Benefit:	
Public Resources Benefit	$290,160
Private Resources Benefit	([1])

BENEFIT—COST SUMMARY—Continued

	Amount
Sediment Removal Benefit	743,750
Total	1,033,910
Total Present Value Costs:	
Projected Deadfall Tree Removal and Disposal	430,100

[1] Undetermined.

Combined B/C Ratio $1,033,910/$430,100 = 2.40:1

SUMMARY NOTES

The B/C ratio does not include the private benefits associated with avoidance of damages associated with an ice jam flood event. Inclusion of this figure would further increase the B/C ratio.

The B/C ratio does not include the lost Federal hydropower revenues associated with the need to cut releases during an ice jam event or the restricted flows under the ice due to the existing and future sediments. These costs were not quantified as part of this evaluation.

The projected costs are based on early projections of time and materials required to complete the project. Additional evaluation and design may result in savings once the plans and specifications have been completed.

ACKNOWLEDGMENTS OF DATA SOURCES

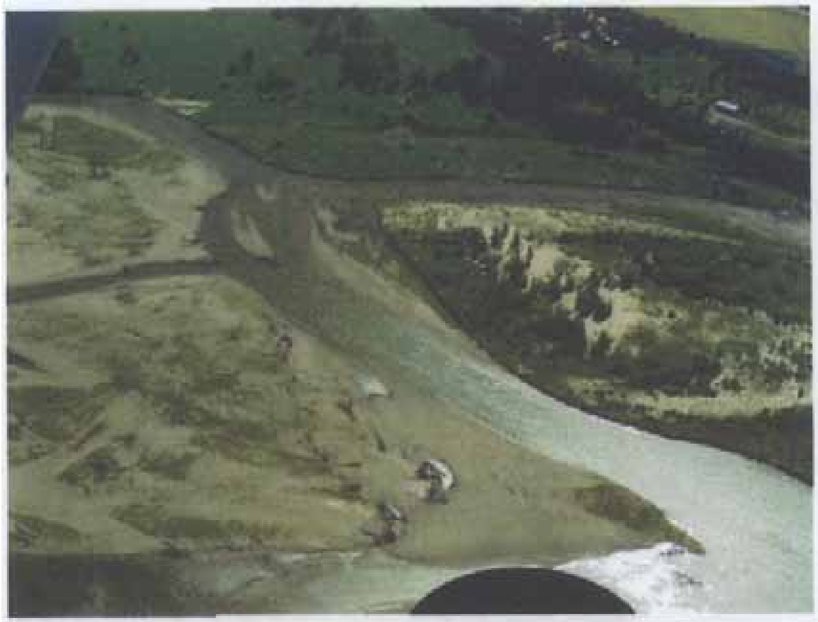
Dale Frink, PE, North Dakota State Engineer
North Dakota State Water Commission
Burleigh County WRD
Morton County WRD
Lower Heart WRD
City of Bismarck
City of Mandan
Burleigh County Emergency Management
Morton County Emergency Management
Square Butte Dredging, Morton County—Hydraulic Dredging Cost Data
Ron Sando, PE, Engineering Consultant
Adventure Divers, Inc, Minot North Dakota—Construction Cost Data
Corps of Engineers—Bismarck Regulatory Office
USFWS—Threatened and Endangered Species Data
NDGF—Enforcement Division

Heart River Confluence – Right Bank of Missouri River
Missouri River Mile (MR ~1311)

Heart River Confluence – Sediment and trees at outfall
Looking west at right bank

New sandbars and deadfall trees MR ~ 1310.8 Right Bank

Existing sandbar and deadfall trees MR ~ 1309.8 Right Bank



Existing sandbar and deadfall trees MR ~ 1309 Right Bank

Existing sandbar and deadfall trees MR ~ 1308.5 Right Bank

Southern End of Penitentiary Property
Bank erosion and tree loss
MR ~ 1308.5 Left Bank looking northeast

Expanded Sandbar south of Sibley Island
MR ~ 1308.5 Left Bank looking north
South end of Washington Street

Expanded Sandbar south of Sibley Island
MR ~ 1308.5 Left Bank looking northwest

Looking northwest and upstream toward the
Missouri River Correctional Center (MRCC)
New sandbars on right side (south) of river MR ~ 1308

New sandbar and deadfall trees south of MRCC Property
MR ~ 1308.5 Right Bank

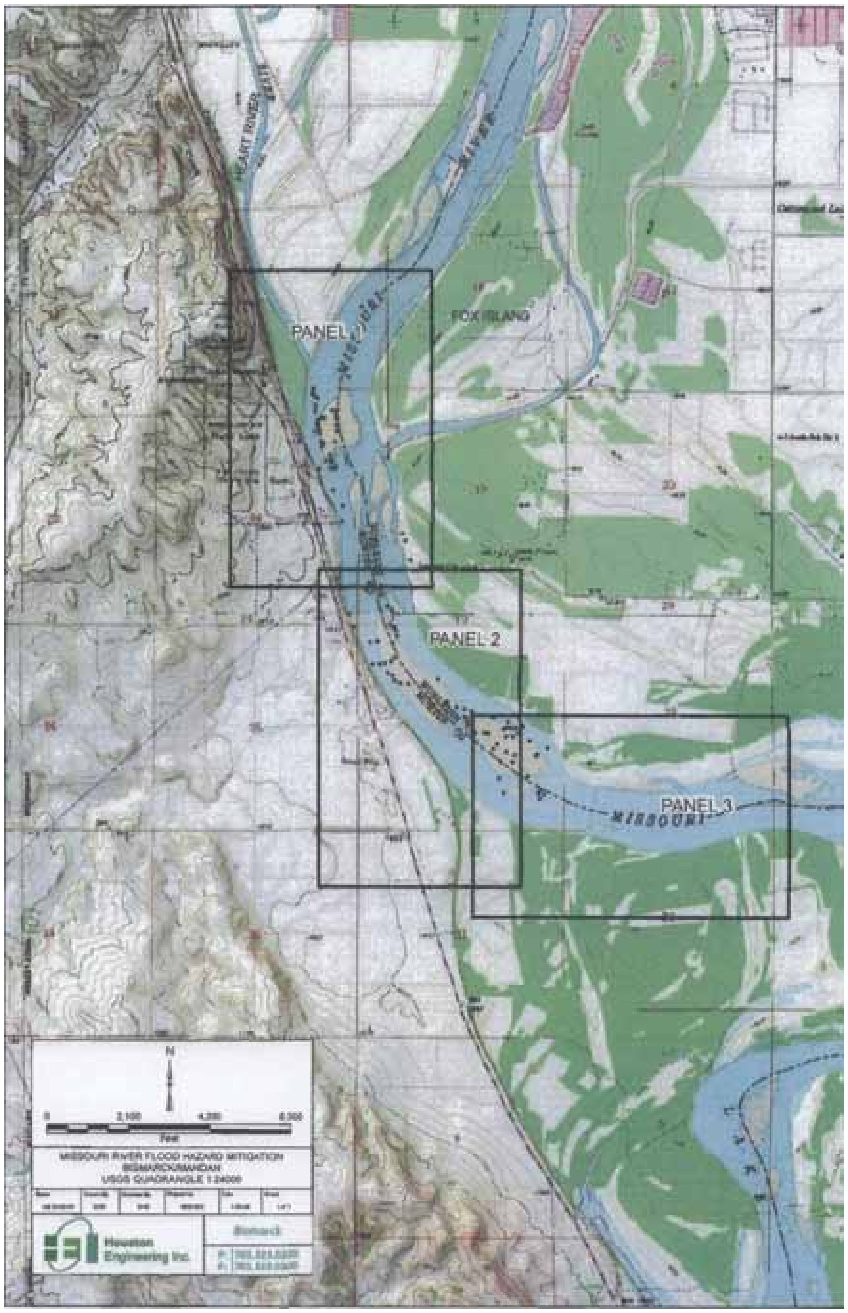
Typical deadfall tree on new deposition sandbar
Note branches and root ball

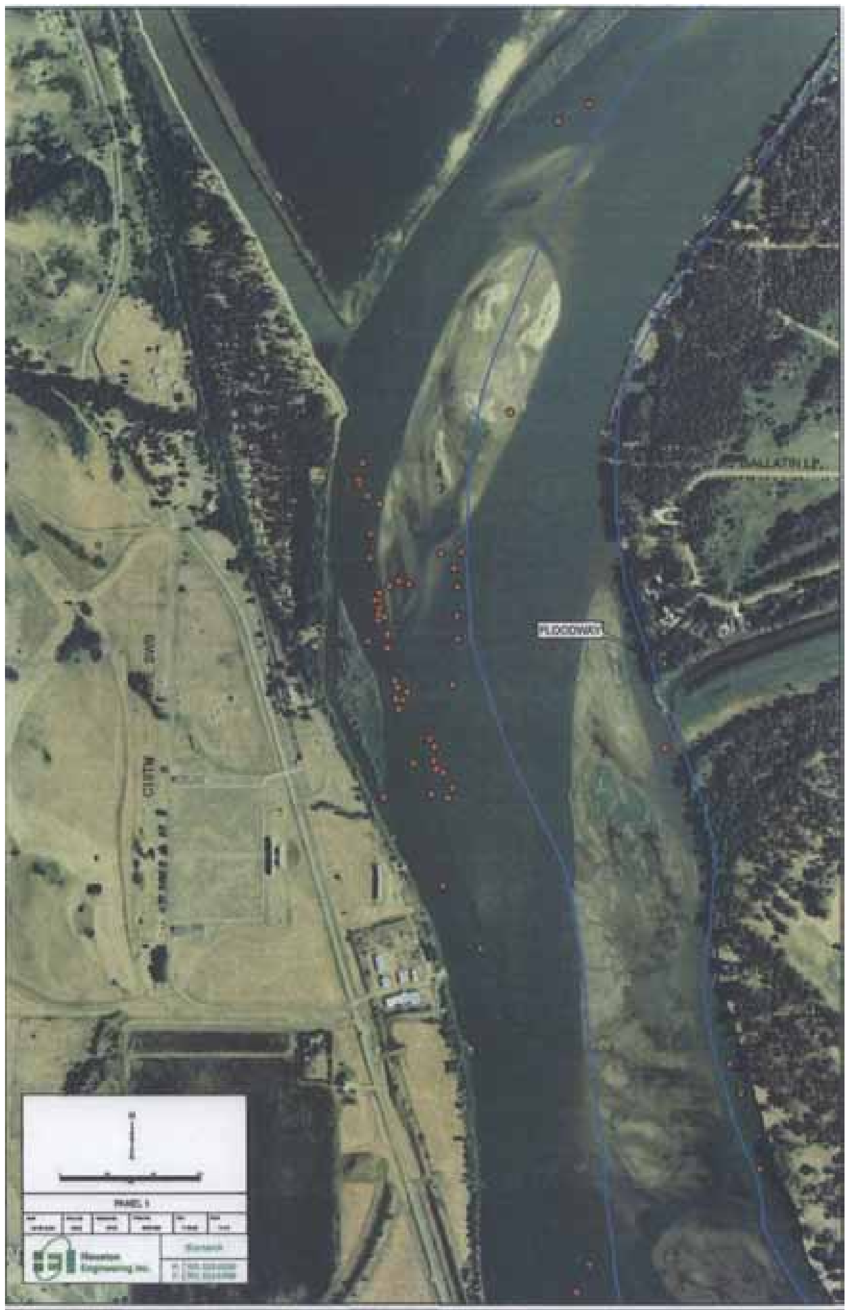
Typical river condition of deadfall tree
Trapped in place by shallow water

