MCCLUSKY CANAL IMPROVEMENTS

Jerry Schaack[1] Warren Jamison[2]

ABSTRACT

The McClusky Canal is a 74-mile (119 kilometers) long channel. It was constructed from 1969 to 1976 for transporting water from the Missouri River Basin to the Red River Basin of the north, which is in the Hudson Bay Drainage Basin. The canal is one of the main features of the Garrison Diversion Unit (GDU), which was authorized by the Flood Control Act of 1944, or more commonly called the Pick-Sloan Act. The McClusky Canal was designed with a capacity of about 2,000 cubic feet per second (56.6 cubic meters per second) to provide water for the Garrison Diversion Project to irrigate 250,000 acres (100,000 hectares) and other purposes in the state of North Dakota in north central United States. The primary water supply for North Dakota is the Missouri River, therefore, water must be transported into the Red River basin to fully develop the water resource in that area.

To transport water by gravity from the regulating reservoir (Lake Audubon) across the continental divide, it was necessary for the McClusky Canal to follow a meandering course and, at times, through over 100 foot (32.7 meters) deep cuts. Some design and construction deficiencies were also not rectified, and the Garrison Diversion project has never been completed nor operated to near its capacity or maintained properly, except during the past five years. Recent efforts to introduce legislation for project completion have renewed the need for rehabilitation and proper maintenance of the canal.

The conditions mentioned above have contributed significantly to a general deterioration of the canal and have necessitated the need for major improvements and an upgraded O&M program. Some of the major problems which are being worked on are summarized briefly below:

- Several miles have cuts as deep as 50 feet (16.4 meters) and one 2½ mile (4 kilometers) length has an average cut of 110 feet (36.1 meters). These factors, along with high ground water conditions

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District Engineer, Garrison Diversion Conservancy District, PO Box 140, Carrington, North Dakota

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Manager, Garrison Diversion Conservancy District, PO Box 140, Carrington, North Dakota

and poor surface drainage, have contributed largely to severe sliding in some portions of the canal.

- Much of the canal was not constructed with adequate side slope protection, resulting in severe erosion of some of the canal banks particularly at bends and areas susceptible to wind erosion (wind frequency and velocity is high in North Dakota).

- Inadequate drainage of the upper berm slopes and on the O&M roads have resulted in erosion, puddling of water, and deterioration and of the O&M roads.

- The O&M problems are significant: 10,000 acres (4,000 hectares) of right-of-way, 150 (240 kilometers) miles each of fence and O&M roads, five recreational lakes, numerous fish and wildlife areas and public access areas to O&M.

This paper will describe and discuss the improvements and O&M which has been conducted during the past five years to upgrade this canal to satisfactory operating conditions. The uniqueness of this canal (very deep cuts, multiple uses, design deficiencies, inactivity, minimum O&M, and general deterioration) has required innovative and unique measures not normally needed for canal improvements and O&M.

INTRODUCTION

The Garrison Diversion Project was originally authorized under the Flood Control Act of 1944 and planned to irrigate one million acres in the state of North Dakota; this was scaled back to 250,000 acres (100,000 hectares) in 1964 and to 130,000 acres (50,000 hectares) in 1986. Legislation was introduced in 1997, which will further reduce the proposed irrigation area by approximately 50 percent and change the emphasis of the project to municipal, rural, and industrial water supply. Figure 1 shows the McClusky Canal and surrounding area.

The long delay in the completion of the project and changed emphasis has caused significant operation & maintenance (O&M), and improvement problems. The McClusky Canal was designed with a capacity of about 2,000 cubic feet per second (56.6 cubic meters per second) to primarily provide irrigation water to 250,000 acres (100,000 hectares) in North Dakota located in north central United States. In addition, right-of-way for the canal was purchased for future expansion of the project to one million acres (400,000 hectares), further complicating the O&M issues.