Typical bunched deadfall trees trapped on sandbar
Note branches and root ball

Typical deadfall on vegetated sandbar
Note the new sediment deposition that has occurred

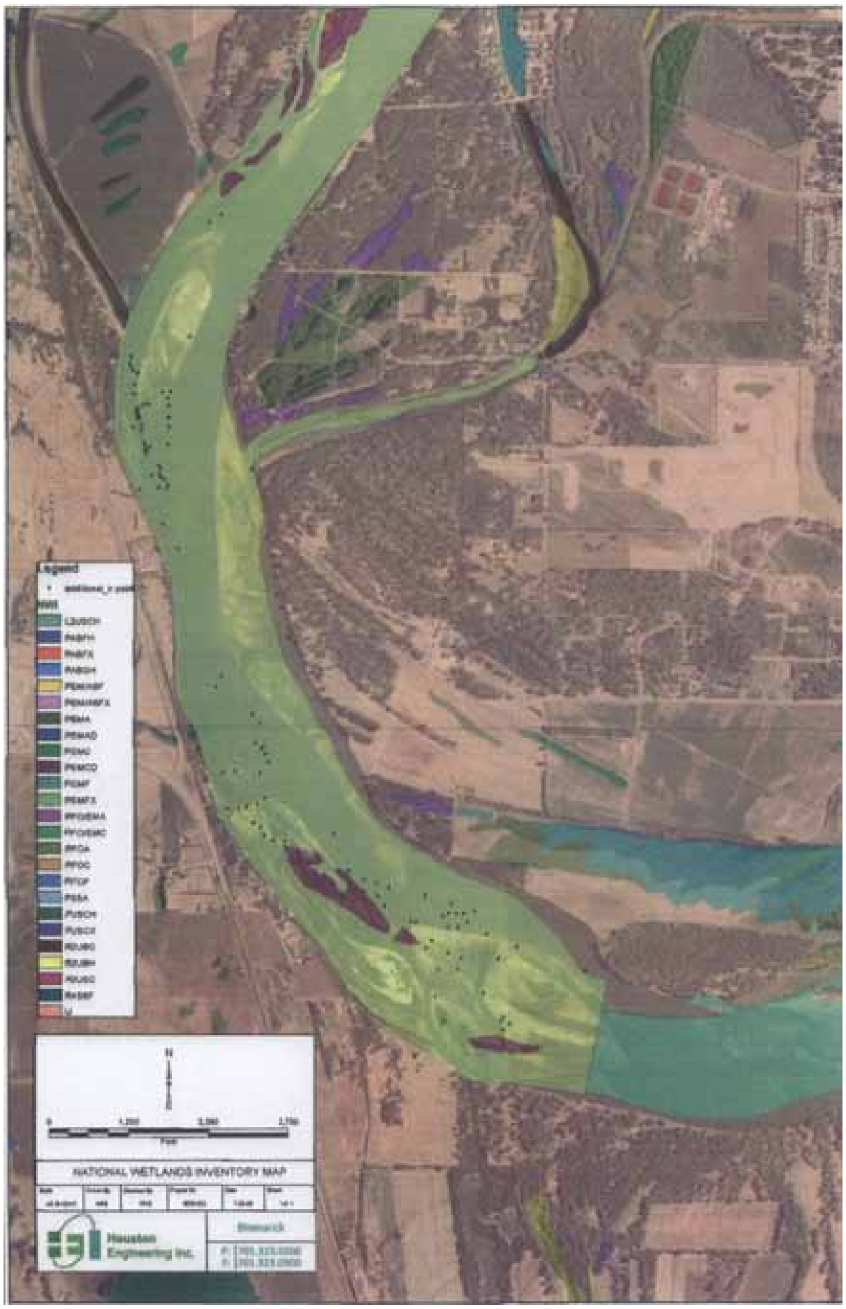
Typical shallow bank deadfall
These trees are not be included in the project removals

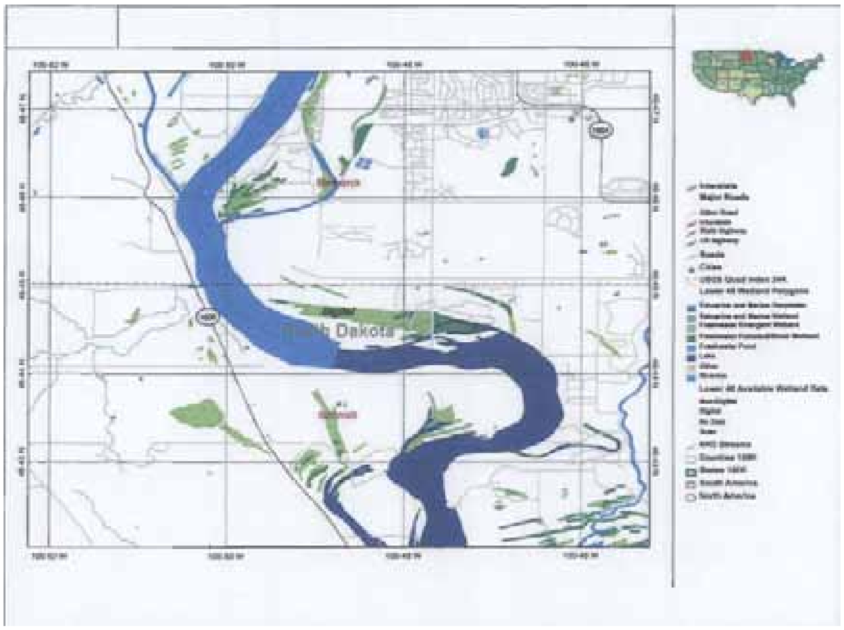

PANEL 1
FOX ISLAND
PANEL 2
PANEL 3
MISSOURI
N
Feet
MISSOURI RIVER FLOOD HAZARD MITIGATION
Houston Engineering Inc.


FLOODWAY
GALLATIN LP
PANEL 1


FLOODWAY


FLOODWAY
PANEL 3


Legend
NATIONAL WETLANDS INVENTORY MAP
Houston Engineering Inc.



Mr. GUNSCH. This grant application was declined. And the project was deemed to be snagging and clearing which is interpreted by maintenance under FEMA's guidelines. That decision has been appealed and is still under review at this point in time.

I'll paraphrase a couple other issues.

Restoring and maintaining flood water conveyance in the Missouri River system through the Bismarck/Mandan area is of critical importance, as is pointed out by all of us being here this evening. Since flood protection is the No. 1 priority for the management of the Missouri River system and the issue of flood protection for Bismarck/Mandan should be a high priority as well. The development of mitigation measures whether they include development controls, dredging, channel modifications, levees or other measures or combinations thereof, need to have attention now to reduce and manage the risk for future flood events.

Another critical issue in the discussion for any flood control or flood hazard mitigation project is the operation and maintenance. And the question has to be asked who maintains the river? While the riverbed is sovereign land owned by the State of North Dakota, the Federal Government has taken and accepted control and management of the river system.

As flood protection and sedimentation issues are a function of that management and maintaining flood conveyance should be a Federal responsibility. We understand this requires the Federal Government to establish the necessary authorities to allow the Corps to participate in that effort. We're also aware of the many ongoing reviews and studies regarding the Missouri River including MRRIC, MRERP, MRAPS and others. And while each has its own commendable effort in their own right, none should preclude the advancement and development of what hazard mitigation efforts to protect Burleigh and Morton County and the communities of Bismarck and Mandan.

A final concern is the completion of the Missouri River cumulative environmental impact statement as there are those who are holding up that particular study on the river at this time.

And if you'd indulge me just a moment, I'd read a statement from the Water Resource District relative to the Fox Island area.

"The March 2009 Missouri River ice jam flood event had significant impact on residents in the Fox Island area located in South Bismarck. This flood happened very quickly and with such little notice to the residents who subsequently had very limited ability and time to prepare or even respond to protect their properties. During a recent public informational meeting Fox Island residents were able to provide comments and concerns to the Burleigh County Water Resource District regarding these events and we summarized these in four major points.

"Having lived on the river for many years some residents noted that the Corps did not raise the river level this winter and again this spring to break up the ice flows as they've seen in the past. And they question why? Others question why the Corps is relying on a gauge that is several miles upstream from Fox Island on which to base the response for ice jam flooding. Thus, in their opinion the Corps' reaction was delayed. And the State of North Dakota had to request action to reduce releases from Garrison Dam.