The McClusky Canal is one of the main features of the GDU designed and constructed to transport water from the Missouri River Basin to the Red River Basin. To transport water from Lake Audubon (regulating reservoir) across the continental divide by gravity, it was necessary for the canal to follow a

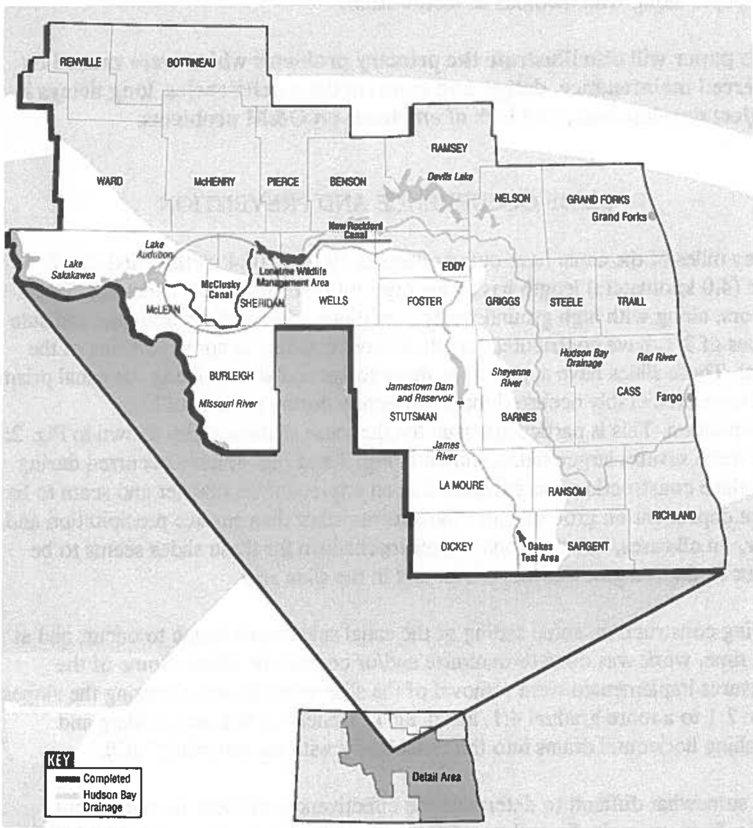

Fig. 1. An overall view of the McClusky Canal and surrounding area.

meandering course and at times through cuts in excess of 100 feet (32.8 meters). In addition, some design and construction deficiencies were not rectified or did not properly address the actual field conditions. The canal has not been operated as intended, and except for the last five years, it has not been maintained adequately. The Garrison Diversion Conservancy District assumed O&M of the McClusky Canal and other project features in 1992 under a cooperative agreement with the U.S. Bureau of Reclamation. Under this agreement, Reclamation funds the O&M of the canal and other facilities.

Recent efforts to pass legislation for project completion have reemphasized the need for initiating canal improvements and proper maintenance in anticipation of future canal operational needs. This improvement work and renewed O&M activity is being done at the present time and will be discussed in this paper along with methods of rectification.

This paper will also illustrate the primary problems which were caused by deferred maintenance, design and constructions deficiencies, long delays in project development, and lack of emphasis on O&M problems.

SLIDE OCCURRENCE AND PREVENTION

Many miles of the canal have cuts as deep as 50 feet (16.4 meters) and one 2 ½-mile (4.0 kilometers) length has an average cut of 110 feet (36.1 meters). These factors, along with high ground water conditions, poor surface drainage and side slopes of 2:1, have contributed largely to severe sliding in some portions of the canal. These slides have appeared in many forms and shapes along the canal prism and have predictably occurred more frequently during periods of high precipitation. This is particularly true for the more shallow slides shown in Fig. 2. The more severe, larger slides, shown in Fig. 3 and Fig. 4, have occurred during and since construction was completed in an unpredictable manner and seem to be more dependent on ground water movement rather than surface precipitation and flow. In all cases, however, the trigger mechanism for these slides seems to be either surface or groundwater movement in the slide area.

During construction, some sliding of the canal side slopes began to occur, and at that time, work was done to minimize and/or correct the slides. Some of the measures implemented were removal of the slide material and changing the slopes from 2:1 to a more gradual 4:1, installing T "french" drains, and drilling and installing horizontal drains into the canal banks with an "aardvark" drill.

It is somewhat difficult to determine the effectiveness of these measures, but generally it was quite limited, as many of the slides have reoccurred. Making the slope less steep helps to a limited degree; however, sliding does not appear to be as dependent on slope as it is on ground water movement in the area. In areas where ground water surfaces on the canal banks, it is likely that sliding will occur regardless of other conditions. The soils through which the canal is constructed are a glaciated nonhomogeneous-type, which is generally slowly permeable but can contain pockets of sand and gravel which transmit water readily. These soils often become unstable when wet.

Fig. 2. The two slides in the center and right side of the picture are examples of shallow slides which have occurred on the McClusky Canal.