"There needs to be more attention paid to the sedimentation issue and ice jam risks as the delta formation is growing and needs to be addressed. And what impacts are the proposed developments having on Missouri River flood plain elevations? And we provided a copy of the power point presentation that was made by the Water Resource District to those residents to give you some background as well.

"The Burleigh County Commission, the Burleigh County Highway Department and the Water Resource District have taken a proactive approach to the issues that happened. They're looking at mitigating to the extent possible within reasonable economic means those issues that happened after the 2009 flood. One critical problem encountered during the flood was the inability to access these residential areas because the primary access roadways were inundated. The county and township are in the process of implementing several road grade raises to improve emergency access for such events. And while not providing 100 year access it is a measured, economical approach to the access issue.

"The Burleigh County Water Resource District has also formally requested that the city of Bismarck and Burleigh County revise their current flood plain management ordinance to require the first floor flood elevations and crawl spaces for new construction to be placed a minimum of 2 feet above the base flood elevation which is currently higher than the one foot requirement.

"In addition a number of local residents have signed a petition to the Water Resource District to implement flood control measures to protect them as reasonably practical from limited ice jam flood events. Again, while this will not provide 100 year flood protection, there is some ability to provide additional protection under existing conditions. Even so residents remain at significant risk for flooding in adverse impacts from ice jams and high water events still exist.

"Another mitigation measure under consideration is the development of emergency action and response plan to govern the actions during the next such event. We understand to some extent this may require the update of the Burleigh County Multi-hazard Mitigation Plan to incorporate those future flood scenarios. While these measures are being implemented it is requested that the Corps conduct a post flood elevation. This should include a written report to the Burleigh County, Morton County and the State of North Dakota on how the flood event occurred from a river management perspective and what if any, reservoir control and operation measures might be implemented to mitigate future risks."

PREPARED STATEMENT

And that particular statement was submitted and read by myself for Gailen Narum, the Chairman of the Water Resource District.

Thank you.

[The statement follows:]

PREPARED STATEMENT OF MICHAEL GUNSCH

Senator Dorgan and subcommittee, thank you for the opportunity to provide testimony regarding the flooding concerns in the Bismarck-Mandan area.

My name is Michael Gunsch. I am a resident of Bismarck, and a registered professional engineer in the State of North Dakota and principal in the firm of Houston Engineering. Houston Engineering is currently the district engineer for the Burleigh County Water Resource District and is an engineering consultant to the Morton County Water Resource District. My remarks today are presented on behalf of the BCWRD, MCWRD and the Lower Heart Water Resource District (LHWRD) and relate primarily to the technical nature of the flooding issues.

In July 2009 Houston Engineering was retained by the BCWRD in cooperation with the MCWRD and LHWRD to identify alternatives to mitigate flood hazards associated with the Missouri River. The costs for this effort are underwritten in part through a cost share grant from the North Dakota State Engineer. The primary focus is to define pre-disaster mitigation alternatives that can be implemented to reduce the existing and projected flood risks for Burleigh and Morton County. After evaluating the March 2009 ice jam flood event and reviewing prior studies, the following objectives were developed for further consideration:

—Sediment and debris removal from within the upper reaches of the Oahe Delta formation below the Heart River Confluence to mitigate the impacts and risks associated with ice jam flood events and future sediment deposition;
—Evaluate the status of potential aggradation and on-going changes in stream channel conveyance downstream from Bismarck-Mandan and its impact on the risks associated with ice jam and open water flood elevations;
—Evaluate the feasibility of alternatives to lower the current Base Flood Elevation (BFE) to those levels documented in the 1985 Flood Insurance Study (FIS). The focus to be on the reach between the USGS Bismarck Gage at Missouri River Mile 1314.5 south to approximately Missouri River Mile 1302 (approx. Oahe Project Boundary). Alternatives shall include, but not be limited to, dredging, channel improvements, reservoir operations, and structural measures or a combination thereof;
—Define existing and future land uses within and proposed bank stabilization measures along the Missouri River Correctional Facilities property, as necessary, to achieve the objectives outlined in Item No. 1, Item No. 2 and Item No. 3. There is nexus between project construction or dredging within and along the river and the need for access and potential use of adjacent properties for the placement of dredge materials; and
—Complete an assessment to determine the potential (economic) flood damages or impacts associated with future increases in the Missouri River BFE and flood risks in Burleigh and Morton Counties. This effort includes a GIS based analysis of the existing and potential flood impact areas.

The tasks and potential costs associated with accomplishing these objectives, which include local, State and Federal issues, are still under development.

Concerns regarding the Oahe Delta have been around for many years with no action taken since 1985 to address the eventuality of what might occur. The March 2009 ice jam flood event significantly increased everyone's awareness of the issue and subsequently has raised the level of concern. The Corps of Engineers (COE) August 1985 study entitled Oahe-Bismarck Area Studies, Analysis of Missouri River Flood Potential in the Bismarck, North Dakota Area evaluated various alternatives to mitigate flood impacts associated with the continuing delta formation. A copy of this report is provided for reference. These included options such as dredging, channel cutoffs, bank stabilization, levees, Garrison operational changes, Oahe operational changes, land acquisition and floodplain management. The study's conclusion was to change reservoir operations to minimize releases during critical high discharge periods, and to recommend communities consider implementing additional criteria for floodplain development, raise access roadways, and encourage participation in the National Flood Insurance Program. Given the March 2009 event we have to question if operational changes alone are adequate to address the ice jam risks.

The 1985 study predicted that the base flood elevations (BFE's) in the Burleigh and Morton County areas would increase and over time eventually reaching a projected equilibrium. Unfortunately these increases and the equilibrium elevations occurred in a 17 year period between the 1981 and 1998 data sets. These increased BFE's are reflected in the 1985 and 2005 Flood Insurance Study (FIS) respectively. There are a number of professionals who agree this is not the end of the increases that will be experienced, therefore more needs to be done before the situation deteriorates further, and we are already 10 years past the last data set.

More recently the COE under section 108—Missouri River Protection and Improvement Act 2000—title VII enlisted the professional engineering services of The Louis Berger Group, Inc. to complete a report entitled Impacts of Siltation of the Missouri River in the State of North Dakota Summary Report 29, June 2009, [Berger Report]. A copy of the Berger Report is provided for the record for reference as it contains significant information and data that documents and justifies our concerns. The following examples are taken from this report and copies of these tables are attached to my testimony for direct reference:

TABLE 2.13—FLOODPLAIN AREA COMPARISON

Table 2.13 provides a tabular summary of the expansion of the special flood hazard areas or floodplain between 1985 and 2005. Based on this table flooding on the 100-year event during this period within the Bismarck City limits has increased from 2.7 to 3.6 square miles, while in Burleigh County it has increased from 28 to 36 square miles. This represents a 28.6 percent increase or expansion of the floodplain between the two studies. No data was provided for Morton County.

APPENDIX F—IMPACT OF SILTATION ON FLOOD CONTROL, TABLE 3.1—FLOOD ELEVATION COMPARISON

Table 3.1 illustrates the documented increases in the base flood elevations along the Missouri River system from 1985 to 2005. The average increase being around 1 foot on the 100 year event in the Fox Island area south of Bismarck. While development standards within this special flood hazard area have changed, continuing increases in the flood elevations presents a significant challenge and unknowns, which have diminished the value of those efforts. Therefore, more information is necessary to protect those located within the floodplain and to adequately protect potential future development.

So the question is this—What can be done?

The response to this is fairly direct and documented in the Berger Report in the following:

TABLE 7: RECOMMENDATIONS FOR ADDRESSING SEDIMENTATION IMPACTS ALONG THE MISSOURI RIVER IN NORTH DAKOTA, UNDER FLOODING RISKS IN THE BISMARCK/MANDAN AREA

This table lists the following four Study/Product Items:

—Tradeoff Analysis of Flood Controls (e.g., development restrictions vs. flow restriction).
—Study impacts of sedimentation of flood risks when Lake Oahe pool is full.
—Develop strategies for mitigating ice-affected flooding exacerbated by sediment deposition at the headwaters of Lake Oahe.
—Conduct debris/snag removal in the Heart River confluence area. This will minimize sediment accumulation in the area and decrease the likelihood of ice-affected flooding.

The timeframe to complete each of these Project/Study items ranges from short term, to 3 to 5 years. The total combined costs range from $2 million to $4.2 million. These Project/Study costs are not inclusive of all the elements under consideration by the BCWRD, MCWRD and LHWRD. Therefore, there are additional costs that remain to be identified.

The fourth item on the Project/Study list, to conduct debris/snag removal (e.g., deadfall trees), is one of immediate concern to reduce the risk for the recurrence of ice jams south of the Heart River. The debris remnants from the 2009 flood will become increasingly more difficult to remove once they are covered by additional river sediments. A Flood Hazard Mitigation Grant was submitted to the North Dakota Division of Emergency Management in July 2009 to complete this mitigation work and had a projected cost of around $430,100. A copy of the Project Summary and Risk Assessment included in this application is provided as a reference with this statement. This grant application was declined the project was deemed to be snagging and clearing which is interpreted to be maintenance under FEMA's guidelines. This decision has been appealed and will undergo further consideration.

It should be noted that there are more benefits provided than were specifically presented in the Project Summary and Risk Assessment as not all costs were readily available at the time of application. We now understand the cost to the rural electric power cooperatives alone, due to the need to purchase replacement power during reduced releases from Garrison Dam during the ice jam event, was in excess of $2 million. As additional background the 1985 study noted the loss in ability to generate hydropower due to sedimentation had an economic loss ranging from near zero in 1985 to a full annualized loss amount of $500,000, in 1985 dollars, occurring around 2005. This economic loss is directly related to operational changes caused by a reduction in flow capacity during the winter associated with sedimentation and ice conditions.