The installation of T "french" drains (trench filled with permeable material and/or pipe drain) generally helped in slide reduction and prevention when they were properly located and intercepted water flowing onto the surface of the side slopes; however, they are quite costly, and it is sometimes difficult to locate these drains properly for effective performance. This is a viable method of slide prevention and specific applications of this method, which were effective, will be discussed later in this section.

The installation of horizontal drains drilled into the canal bank at a 90 degree angle to the longitudinal axis using the "aardvark" drilling machine resulted in very limited slide prevention. It appears that the area of influence from these drains is very small since water is moving downslope parallel to drains; thus, resulting in very little interception of the water.

Slide prevention methods during the past four years on the McClusky Canal have been intensified and quite successful. The primary methods implemented during this time are the removal of the slide material to unload the slope, along with installing a gravel "french" drain or conventional plastic pipe drain with a gravel envelope. These methods have been generally successful. In cases where flowing water is not apparent, drains are installed anyway based on observed conditions in case water movement occurs in the future.

Fig. 3. This is an example of some of the severe deep slides which have occurred on the McClusky Canal (note movement of pipe at mid right of picture)

Figure 4 shows the area where a slide occurred at a tunnel outlet and threatened a railroad track and state highway above. This was the first slide improvement completed by the District, and it proved to be successful, as the sliding has completely stopped. The procedure used was to remove some of the slide material and dig three trenches up the slope as shown in Fig. 4 to be used primarily as outlet drains to the perimeter interceptor drain also shown in Fig. 4. A corrugated plastic pipe was installed in the perimeter and outlet drains and they were filled to the surface with a gravel envelope material. As mentioned above, this method has proven to be quite successful, especially when the flowing water is evident, which makes it easier to locate the drains to achieve maximum effectiveness.

Similar work has been completed in other areas of the canal, which included unloading the slopes and installing a T "french" drain with gravel envelope.

Fig. 4. Completed french drain work on a slide which jeopardized a state highway and railroad track above the slide.

Another successful method used has been the placement of a conduit in the channel where sliding has occurred. An illustration of this work is shown in Fig. 5 displaying installation and Fig. 6 showing preparation for seeding with grass. The channel, in this case, was a 40 cfs outlet channel where sliding became apparent in 1994. The first method tried was to unload the canal banks of the slide material and change the slope to about 4:1 without installation of drains; the slide reoccurred in about two weeks. Since the slide was encroaching on the channel right-of-way, it was decided to install a 3' by 5' (0.97 meter by 1.61 meter) box culvert to eliminate the slide problem over a length of about 450 feet (145.2 meters). This work was quite costly (U.S. $250,000); however, it has been successful and will not likely cause future problems. This method may be cost prohibitive in a large, long channel; however, it should be considered for shorter, smaller channels.

Fig. 5. Placement of box culvert to repair slide area where right-of-way width was limited.

V DRAIN IMPROVEMENTS

Shallow, open V drains were dug at the intersection of the berm side slope and the outside of the O&M road during construction. The purpose of these drains was to provide drainage for the O&M roads and for the berm areas. However, snow and water accumulates and freezes in these drains in the late fall and spring and thaws very slowly, making them ineffective when they are most needed. It should be noted that these conditions are unique to northern latitudes in the United States, which experience freezing temperatures during much of the October to March time period. Weed growth and sediment also collect in these drains, which accentuates the problem. This inadequate drainage has caused the O&M roads to deteriorate rapidly, making them unusable for long periods of time.

The purpose of this drainage improvement work is to protect and improve the O&M roads and make them usable on a more timely basis, especially during the spring and after heavy rains by providing drainage for the O&M roads and intercepting surface and subsurface water moving down the berm banks. This drainage problem is a design and construction deficiency which requires correction.

Fig. 6. An overall view of the completed work shown in Fig. 5. The area has been seeded and a mat installed to prevent erosion.

This deficiency is being corrected by the installation of a six-inch (15 cm) diameter slotted corrugated pipe tubing into the open drain, which is excavated to the desired grade at an average depth of about four feet (1.29 meters). A graded gravel envelope material, ranging in size from 0.75 inches (1.9 centimeters) to a 200 screen size, is placed in the trench so that the drain tubing is enveloped in at least four inches (10.2 centimeters) of the material. The graded envelope material is brought to about 1.5 feet (0.48 meters) above normal ground surface. The purpose of extending the gravel envelope above ground surface is to provide a catch basin for sediment accumulation and removal. Figure 7 illustrates the installation of these drains on the McClusky Canal.