Restoring and maintaining floodwater conveyance in the Missouri River system through the Bismarck-Mandan area is of critical importance. Since flood protection is the number one priority for management of the Missouri River system the issue of flood protection for Bismarck-Mandan should be a high priority as well. The development of mitigation measures whether they include development controls, dredging, channel modifications, levees, other measures, or a combination thereof need to have attention now to reduce and manage the risks for future flood events.

Another critical issue for any flood control or flood hazard mitigation project is operation and maintenance. The question has to be asked—who maintains the Missouri River? While the riverbed is sovereign land owned by the State of North Dakota the Federal Government has taken and accepted control and management of the river system. As flood protection and sedimentation issues are a function of that management, maintaining flood conveyance should be a Federal responsibility. We understand this will require the Federal Government to establish the necessary authorities to allow the COE to participate in this effort.

We are aware of the many ongoing reviews and studies regarding the Missouri River including MRRIC, MRERP, MRAPS and others. While each of these is a commendable effort in their own right none should preclude the advancement and development of flood hazard mitigation efforts to protect Burleigh and Morton County and the communities of Bismarck and Mandan. A final concern is the completion of the Missouri River Cumulative Environmental Impact Statement as there are those who are holding up any project on the river until this is completed.

Thank you for the opportunity to present this information.

TABLE 2.13.—FLOODPLAIN AREA COMPARISON

Burleigh County	Bismarck City Limits
1985 100-year Floodplain—28 mi^2	1985 100-year Floodplain—2.7 mi^2
2005 100-year Floodplain—36 mi^2	2005 100-year Floodplain—3.6 mi^2

mi^2 = square miles.

In urban areas such as Bismarck and Mandan, flood plain development restricts the Missouri River's ability to accommodate increases flows during certain storm events (e.g. river channel has no room to widen without affecting properties). Aggradation in this area of the river compounds the problem resulting in an increase risk of flooding and the loss of property. Potential buyouts due to flooding concerns in the Bismarck-Mandan area are estimated at over $100 million.[1] The impact of flooding is estimated to be greatest between RM 1300 and 1316, i.e., in downtown Bismarck and Mandan.[2] Flooding also occurs outside of urbanized areas, affecting cropland and causing soil erosion.

Property owners whose property now lies within the expanded flood plain may also be impacted by a decline property values and increased insurance cost. Homes, businesses, and agricultural land are among the types of properties most heavily affected by an increase in the 100-year flood plain.

FEMA manages the National Flood Insurance Program (NFIP) which insures buildings and structures against flood damage. As a result of changes in the Flood Insurance Rate Map, all entities requiring a mortgage for structures on property within the 100-year floodplain will be required to purchase insurance under the NFIP. Owners of buildings must purchase insurance against damages to the structure of the building itself and also against damages to the contents of any floors below flood level that would be inundated in the event of a 100-year flood. Owners may purchase a basic level of coverage or increase coverage for an additional cost. The cost of the insurance is based on the area of the building (square feet). The insurance rate per square foot is dependent on the building's characteristics, on the date of construction of the building, and on the "flood zone" that the building is located in.

There are four different types of buildings covered under NFIP: Non-residential; Single-family dwellings; Condominiums; and 2–4 family dwellings.

[1] Remus, John, Personal Communication, November 2008.

[2] FEMA. *Flood Insurance Study—Burleigh County, North Dakota and Incorporated Areas.* FIS Number 38015CV000A. Federal Emergency Management Agency, July 2005.

TABLE 3.1—FLOOD ELEVATION COMPARISON

Key Milestone	River Station	Flood Elevations, (feet) NAVD						Changes in Flood Elevations from 1988 to 2005 (feet)		
		1988 Flood Data			2005 Flood Data					
		50 yr	100 yr	500 yr	50 yr	100 yr	500 yr	50 yr	100 yr	500 yr
Confluence Apple Creek	1,300.21	1,626.7	1,627.7	1,631.0	1,627.9	1,629.0	1,632.1	1.2	1.3	1.1
Confluence Little Heart River	1,302.22	1,628.3	1,629.3	1,632.8	1,629.6	1,630.7	1,633.8	1.3	1.4	1.0
Confluence Heart River	1,310.72	1,633.7	1,634.9	1,638.3	1,634.5	1,635.7	1,638.8	0.8	0.9	0.5
Bismarck Expressway	1,313.41	1,635.1	1,636.3	1,639.8	1,636.0	1,637.3	1,640.4	0.9	1.0	0.6
Memorial Bridge	1,314.21	1,635.4	1,636.5	1,640.0	1,636.3	1,637.5	1,640.8	0.9	1.0	0.7
Railroad	1,314.99	1,635.9	1,637.0	1,640.5	1,637.7	1,637.9	1,641.2	1.8	0.9	0.7
Interstate 94	1,315.49	1,636.1	1,637.3	1,640.7	1,636.9	1,638.1	1,641.5	0.8	0.9	0.8
City of Bismarck Limits	1,317.42	1,637.7	1,638.9	1,642.9	1,638.2	1,639.6	1,643.6	0.5	0.7	0.6
Confluence Burnt Creek	1,319.88	1,638.9	1,640.0	1,643.9	1,639.5	1,640.8	1,644.6	0.6	0.8	0.8
Burleigh County Limits	1,328.64	1,644.0	1,645.0	1,648.5	1,643.7	1,644.8	1,648.4	−0.3	−0.2	−0.1

Source: Elevations are from HEC–2 data and HEC–RAS data from the 1988 and 2005 Flood Insurance Studies, respectively.

TABLE 7.—RECOMMENDATIONS FOR ADDRESSING SEDIMENTATION IMPACTS ALONG THE MISSOURI RIVER IN NORTH DAKOTA

Input/Resource/Study/Product	Timeline	Cost	Remarks
Flooding Risks in Bismarck/Mandan Area:			
Tradeoff Analysis of Flood Controls (e.g. development restrictions vs. flow restrictions)	Short term	$500,000–$1,000,000	Would require local partner
Study impacts of sedimentation on flood risks when Lake Oahe pool is full	Two to three years to complete.	$500,000–$ 1,000,000	Would require a cost-share sponsor
Develop strategies for mitigating ice-affected flooding exacerbated by sediment deposition at the headwaters of Lake Oahe.	Three to five years to complete.	$500,000–$1,000,000	Would require a cost-share sponsor. Detailed Environmental Assessment (EA), may be an EIS
Conduct debris/snag removal in the Heart River confluence area. This will minimize sediment accumulation in the area and decrease the likelihood of ice-affected flooding.	Short term; Less than two years to complete.	$100,000–$150,000 for design. $400,000 to $1,000,000 for construction.	Would require a cost-share sponsor
Garrison Reach:			
Complete cumulative Environmental Impacts Statement (EIS) for Garrison Reach	Two to three years to complete.	$1,000,000–$2,000,000	Would require a cost-share sponsor

TABLE 7.—RECOMMENDATIONS FOR ADDRESSING SEDIMENTATION IMPACTS ALONG THE MISSOURI RIVER IN NORTH DAKOTA—Continued

Input/Resource/Study/Product	Timeline	Cost	Remarks
Conduct bank stabilization projects	Short term; Less than one year to complete.	$300,000–$500,000 per site.	Very difficult without EIS
Evaluate potential operational changes of the Garrison Dam and/or flow modifications	Three to five years to complete.	$1,000,000–$5,000,000	Controversial; Re-opens master manual issues; Possibly outside the scope of title VII
Fish and Wildlife:			
Study to evaluate the needs of multiple species along the Missouri River		$250,000–$300,000 (Two-year study).	Would require a cost-share sponsor. Overlap with the BiOp could be complicated
Study the life-cycle of the pallid sturgeon on the Yellowstone River		$200,000–$250,000 (Two-year study).	This is part of the Missouri River Recovery Program
Cultural Resources:			
Prepare a research design for cultural resources along the Missouri River. Provide a framework for management and treatment of cultural resources across jurisdictions.	Short term; less than two years.	$200,000–$250,000	Would require a cost-share sponsor
Study to access cultural and historical resource sites to determine if impacts are occurring	Short term; less than two years.	$250,000–$500,000	Would require a cost-share sponsor

Senator DORGAN. Mr. Gunsch, thank you very much. We appreciate your testimony. By the way, you cited the Missouri River cumulative environmental impact statement. I'm not familiar with that.

What are you referring to?

Mr. GUNSCH. The cumulative environmental impact statement was being written and evaluated for bank stabilization facilities. In other words there was an issue where people want to stabilize their banks along the Missouri River and issued permits because the environmental groups are saying the cumulative impact of all those facilities is having an adverse effect on the river.

Senator DORGAN. Who's conducting that?

Mr. GUNSCH. I believe the Corps was doing the original study.

Senator DORGAN. Colonel Ruch, are you familiar with that?

Colonel RUCH. My familiarity is with the length of bank. Right now I think they're down to where they can only do a 200 foot section at this time. And I know there is some ongoing work. But I'll have to give you an update on that.

Senator DORGAN. Alright. Roger indicates it may be a regulatory function. But we'll check back on that.

Let me try to understand, Mayor Warford, you talked about heavy spring runoff. Do we know how heavy the spring runoff was? Is this like once in 50 years? Once in 100 years?

Does anybody know?

Mr. WARFORD. I certainly don't know. I do know that, you know, we had 100 inches, within an inch of an all time record snow last year in the city of Bismarck. So that would lead me to the conclusion that we had significantly more runoff last year than we've had in most years.

Senator DORGAN. Colonel, have you studied this?

Colonel RUCH. All it takes on top of the 100 inches we had is a very rapid meltoff and rainfall on top of that. And that kind of gives a worse case situation where you get all that released at one time.

Senator DORGAN. Alright, and that was in addition the ice jams?

Colonel RUCH. Yes.

Senator DORGAN. Ok.

Mr. Royse, you talked about the title VII program. I want to ask you and the Colonel where we are on that. Is my understanding correct that there's been a reconnaissance study on that and to move to the next stage would require a local sponsor?

Colonel, is that correct?

Colonel RUCH. It is correct. And Mr. Gunsch did a good job of recapping his table 7 that he submitted. Basically the legislation outlined three phases.