This improvement program has been very effective in providing drainage for the O&M roads and intercepting and draining surface and groundwater from the berm area. Many of the O&M roads are now passable in a timely manner throughout much of the year, and the general condition of the roads and berm areas have improved dramatically, resulting in a significant savings of time and money. Prior to the installation of these drains, sloughing and sometimes total collapse of the O&M roads were experienced; this problem is now minimal.

Fig. 7. V drain installation at the outside of the O&M road. Note the drain tubing at the bottom center of the picture.

These drains are functioning properly; however, a program for drain evaluation is planned for this year to determine drain effectiveness and possible changes that should be made in drain construction and operational activities.

All of the drainage improvement work has been done with District forces and equipment, which is shown in Fig. 8; an average of about 600 feet (193.5 meters) of drain can be installed in an ten-hour day with a six-person crew. This drainage program has been in effect since 1992, and about 40 miles (64 kilometers) of the drains have been improved in the manner described above at about a cost of U.S. $50,000 per mile.

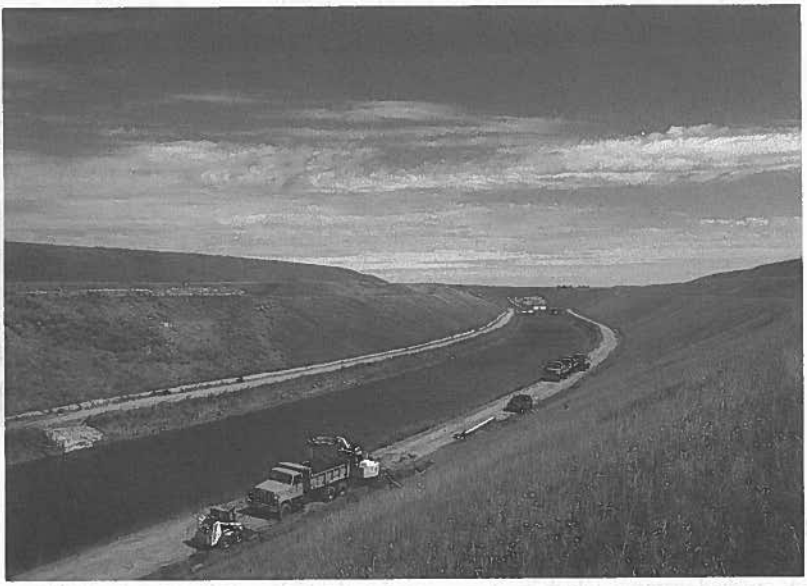

Fig. 8. A bird's eye view of the V drain installation showing the equipment used. The canal cut is about 110 feet, one of the deepest cut areas of the McClusky Canal.

CANAL SIDE SLOPE PROTECTION

Much of the McClusky Canal was constructed with inadequate side slope (bank) protection. This has resulted in severe erosion and undercutting of the canal banks, particularly at bends and areas susceptible to wind erosion, which is quite intensive in this area. This erosion has also caused concern for losing the integrity of the canal, particularly in some of the high fill sections. The canal is lined in some sections, and the erosion has encroached on the lining under certain conditions. Most of the McClusky Canal has been constructed in glacial till soils, which are quite variable and mixed and often susceptible to sloughing. These soils have accentuated the erosion problem and emphasized the need for timely correction. Figure 9 shows a typical example of erosion that has taken place on the unprotected canal banks.

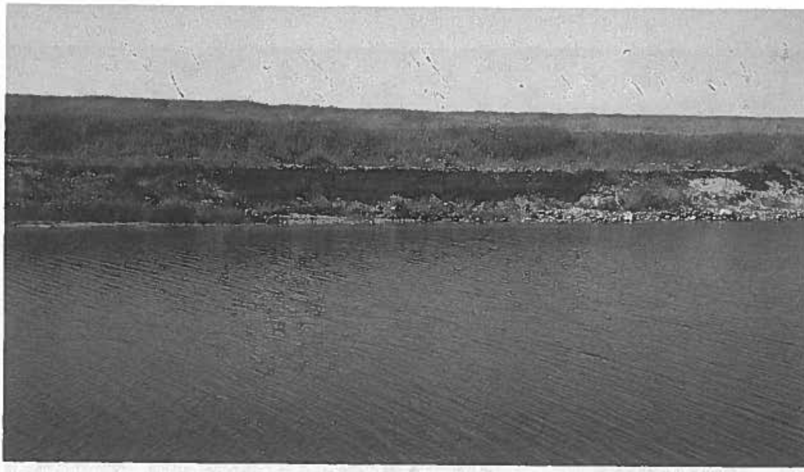

Fig. 9. A typical example of erosion and sloughing of the canal banks (side slopes).

The lack of canal bank protection is being corrected by placing a graded material (often referred to as beachbelting) on the side slopes of the canal. The gradation of this crushed material, which is normally used in the highly eroded areas and where the integrity of the canal may be in jeopardy, such as a high fill area, is given below.

Screen No.	% by weight passing
4 inch (10.16 cm)	100
1 ½ inch (3.81 cm)	40-60
3/4 inch (1.91 cm)	5-15
3/8 inch (0.95 cm)	less than .5

In the cut portions and other lengths of the canal which are less susceptible to erosion and loss of canal integrity, other types and gradations of beachbelting has been used. This material has varied from pit run gravel to a rounded-type material that is available on the project. These types of materials have been primarily used on a test basis; however, they appear to provide adequate bank protection at a much lower cost than the crushed graded material described above, which is relatively expensive.

The installation of the graded crushed material has been primarily done under contract, and the cost has varied from US $17-20 per linear foot (0.32 meters) of canal. A procedure for the installation of the beach belting material, which is quite effective and efficient has been developed. It consists of clearing the bank of vegetation and other material about ten feet between stipulated elevations and hauling in and placing selected material to obtain a smooth side slope. The bank is then watered and compacted with a roller attached to a backhoe. About a 12-inch (30.5 cm) keyway is cut into the bank at the bottom elevation and sloped upward to prevent slippage of the beachbelting material. A permeable geotextile material is then placed on the canal side slope to hold the soil in place. A front-end loader or conveyor attached to the rear end of a dump truck distributes the beachbelting material evenly on the geotextile and canal bank.

A limited amount of this work has been performed by District forces, and we anticipate more will be done in the future as most of the critical areas are complete. Depending on the results of the test sections, which to date look very satisfactory, it is anticipated that a significant amount of this work will be completed using pit run or a less restrictive graded material resulting in optimum utilization of District forces and equipment and cost savings.

Figures 10 and 11 illustrate the installation of the beachbelting material on the canal side slopes and Fig. 12 shows the completed work.

Fig. 10. Organic and other foreign material is removed followed by placement of material on the bank. The bank is then smoothed, compacted and a keyway (upper right) installed to prevent slippage of material.

Fig. 11. The beach belting material being placed on the geotextile on the canal bank.

Fig. 12. The beach belting placement is complete.

OPERATION AND MAINTENANCE ACTIVITIES

General

The operation and maintenance (O&M) activities on the McClusky Canal are significant: 10,000 acres (4000 hectares) of right-of-way, 150 miles (240 kilometers) each of fence and O&M roads, five recreational lakes, public access and use and numerous wildlife development and habitat areas. The problems normally anticipated in the O&M of an irrigation canal have been magnified by the factors stated above along with deferred maintenance, and design and construction deficiencies. The different aspects of the O&M program activities are described below.

The annual expenditures for normal O&M activities is approximately US $1 million, and the average cost of the canal improvement work is approximately US $1.4 million. This improvement work includes repairing of slides, installation of pipe drains, and beachbelting work as discussed above. At the peak of the season, about 20 personnel, who are stationed at the McClusky O&M Office, perform work on the canal. These workers are employed as permanent, permanent seasonal, and temporary employees at salaries commensurate with similar jobs in the regional area. Health, retirement, vacation and other benefits are also provided to all but the temporary workers.

Right-of-Way Operation and Maintenance (ROW)

The ROW for the canal is much larger than is presently needed because it was acquired in anticipation of expanding the project to about four times its original size. The ROW is managed for optimizing wildlife habitat, noxious weed control, recreational activities, and public use such as camping, hunting and hiking. The District has developed and implemented an integrated pest management (IPM) program to enhance the environment and minimize chemical usage for vegetative control. Some of the methods used include mowing the ROW on a five-year rotation, grazing, burning, fish and insects.

The mowing and grazing programs are done in cooperation with area farmers on a competitive bidding process. The Garrison Diversion Conservancy District is presently seeking approval for the use of grass carp in the canals for aquatic weed control, and insects have been released in certain areas for leafy spurge control.