The first phase was an assessment which has just been completed.

The second phase of the plan would identify selection criteria for the project's implementation process of those projects he actually discussed.

The third phase would go to construction.

The assessment was a cost-shared study with the Missouri River Joint Water Board. And it identified these projects that he listed for task force consideration in the plan and project phases. The assessment was completed in 2009, but no sponsors have stepped forward to cost share.

Senator DORGAN. Now you would not move forward unless there's a local sponsor. And the local sponsor at that next stage, that's a 50/50 cost-share, is it?

Do you know?

Colonel RUCH. I believe it's a 75/25 cost-share on that.

Senator DORGAN. Is it? Ok.

Colonel RUCH. It's a little different than most.

Senator DORGAN. But in order for you to move to the next phase you need a local sponsor? Is that your understanding, Mr. Royse?

Mr. ROYSE. Senator, that is correct. And the Missouri River Joint Board was a local sponsor on the study. This is the study. It is complete.

Senator DORGAN. Is it likely that there will be a local sponsor for the following step?

Mr. ROYSE. Well, Senator, I will tell you this. That of the projects they identified most of the projects appear to be further studies. And we have a concern about that.

Senator DORGAN. Ok.

Mr. ROYSE. And so if there are further studies I'm not sure the Missouri River Joint Board would be a sponsor on that.

Senator DORGAN. Alright. Colonel, if a local sponsor is required to come up with local money for additional studies, I assume what Mr. Royse is referring to is that they would like to see something other than a study. So how do they get to that point?

Colonel RUCH. We have to go through that next phase and do this study. Even on the number four that he discussed which was debris and sag removal from the Heart River, we still have to do the environmental documentation that you discussed at the beginning of the testimony to be able to go to construction. So it's not as simple as going out there and getting the work.

Senator DORGAN. Let me have you describe for us, Colonel, if you would, what are the authorities that the Corps of Engineers has available to relate the flooding problems in this area?

Colonel RUCH. I think we've discussed several, especially title VII of WRDA 2000. But some of the others that you may be referring to would be section 205 or section 208. I could give you a little bit of a detail on them.

Senator DORGAN. Just give us a thumbnail of those two. I'm generally familiar with them.

Colonel RUCH. Section 205 provides standing authority for the Corps to study and implement flood damage reduction projects without specific authorizations for those projects.

Section 205 projects can consist of structural or non-structural flood risk reduction measures to protect urban areas including towns and villages.

Feasibility studies investigate. It is cost-shared 50/50 for Federal, non-Federal. And for any cost above the initial $100,000 in unmatched Federal money, construction is shared at 65/35 as you stated earlier.

This program generally looks at small to moderate sized projects with construction costs capped at about $7 million.

Senator DORGAN. I would like to ask about the issue of debris removal, and several have mentioned that tonight. Is debris removal something that generally would require less environmental analysis than dredging, for example or larger flood control projects?

Colonel RUCH. You have to go through the basic steps of an environmental assessment. So until you actually study and see what the environmental conflicts would be, I can't really say that it's simpler. It has to do with the ecosystem you're involved in.

As you know we're involved in an area that is under the BiOp. So there are many organizations that we have to satisfy.

Senator DORGAN. I've got a number of questions for other witnesses as well, but I want to try to understand a bit, if I can, the discussion about debris. The discussion about silting. A series of things have been discussed here about what I think is probably incontrovertible with respect to the condition of the river that exacerbates flooding.

The question is who's responsible for trying to do something about that, debris removal or dredging? Is the Corps responsible?

Colonel RUCH. This area is not within the limits of our project. So we do not have the ability to go out there without an additional study. We cannot do it within the operations of our reservoir because it's not within our reservoir boundaries.

Senator DORGAN. Are there additional necessary authorities that you need?

Colonel RUCH. No. I believe within title VII of WRDA 2000 and the other authorities we have discussed we could move forward if we identified a cost share partner.

Senator DORGAN. Ok. What would be the length of the studies, for example under title VII that you're describing?

Colonel RUCH. A year to 18 months. We believe that it would be less than 2 years to complete. And that's on table 7 that was referenced.

Senator DORGAN. Mr. Royse, Mr. Gunsch, you both spoke of this, I'm trying to understand if there are things that can be done and the Corps has existing authority, provided it goes through the steps. How long does it take to get through the steps to actually do the things that we believe will mitigate the potential for future flooding?

Colonel RUCH. It was referred to in the 1980s. There was a study done like this. And granted we are many years later, but many of these things were discussed back then. And we did not get a cost share sponsor.

Senator DORGAN. I'm going to come back to that question of a cost share sponsor because one of the problems that we have is things don't move forward unless there is a local sponsor. You know, we can gnash our teeth and wipe our brow and wring our hands about it, but unless there's a local sponsor, we're not going to make that kind of progress.

Mayor Warford, you talked about the issue of the ice jams and reaching out to call in teams from across the country and so on. Can you give us a bit more information?

What have you learned about that? Perhaps you and Mayor Helbling, what have you learned about that? I assume that the issue of ice jams will be with us in the future.

Who do you think should assume responsibility? You talked about trying to find some mechanism that would identify ice jams more quickly and the potential damage or danger from them. So what was it that you learned this spring with respect to ice jams?

Mr. WARFORD. Thank you, Senator. The city of Bismarck is concerned with three things.

No. 1, more adequate warning with regard to the rise of the water for the Fox Island area and South Bismarck and what we learned was that essentially there is no real data out there on ice jams. But our feeling is that there would be more monitoring of the water flow in the tributaries along with some devices along the Missouri River that we, as a community, could at least have more warning than just a few hours that the water is rising.

You know, we were alerted by the citizens that the water was rising. And you know, we don't have, you know, any means to do that.

Our second, you know, point is warnings are our first. The second is, you know, to have an adequate response once there is flooding to look at, you know, a study so that we have a response. And maybe do we need some diking or a temporary diking plan.

And the third thing the city of Bismarck is concerned with and what we're talking about with the Corps are solutions. Are there solutions that can, you know, help mitigate it for the future?

Senator DORGAN. I was on the eastern side of the State when I received reports that the consequences of a significant action with a certain ice jam could have caused massive flooding in a significant part of Bismarck. What would have been the worst, disastrous consequences? And how close were you to that last spring?

Mr. WARFORD. We think we were pretty close, you know, to it. So when the ice jam was in place and the Corps ice jam expert came to Bismarck, really there's not a lot of data out there on what to do with ice jams. The ice jam experts, they were talking about salting the ice jam and then talked about the demolition of it. And the decision was made to bring in the demolition team.

We were prepared as the city of Bismarck for a worst case scenario had that, the blasting of the ice jam, not been successful for a rather significant flooding of Fox Island, Southport. We even had a contingency plan where we were going to put a temporary dike all the way down Washington Street to try to save property and possibly lives, you know, east of there. So our concern is that without the solutions that are being talked about with, you know, siltation and a lack of channelization and the flow of water into the Oahe that we're going to be faced with this again.

And so, we would like to see, you know, some solutions so that we're not faced with that worst case catastrophic scenario. We were very, very concerned. We came very close in our opinion to, you know, having a major disaster had the blasting not worked.

Senator DORGAN. How many were evacuated in the Bismarck/Mandan area?

Mr. WARFORD. I don't know exactly. I think there were around 200 in McLaughlin and in——

FEMALE SPEAKER 1 [off mic]. More than that.

Mr. WARFORD. More than that, ok. There was more than that.

Senator DORGAN. Alright. Mayor Helbling, your response to that question?

Mr. HELBLING. One of the things the city of Mandan learned through this experience is some type of computerized monitoring would be very helpful. One thing that we had a hard time doing is getting accurate information. And it seemed like Mayor Warford and I were constantly on the cell phone to each other. Have you heard anything? You know, what's going on?

And then it was the State. I mean, everybody seemed to be all over the place. We need some type of computerized monitoring of the river system, not only the Missouri, but the Heart River system.

We think there needs to be more emphasis placed on the Heart River. This is the first time that I can ever remember where the Heart River went out well before the Missouri River went out. And I was down there and watching it. And the tremendous amount of debris that was coming out of the Heart was just coming over the top of the Missouri and laying and stacking up. And I don't ever remember seeing that happen.

Usually the Missouri River is open before the Heart opens up. So there was a tremendous amount of water and debris flowing down the Heart River. So we think more emphasis needs to be placed on the Heart River and the debris that's laying in the Heart River.

Some of the things that we've done, we've had some debriefing meetings after the flooding. And we're working on some response times, at what elevation we should do what, you know, at *x.* We need to notify these people that there's a concern. At *y,* this is what we need to do.

So we've been working on some response times and hard communications within the county, the city and all of the Water Districts to see when we have to put specific plans in place.

Senator DORGAN. Alright. Colonel Ruch, has the operation of the Garrison Dam in any way contributed to the flooding problems experienced here earlier this year? I guess the follow up question would be is the Corps looking at any changes to the operation of the Dam given the experiences this spring?

Colonel RUCH. It's interesting when you look at the different advice you get on how much water to release in some of these situations. You know, you'll get advice that you need to release more to break the ice jams up. You'll get advice that you need to go in the other direction and turn off the water, which is what we did last year.

Senator DORGAN. Is that the first time since the Dam was built that the releases were shut down?

Colonel RUCH. That is the first time ever that the average daily release has gone below, I believe, 4,100 cubic feet per second. And it was shut off completely.

Yet, the real dilemma here is you have intakes upstream of Bismarck. And you need, at about 10,000 cubic feet per second you can have your intakes in the water. There are two powerplants and there is a municipal plant as well. When you cut the water below that then you have to shut down powerplants at a very cold time of the year.

There is a lot of consultation that goes on there. I'll give you the book answer here. How has the operation of Garrison Dam contributed to the flooding problem?

Garrison Reservoir provided significant flood damage reduction during this year's spring event. Corps preliminary estimates of actual flood damages in Bismarck are in the range of $18 million. Damages would have been in excess of $100 million without the Dam in place.

The regulation of Garrison reservoir significantly reduced the peak stage in the Bismarck area during the spring flooding event. This peak stage and discharge that occurred during the event was 16 feet, had an estimated flow of 27,000 cubic feet per second. Had Garrison Reservoir not been in place the peak would have been approximately 82,000 cubic feet per second which corresponds to an open water stage of nearly 20 feet.

It's impossible to determine whether or not the ice jam would have formed without the reservoirs in place or if those stages had not formed. As far as looking at operations afterwards, we continue to monitor. But really the bottom line is you cannot predict the ice jams.

Senator DORGAN. Sorry?

Colonel RUCH. You cannot predict when an ice jam is going to occur. We were already dropping our water levels. So we will continue to monitor and control releases as best we can in every situation. We don't think there's an overall lesson learned here that tells us to do something different.

Senator DORGAN. What mechanisms exist to try to detect the formation of an ice jam? Is there an opportunity in the early formation of an ice jam to address it as opposed to allowing it to——

Colonel RUCH. The ice tends to pile up very quickly.

Senator DORGAN. Very quickly.

Colonel RUCH. It's not as if you can get in there. Where you're talking about measures for dealing with ice jams, there are permanent structures that are very, very expensive. I doubt that we could ever get the cost benefit ratio required for that. There are places that have effective monitoring, early warning systems.

I have a note and I can't give you a lot of detail about it, but the State of Nebraska implemented an ice jam reporting network in 1993. Basically it tied together emergency management authorities just to keep everybody tied in and aware.

Senator DORGAN. Do you have the authorities that you need at the Corps to deal with the Heart River? Mayor Warford mentioned Apple Creek. Do you have all the authorities you need in all those areas?

Colonel RUCH. Yes. I believe we do have the authorities required, if requested under section 205 of title VII.

Senator DORGAN. Let me go back to this question of the title VII programs, because I understand what you're saying Mr. Royse that you've provided some funding and now the question is, is there a local sponsor for the next step. You're saying the next step is a study.

On the other hand the next step could be a study that results in debris removal or dredging 18 months from now. Seems to me that's better than not having the local sponsor and 18 months from now sitting at a table like this saying, you know what, we don't want to have a study. Because, you know, the only way that the Corps can get from point A to point C is to complete point B as well because that's a legal requirement for them.

So I guess the question I ask is with a pretty complete understanding that debris removal is probably important here. The issue of dredging is important. I mean, that's not a new issue for any of us.

So how do we get to that point of actually getting the debris removed and the dredging that is required? Do you see, Mr. Gunsch or Mr. Royse, do you see at some point local sponsorship for this?

Mr. GUNSCH. Senator Dorgan, the, you know, one advantage of having a joint water board is we are in position to be a local sponsor and speak on behalf on a number of county water boards. So it makes it advantageous that we have this board in place. And so we've been able to step up and be a local sponsor, not only on title VII, but a few other Corps programs to this area.

But these are expensive cost share procedures. We have to rely upon the State water commission to provide us funds so we can become a local cost share. And how many times can we go back to the State water commission for funds to be a cost share partner on these programs is an issue.

Senator DORGAN. No, it's unlimited.

The reason I say that is the State engineer is in the back of the room. I'll invite him to say a word in a moment. He's going to be testifying tomorrow when I'm holding a hearing talking about the Hazen/Stanton area and also down in the Linton area where we had some significant flooding events as well.

Dale Frink is here. He is the State engineer. Would you pull a chair up here? As I said, you're going to be testifying tomorrow, but would you also want to weigh in on the issue of local sponsorship?

I know this is not putting a collar around your neck. But it is the case, as Mr. Royse has just indicated the State water commission plays a significant role in this.

STATEMENT OF DALE FRINK, STATE ENGINEER, NORTH DAKOTA STATE WATER COMMISSION

Mr. FRINK. Well, thank you, Senator. And, you know, in terms of the local sponsor, we really push to have a local representative be in charge. We will help fund them, if at all possible.

But, you know, if you—we don't like to, especially, you know, like Bismarck and Mandan, you know, they're large communities and certainly are capable of managing something like this. But, you know, we do like to have a local sponsor so that they are in charge and the residents have a State agency come in and start dictating some things to them.

Senator DORGAN. You see that the dilemma here is that, I think, there's general understanding in this room that debris is a problem. Dredging, the lack of dredging is a problem. Both of which contribute to an event like this when you have very heavy runoff and an ice jam. It seems to me both the issue of debris and dredging are something that seems to be significant.

So the question is how do you get to the point of having both addressed by the Corps?

Mr. FRINK. Well, there are really two issues here. One is funding. And I think that's the easier part.

And I think where Mike and Ken are getting a little, you know, concerned is that, you know, even if the State and locals funded it, we still need a permit from the Corps. And you know that could be a 2 year study. So you get—you've got two people here talking to contractors about when can we start. And then we talk to the Corps and say, well, we've got to do a 2 year study. And to, you know, with the result being a permit at the end.

So it's, you know, it's kind of a timing thing. But the funding is probably easier than, you know, getting through the other type of things.

Senator DORGAN. I still want to try to get to this understanding. How do you get from point A to point C without going through point B, if point B is a legal requirement?

Mr. FRINK. Right. Well, in terms of a local sponsor, I guess I would encourage, you know, the two cities and the two counties to try to come up with a local sponsor. You know, the joint board is certainly one possibility. I know they don't have a lot of money, but, you know, the State Water Commission could provide some money.

And then you'd still have the local control that I think is really important here.

Senator DORGAN. See how much I'm helping you here?

At least I'm trying. Thanks, please stick around for a moment.

Let me ask some questions that Mr. Narum submitted. I think Mr. Gunsch raised them, and we just will put them on the record.

This from Gailen Narum, having lived on the river for many years some residents noted that the Corps of Engineers did not raise the river level since winter and again this spring to break up the ice flows as they have seen in the past. They'd like to know why.

Colonel, can you respond to that?

Colonel RUCH. Well, once again by the time these ice jams formed and the river was coming up I don't believe that releasing more water is what anybody downstream really wanted at that point. We look at each one of these events and decide how to move forward. More water would have piled more ice up.

Senator DORGAN. Is there a strategy the Corps has inevitably in the spring or the late winter and spring to release water to break up or in order to prevent jams from forming?

The implication of this question suggests there's always been a strategy.

Colonel RUCH. The typical response to fight the stuff is perhaps to cut it back a little bit. And then once it stabilizes to release some more water to increase the channel underneath. You probably won't find that in a manual, but that is kind of how it is done. But this ice piled up very quickly.

Senator DORGAN. The other question was why is the Corps of Engineers relying on a gauge several miles upstream from the Fox Island area on which to base its response to ice jam flooding? Thus in their opinion the Corps of Engineers' reaction was delayed and the State of North Dakota requested action to reduce releases from the Garrison Dam.

Again, that's from the letter from Gailen Narum. Can you respond to that?

Colonel RUCH. Not to that individual gauge. I will get an answer and put that into the testimony. But we rely on the gauges that are out there.

I will get a better answer for you on that.

[The information follows:]

The Corps utilizes all of the USGS gages available on the Missouri River and tributaries when making reservoir regulation decisions. It is unlikely that an additional gage a few miles away from the existing gage would have resulted in any appreciable difference in our response or in the effects of our response given there is a two-day travel time from the dam to the Bismarck area. In addition, since ice jams can occur anywhere along the river it would be infeasible to site a gage or series of gages to cover all potential ice jam locations.

Mr. FRINK. Senator Dorgan, just a couple of things. I think tomorrow at the hearings and today there's going to be a commonality that we need a little more measurements along the river. And those are USGS gauges. And once they're in place and then they're available on the Internet for everybody to see.

But I think we do need to look at installing some measuring devices both on the Missouri and the two locations that we're talking about tomorrow. And I think we are already looking at that. And I think we can make that happen.

Senator DORGAN. Alright, we'll discuss that further. Some have, in testimony, mentioned various structures that might be advisable. I think Mayor Helbling you talked about structures on the Heart that you might see as advisable.

By the way, I am going to ask about the jetty question in just a moment. But structures on the Heart, I think Mayor Warford, you also talked about a potential structure in Apple Creek, didn't you?

Mr. WARFORD. Yes. I'd like to maybe just address, you know, one other issue too with regard. I'm feeling a little target on my back. I don't know if Mayor Helbling is as well. But you know the discussion of the local cost share on this.

You know, I'm hearing that the river is on sovereign State land. And the Corps is in charge of the water. Yet when it comes down to, you know, mitigating some of the problems they're looking at Mayor Helbling and me and our local communities to come up with the cost sharing money. And so, I hope that, at least my position is, is that, you know, we are maybe more victims rather than participants. I don't know how the Mayor feels about that.

But as far as the structures, if you're referring to more gauges and more information, I would be a strong advocate of that. And would encourage the Corps to, you know, place gauges where the water rises so that we can make a direct decision that water is rising here, that there's an imminent flood rather than having the gauge way up the river and you know, having the delay. You know, we're you know, based as local leaders with, you know, coming up with a response we feel we would—we need to be notified and warned more quickly so that we can respond more quickly to the citizen's needs.

Senator DORGAN. My question, though, is I think you talked about the need to put up a temporary dike down Washington and so on. I also thought you mentioned the contribution of Apple

Creek to certain flooding activities that could be controlled with a structure. I thought Mayor Helbling talked about a potential flood control structure on the Heart. I didn't quite understand what you meant.

So, whenever you talk about flood control you talk about the things that can exacerbate flooding issues, the lack of dredging or debris and so on. Then you talk about the other issues of putting up structures that would probably control water. I'm asking the general question: are there structure questions here that are just tangential or are they central to any flooding issues?

Mr. WARFORD. Well, the city of Bismarck feels that they would be a central issue. You know, I talked about in my testimony the 2009 flood. But a catastrophic flood with a scenario where let's say the blasting did not work and the Apple Creek let loose that there would have been more flooding in Bismarck. And we put up a temporary dike in the Cottonwood area. And we're prepared to put up more which could maybe be a permanent dike.