The IPM program has been very effective from the standpoint of cost savings, environmental enhancement, safety and improved control and additional emphasis will be placed on this program in the future.

Operation and Maintenance Roads and Fence Repair

There are about 150 miles (240 kilometers) each of O&M roads and fence to maintain on the canal and ROW. The roads are bladed at least two times per year, depending on rainfall and usage. In the public access areas where use is high, they are sometimes maintained more frequently. All of the ROW was originally fenced; however, in areas where fencing is not needed, it is removed and permanent ROW markers constructed.

Recreational Lakes and Public Access

There are at least seven major lakes on or adjacent to the canal which are used for fishing, boating, swimming and other water recreational activities. The water levels and quality are maintained in these lakes in cooperation with fish and wildlife and park personnel to optimize all recreational activities. Minimum flows are also maintained in downstream creeks to enhance aquatic life and water quality and the environment. Most of these lakes are excellent fisheries and receive high usage throughout the year. Some portions of the canal are also fished quite heavily and hunters frequently use the O&M roads to gain access to their favorite hunting spots, which are often in the vicinity of the lakes and canal. Public use of the canal ROW is allowed, as long as long as it is reasonable and safe.

The McClusky Canal ROW has recently been designated as part of the North Country Trail, which is a non-motorized national trail extending through the northern United States from the state of New York through North Dakota.

Wildlife Areas

There are about 20 wildlife management and development areas along the McClusky Canal, and these are managed in cooperation with the North Dakota State Game and Fish Department and the U.S. Fish and Wildlife Service to obtain optimum benefits. An excellent example of cooperative and conjunctive benefits is the enhancement and development of Lakes Brekken and Holmes as recreational lakes in conjunction with the development of six wildlife areas and stream enhancement. Lakes Brekken and Holmes were initially saline lakes dependent on precipitation for their water supply. Water from the McClusky Canal is now used to improve their water quality and stabilize levels. The poorer quality water is drained and used for the development and management of six wildlife areas downstream. The water is ultimately released further downstream for stream enhancement before it flows into the Missouri River. A win-win situation.

SUMMARY AND CONCLUSIONS

This paper illustrates several problems and conditions which were encountered in the planning design, authorization, construction, operation and maintenance of a major water project. The history of the Garrison Diversion Project began in 1944, when the original authorization was passed and continues on today with the recent introduction of legislation, which will dramatically change the focus of the project. Most of the main supply works were constructed in the time frame of 1968-1976 for a 250,000 acre (100,000 hectare) transbasin irrigation project. The legislation introduced in 1997 would provide funding for a comprehensive water project providing municipal, rural and industrial water development, irrigation development of 70,000 acres (28,000 hectares), fish and wildlife, and other interests. When constructed, it will provide a badly needed affordable and reliable water supply to develop the water resources of North Dakota.

The major problems which have been encountered during the development and construction of this project are discussed in this paper and are summarized below.

Design and Construction Deficiencies: The design did not take into consideration the susceptibility of the canal side slopes and berms to major sliding. The cause(s) of slide occurrence during construction was not adequately addressed. The canal side slopes were also not properly protected, and drainage of the O&M roads and berms was inadequate for the conditions normally encountered. These conditions have caused major problems in the O&M and improvement work on this canal.

Deferred Operation and Maintenance: Much of the needed maintenance and improvement work on the canal was deferred for a relatively long period of time, resulting in significant deterioration of the canal due to erosion, general inattention, inadequate drainage, and sliding.

Delays and Changing Objectives: Due to the extremely long delays in final approval and funding, project objectives changed significantly. For example, the primary benefits changed from irrigation to a more comprehensive water resources project. This, in turn, dramatically reduced the water requirements for the project. Other project needs are also changing, which will likely result in changed development and operational requirements.

Approximately 550,000 acres (220,000 acres) of prime North Dakota farmland was inundated by Oahe and Garrison Reservoirs, which provide benefits to all Missouri River Basin states under development of the Pick-Sloan Act. North Dakota has received fewer benefits than most states and has given more in the form of lost farms and economic development. This is an irritant and constant frustration to project proponents.

Some of the problems encountered in the history of this project, such as design and construction deficiencies and deferred O&M were probably preventable: however, it is always easier to look back and be wiser. Hopefully, this history will provide a more efficient process for the future. However, the history of water project authorization, funding, and development is an arduous one and is sometimes inherent in our legislative and political process even though it is costly, frustrating, and time consuming. The GDU project has been no exception to this process.