And we talked about other temporary dikes to mitigate that sort of doomsday scenario which, you know, could have taken place. So that's what I was speaking of. We need guidance from experts that, you know, who claim they have models that can predict, you know, scenarios that would be greater flooding than we had in 2009. And, you know, what should we be doing as a community to respond to that situation?

We'd like to be prepared for any and all situations if we could.

Senator DORGAN. Mayor.

Mr. HELBLING. Senator Dorgan, we have several areas along the Heart River where we've had massive erosion. And we feel it's very important to take care of these areas or we're going to start jeopardizing our Highway 6 Bridge. And then also east of the city, Sitting Bull Ridge, where the river turns there's a secondary dike that's in place. And it's eroded all into the tow of the dike already.

And we feel if we don't get that repaired we're going to wind up redirecting the channel of the Heart River and causing massive flooding in the southside of Mandan. So there are two areas of concern for us.

Senator DORGAN. Can you respond, Colonel Ruch, to the issue Mayor Helbling has raised about the jetty? Mayor, do you want to repeat that issue that you had with the Corps?

Mr. HELBLING. Well, we have that secondary dike system. There's a secondary structure. And that that has massive erosion on it right now.

And that's an area where the Heart River turns. And there's so much erosion there it's already cored a way through the structure. And we're very afraid that if we do not repair that area it's going to change the river channel.

The river is actually trying to change. It's taken out that levee. And we're very concerned with that area. And need to have it addressed in some manner.

Colonel RUCH. I will answer that one. But also the one thing I wanted to point out earlier when we were talking about gauges upstream and where the gauge should be. You have to remember that the travel time for water from Garrison down to Bismarck is 2 days.

So more data is better, but no matter what we do, the impact is 1½ to 2 days to when we make a change to what will be seen down here. On this actual issue, I just heard about this today. I got up here a little bit early and did a little touring around the area.

So what I'll promise to do is have somebody take a look at that and work with your folks and make sure we make a good assessment of the situation. I'm not even certain that it's a Federal structure. But we will take a look at that and we will work directly with you and your people on that.

Senator DORGAN. I don't know if there are people in the room who are old enough to have been here, in Bismarck and Mandan, when there was chronic flooding with a rather wild Missouri River that in the spring would—there's one. Anybody else? So there's three or four, five people in the room who remember the days before there was a dam that controlled the river, before we had a series of stem dams on the Missouri River and controlled flows.

I wasn't here, but as I recall it was not terribly unusual to have massive flooding and a huge flood threat that would come running through these two cities and cause very serious problems. Then we had the building of this dam and the ability to somewhat control the Missouri River.

So news of significant flooding threats in the Bismarck/Mandan region has been pretty unusual. That's why what happened this spring was something that seemed kind of out of the ordinary. It's why I asked the original question. What has caused this?

If not a perfect storm, pretty close to a perfect storm in the sense a substantial snowfall. I think the key that, Colonel Ruch, you described was very fast melt that has, you know, unfortunately over in the Fargo area they had a relatively slow melt which I think saved them a lot of heartache and damage. Then the two ice jams which together apparently caused problems and it's very hard to understand what an ice jam means and how to deal with it.

So this was a very unusual situation. As I indicated wouldn't have been so unusual 70 years ago, perhaps or 60 years ago, but it certainly is now.

What I'd like to do for the next 15 minutes or so would be to invite some in the audience who wish to contribute to do so. If you have questions for the witnesses I'd be happy to entertain those as well. If you would stand up and state your name before asking the question I'd be happy to entertain questions for about 15 minutes.

Yes, ma'am?

Ms. BERGER. My name is Rosemary Berger. I reside at 2826 Woodland Place which is down on Fox Island. My family was one of five that was rescued by a boat in the spring to get out.

We had water over our mailboxes when they came by boat to get my family and my neighbors. I want to know. You're saying that the Corps does not have some kind of a mean. But I've been told many times that they've raised the river after the first freeze so that water, the ice pushes up. It breaks that ice.

This is the question that the Fox Island people are asking. Why wasn't it raised after that first freeze? This ice that we had this winter because of the cold winter we had and the amount of snow and rain, whatever we had, was extremely thick. It was never raised like it normally is.

You're saying this is in the spring that you didn't raise it. No, we're talking after the first freeze. This is the question that we have been asking. You did not answer it to that, if that.

Senator DORGAN. Alright, Colonel, would you respond to that?

Colonel RUCH. I'll take you through a history of release. And minimum, once again, minimum release for intake and for the power plant is 10,000 cubic feet per second.

Again we were coming out of drought conditions still conserving water. On March 1, Garrison releases were lowered from the winter release which is 16,000 cfs which is more upper level to 11,000 cfs in preparation for the expected snow pack melt in North Dakota between Garrison and Oahe.

The 11,000 cfs release rate was considered the minimum necessary to support the downstream intake. On the 23rd of March the river stage at the Bismarck began rising significantly. The Garrison, the releases were reduced from 11,000 cfs to 6,000 cfs since the downstream tributaries, particularly the Knife River were getting enough added flow but continued to support the intakes.

On the 24th we dropped 4,000 cfs and Bismarck continued to rise, so later that day the decision was made to go to zero. During the period when the releases were cut to zero we did shut down power plants and we did take a municipal water intake out of service.

So we were up at 16,000 cfs. And once again coming out of drought conditions we were within the acceptable range. I don't know the actual numbers and whether that's a good answer. But that's how we were releasing. And we dropped to 11,000 cfs on March 1.

Ms. BERGER. Ok. This last winter was a high measured amount of snowfall. We never had our January thaw, ok? It was always in North Dakota have had some kind of January thaw.

So when we talk about this record snowfall. We were short by one inch. But any other time we would have had some kind of a thaw during the year. We never had that.

But you're still talking about March. I'm talking something that would have happened a year ago, when we had our first blizzard. We got into a freeze situation back maybe, November, December. Usually that river would rise and that didn't happen.

The year prior to this we had a substantial amount of rain that came from Montana. Montana had record amounts of snow. And I sat at your meeting that you had here a couple of months ago. And everybody at that meeting was praising the Corps of Engineers for raising the Lake Sacajawea.

Well, you know what, I was angry at that meeting because I am one of these people that was affected. And you guys didn't do anything to raise Sacajawea. That was Montana that did it. That was God that did it. It wasn't you. Ok?

So Sacajawea was raising.

Senator DORGAN. Let me just make another point, however. We have been through a lengthy drought in which the main stem reservoirs have been largely depleted. Now in the last 2 years or so more water has come in.

It doesn't have anything to do with the Corps. It has to do with snow pack in the Rocky Mountains.

Ms. BERGER. Right.

Senator DORGAN. That additional water has come in, and because the reservoirs have been so depleted they have not wanted to maximize the releases. That is what they have wanted to do is to restore additional water in those reservoirs. So they have not, as additional water has come in, increased releases just because they're trying to make up what they should have conserved previously.

Ms. BERGER. I'm not asking them to increase. I'm just asking them why didn't they do what they had done on any normal year. They would have raised that, any normal year, to allow that water, that ice to break up so that the water could go underneath it.

Senator DORGAN. I think you're asking a question that I had asked the Colonel, and I think he answered it already. Is there a strategy, in terms of the management of the river flow that beginning early in a winter is designed to address the issue of ice?

I've not ever heard of that, and you're saying that that strategy does not exist?

Colonel RUCH. It does not relate to that day. Once you get ice on the river then in the beginning you don't release quite as much. Then you increase your releases to increase the channeling.

In this case I think you hit on it very well because we have less of it, but there was more water, like you said before. It might not have been 20,000 cfs like years before. It was up at 16,000 cfs because that is what we could afford to do based on our annual operating plan to get the reservoirs right.

Senator DORGAN. But that had nothing to do with what was happening this winter. That had to do with trying to refill a reservoir that had been depleted. Let me suggest something to you, ma'am.

What I'd like the Colonel to do is to provide us with 5 years of releases/discharge by month for the past 5 years. Let's all take a look at that and try to understand what was done by the Corps.

[The information follows:]

GARRISON DAM—AVERAGE DAILY RELEASE FOR MONTH (1,000 CUBIC FEET PER SECOND)

Month	2004	2005	2006	2007	2008	2009
January	19.2	15.4	17.8	15.9	15.0	15.7
February	23.1	13.0	15.5	15.8	15.3	16.1
March	16.7	12.1	14.5	14.8	12.8	10.0
April	16.9	17.4	13.8	13.5	12.5	9.0
May	15.8	16.5	15.3	13.3	12.9	13.3
June	18.0	15.0	19.8	16.0	14.3	15.9
July	17.9	15.2	20.6	15.9	13.6	15.7
August	17.2	15.5	22.0	16.0	13.9	16.0
September	15.0	14.1	18.1	11.6	12.6	14.8
October	11.5	12.6	12.1	10.8	11.0	12.6
November	12.7	13.4	13.1	10.8	11.0	12.8
December	15.2	15.4	15.3	14.9	13.9	....

Ms. BERGER. Ok.

Senator DORGAN. And I appreciate your coming and raising those questions.

Do others wish to ask questions?

Ma'am, if you would give me your name and address following the meeting because I will provide that for you when the Corps gets it to me.

Ms. BERGER. Ok.

Senator DORGAN. Alright. Sir.

Dr. KRONBERG. I'm Dr. Scott Kronberg, a range scientist out at the Northern Great Plains Research Lab. But I like trees too, so I elected to live on Fox Island.

And one concern I have after listening to the comments was assuming a study is done to allow for the removal of these Cottonwood trees and other debris and possibly dredged, how long is that study good for? I mean, can we remove debris for 5 years, 1 year, 10 years?

Senator DORGAN. Colonel?

Dr. KRONBERG. It would be a bummer if we spent 2 years doing a study and get to remove debris for a year or dredge for a year.

Colonel RUCH. Your question is a great one because that's why we really have to do the study because all of these authorities allow us to go into a project and it is dredging. It doesn't allow for follow on maintenance dredging. So you really have to make sure you're solving a problem.

Typically sedimentation occurs at a place in the river reach for a reason. So just dredging it out doesn't mean it stays open. We really have to make sure that we're addressing the bigger problem and not just getting to a quick solution that might last 6 months, might last a year.

It's a good question.

Senator DORGAN. You know, the one thing I'm understanding from tonight's discussion is that this is not a question of whether there needs to be action to deal with debris and siltation in this river. The question is how do we get that done. Right?

Most of us understand even if we never run into this problem again with the ice jams and the perfect storm of massive snowfall, we've still got a problem with debris and siltation that ought to be taken care of. There is the point that's raised that well, the river bottom belongs to the State and the management of the water belongs to the Federal Government and then the consequences of the problems are inherited by those who live in those areas.

So somehow we need to get again, from point A to point C so that at point C we address this issue, siltation and debris. Then the other questions would be developed from whether it's a title VII program or other program. Are there other devices, structures or other things necessary to try to provide added protection?

Would local government want that to happen and initiate that as a plan? Because the Corps won't come here and say here are the six things that you should have. Largely, it goes the other way. The local government, through a study says here's what we think we need, and then you develop this criteria.

Is there a Federal interest? Does it meet the cost benefit and so on? But you've asked a very important question. You don't want to go 18 months down the road, finish a study, only to decide that there's a very brief period in which you can do half the job. That doesn't make any sense.

Dr. KRONBERG. Right.

Senator DORGAN. Mr. Gunsch?

Mr. GUNSCH. Senator, if I could address kind of the question relative to the debris removal. I agree from the standpoint and having discussed with the Fish and Wildlife Service and Game and Fish in the preparation of the flood hazard mitigation grant that this particular event was very unusual in the amount of debris and stuff that came out of the Heart River. The number of very large Cottonwoods, you know, 4 foot in diameter in some cases that were put down there.

Is this going to happen again? It certainly could. But the debris removal, as we saw it from the three water resource districts, this is probably a onetime thing that we shouldn't have to do for a long time again. As far as the dredging, that's a larger perspective. And it may need to be done on a regular basis as was pointed out in the 1985 study.

But again, as far as even the debris removal, there was discussion of even in the Flood Hazard Mitigation Grant as a 75/25 that the 25 percent cost share needed to come up with. And they were willing to consider that opportunity if they could move forward. But again, the permitting side of that has to be stepped through.

Senator DORGAN. Alright. Yes, sir?

Dr. HUGHES. My name is Jim Hughes, Dr. Jim Hughes. I've lived on the river, south of the ice jam in the Oahe bend area at the bottom of South 12, that area, since 1981. And I e-mailed your office the morning before the water began to rise. You could look back and see when that was.

But I looked out the window and saw a 5 foot rise in the river, nothing on the news below the ice jam. I guess the point I want to make is that whatever was happening north when the river was blown, when the charges went off. I was downstream of that.

The water was in my yard at the same level it was in 1997 when the river was running at 60,000 cfs. So I think what decompressed the river, ultimately was the river overtopping the oxbow that is just south of Bismarck/Mandan. And I think the 1988 flood plan from the Corps of Engineers did include an idea of having kind of a decompression channel that would take—that would go across that oxbow.

I mean it seems to me that you can't prepare for the amount of silt that's going to arise and all of that. You have to somehow have a plan that allows for decompression to occur in an unnatural way or natural way. When you look at Google maps, Google sky, Google history, you can see where Sibley Island was in the past in the whole area to the west of us is underwater. I mean, Sibley Island apparently is an island because it was an island at a particular time of year.

But the normal decompression or normal—it's a quantitative change that happens and how the river is working when it reaches a certain level that overtops that oxbow south of Bismarck/Mandan.

Senator DORGAN. Thank you very much. Other observations or questions? Alright.

What I would like to do is first of all I want to be helpful. I mean I'm chairman of the committee that funds the Corps of Engineers. I can't create miracles, but I certainly can be helpful.

I want to be helpful in areas across the country and in areas where we've got, Lord knows, we've got a lot of water issues all across the United States that we're working on. In this State, though, we had plenty of water issues to consume our time that were significant and potentially dangerous in many areas of the State. One of those areas was Bismarck.

When I ask about Bismarck/Mandan, when I ask about the potential catastrophic result, had everything gone badly my assumption is there would have been massive damage, massive evacuation. This would have had a very, very significant impact on a region of our State. So coming that close to that significant an impact, the question is what can be done to try to reduce the possibilities of that happening again?

I think from this discussion there are some obvious answers. There are also some which are not yet obvious that may come from some further inquiry. There will need to be, it seems to me, further discussions with the local government officials, the mayors, the State water commission and the Corps of Engineers so that we can understand what use of the authorities the Corps now has, and what could move us in the direction of getting these issues solved. Also, what additional authorities does the Corps need that I might be able to provide if they need additional authorities to address these issues.

I'm pledged to do that, but I don't necessarily know what that might be as a result of this hearing. I just wanted to hold the hearing to try to understand, as best I can, what really needs to be done.

I think much of that is still going to rely on you, with the Corps, to tell us what we can do to be helpful. I think that there is a common determination. Nobody wants to go through this again.

I think one thing I have learned is that there clearly needs to be more monitoring. That is a U.S. Geological Survey issue. We'll work with them to see that we do that.

I think the woman at the back of the room and the doctor talked about trying to understand what the river is doing. Well the more monitoring you have, the more information you're going to have. With computer technology these days and the Internet, you have access, real time access, by everybody to that information which I think could be helpful.

Colonel, would you wish to make any additional contributions tonight?

Colonel RUCH. Just once again to thank you, Senator, for bringing us out here and letting us get a perspective from the people who live in this city. And these are good partners I'm sitting with up here. And we have met with many of their staff since the flooding and we will continue to do so to move forward.

Thank you.

Senator DORGAN. Ok. Mayors, did you want to make any additional comment?

Mr. WARFORD. Thank you again, Senator, for the hearing. And I'll go back to my original talking points.

We want in the city of Bismarck, more warning.

We would like to partner with whomever to get a more adequate response. We could up our game there.

And finally, long term solutions to the river are of strong concern to us.

But thank you for the hearing.

Mr. HELBLING. I'd also like to thank you for the hearing. I would like to thank the Corps that one of those water intake structures that the Colonel was talking about was the city of Mandan's. And the city of Mandan shares that structure with Tesoro Refinery.

And the Corps did work very well with the city of Mandan. How long? How much water supply do you have? When do we need to get more flows in there? How long can we cut it off?

So I realize it was an unusual event. But I think under the circumstances everybody did work phenomenally together. Sure we can all do better, but I think we learned a great deal from this. And I think if we all work together there are good solutions on the table.

Thank you very much.

Senator DORGAN. Anyone else, any final comments?

Mr. ROYSE. Senator, I would just say I'm pleased that you're able to focus on the problem of cost shares as quickly as you did because that becomes a central problem we have. Trying to be a cost share partner, when we cannot control the costs or the time of the project, is a problem.

The second thing I would like to say is I think the opportunity that we may have to influence how this management of the river is going to be performed through the MRAPS study is going to be important. And I'm hoping that the Corps will involve local and State officials in the process of some real formal processes, rather than just stakeholders meetings or task force meetings. But some process, however, has had real input from State and local officials on this process.

We see this process through MRAPS as not only solving maybe a flooding issue, but balancing the benefits of that river system through the upper and lower basin States. Thank you.

Senator DORGAN. Thank you very much, Mr. Royse.

Mr. GUNSCH. Thank you very much, Senator, for providing the opportunity for everybody to communicate in this form. I think it's advantageous from the water resource districts perspective to bring these things to the table and have the opportunity for the Corps to hear them. And I guess everybody always looks forward to working toward a solution.

And with that I just want to thank you for the opportunity.

Senator DORGAN. Dale, if you have any comments? Thank you for being here. I know I'll be seeing you tomorrow morning as well.

Mr. FRINK. Well, thank you. And I'd just like to say that, you know, we do work together very closely. And we work very hard at this.

This was rather an unusual event. And it's one that hasn't happened in over years. And we learned some things.

The Colonel mentioned the 10,000 cfs for example, labeled for the power plants. It used to be 8,000 cfs. But what is happening between Garrison and Price is the river is getting deeper. And that sediment is being deposited down here by Bismarck. And that's causing you a problem.

So the river is getting deeper up in that end. And that's why they ran into more problems that we realized they would. And so we learned something there.

And we've learned a lot of things in some other areas. So, you know, hopefully next time we'll be able to do it a little better. But it is a learning process.

Even, you know, on Washington Street this gate was put in in 1967. It's the first time we used it. So you know you use things that infrequently, you know there is a learning curve involved here.

So, ok, thank you very much.

Senator DORGAN. Thank you. You mentioned the authorizing purposes study. When I drafted that and put that in the bill it was very controversial, as you can imagine. One State in particular downstream is having an epileptic seizure.

But at any rate, it's the right thing to do and an important thing to do. We have waited for longer than I have patience to, and finally we're going to drive through this and get it done.

I'm going to ask Justin Schardin, who works with me on water issues, to work with the two cities and the water districts and the Corps to see, on this specific set of issues, what more we can do, what you want us to do, and what you want to do for yourselves.

Roger Cockrell and I will work on the subcommittee to evaluate what is possible to do in our subcommittee work beginning now in January.

CONCLUSION OF HEARING

I want to thank all of you for being here. As I indicated tomorrow morning we're going to have a hearing dealing with the Beulah/Stanton/Hazen flooding issue. Then one dealing with the Linton area, just to try to get a sense of what happened there, and what might be necessary to try to mitigate that in the future.

This hearing is recessed.

[Whereupon, at 8:57 p.m., Wednesday, November 11, the hearing was concluded, and the subcommittee was recessed, to reconvene subject to the call of the Chair.]

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