NAVAJO NATION
DEPARTMENT OF WATER RESOURCES
WATER MANAGEMENT BRANCH

FINAL DRAFT

TECHNICAL MEMORANDUM

FEBRUARY 9, 1998

AN APPRAISAL-LEVEL STUDY OF THE CAPACITY AND WATER DEMAND OF THE SHIPROCK IRRIGATION PROJECTS

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EXECUTIVE SUMMARY

The primary objective of this technical memorandum is to determine if the current canal capacities are adequate to meet the water demands of the Shiprock irrigators. The second objective is to compile background information on the irrigation projects which may help to ensure their successful participation in a number of water resources programs. And, the third objective is to present a plan of action for improving the operation of the irrigation systems. This action plan describes the initial steps toward transferring a greater portion of the system's operational responsibility to the local water users and the development of a comprehensive Rehabilitation Plan that can be submitted to Congress in FY2002. This technical memorandum also includes many of the elements needed for a Water Management Plan.

The Shiprock Irrigation Projects include the Hogback, Fruitland, Cudei and Cambridge Projects Based on the literature reviewed for this Technical Memorandum the Hogback Irrigation Project includes approximately 510 farming plots, 8,268 assessed acres, 28.6 miles of canals and 135 miles of laterals. The Fruitland Irrigation Project includes approximately 350 farming plots, 3,830 assessed acres, 24 miles of canals and 120 miles of laterals. The Cudei Irrigation Project includes approximately 46 farming plots, 627 assessed acres, and 4 miles of canals. And, the Cambridge Irrigation Project includes 9 farming plots, 160 acres, and 4 miles of canals.

Based on a combination of historic measurements, design documentation, and hydraulic analysis the flow capacities for each canal reach were bounded between theoretical lower and upper values. Using the BIA 1993 crop utilization data and the Keller-Bliessner Engineering crop water requirements the demand for each reach and the aggregate demand downstream of each reach was determined. The maximum peak water demand is based on a conveyance efficiency of 50 percent, an on-farm efficiency of 40 percent, and the total project acreage as reported in the 1993 BIA study with 20 percent of that acreage idle or fallow. The minimum estimate of the peak water demand is based on a conveyance efficiency of 50 percent, an on-farm efficiency of 60 percent, and the total irrigated acreage as reported in the 1993 BIA study with 20 percent of that acreage idle or fallow.

Uncertainty surrounding the canal capacities and water demands makes it difficult to reach definitive system wide conclusions regarding the adequacy of the canal capacities. However, from the data presented, it appears that the reaches upstream from the siphon under Highway 666 (including reaches 140 through 175) are not passing enough water. The peak water demand is between 200 and 340 cubic feet per second while the capacity is only 160 cubic feet per second. The up stream end of the siphon is submerged during most flow conditions. One hypothesis is that the down stream canals are choked with sediment causing water to back up in the system. Another hypothesis is that poor control on the wasteways may be responsible. Unfortunately, it is not immediately obvious which of the hydraulic control structures may be causing this problem. It also appears that on the Fruitland Project the reaches downstream from Reach 40, the Yellowman Siphon Turn Out, are just barely adequate to meet the existing demands.

Water users, operators and other staff familiar with the operation of the Shiprock irrigation projects were interviewed to identify additional concerns. For completeness, all of the comments received from the water users were included. These comments and the reaches cited will be further investigated to develop a better hydraulic understanding of the problems and possible solutions. The comments primarily reflect a lack of system resources to keep up with long deferred system maintenance. Shortages were reported at toward the ends of many of the major laterals.

Performance parameters for the Shiprock Irrigation Project were compared to parameters of other non-Indian irrigation system in the western United States. Including Tribal General Funds, the NDWR spends approximately 700 dollars per mile of canal. Non-Indian systems in the western United States typically spend approximately 3,000 dollars per miles. The gross crop value on the Shiprock Projects is 189 dollars per acre while the gross crop value of the non-Indian projects in the area is 341 dollars per acre. The cropping intensity on the Shiprock Projects is less than 50 percent while the cropping intensity of the non-Indian projects is between 80 and 90 percent. The Shiprock Projects have 40 acres of irrigated land per mile of canal, while the non-Indian systems have between 100 and 140 acres for each mile of canal.

The Navajo DWR receives approximately $215,000 of General Funds for the operation and maintenance of the Shiprock irrigation projects. The Shiprock irrigation staff includes five permanent employees and two part time employees. The staff consists of a supervisor, a clerk, four equipment operators and a welder. At the present time there is no ditch rider position. Low salaries and personnel policies were cited as obstacles to modifying the staffing system. The current personnel policies make it difficult to provide delivery service over the weekend which is when most of the water users prefer to irrigate. The Shiprock Irrigation Office maintains 16 pieces of heavy equipment. During the summer of 1998 about half of that equipment was inoperable. The irrigation office has no funding for equipment repairs.

The Navajo Nation farmboards are a division of Chapter government. They are responsible for a wide variety of farming activities including input on land use permitting, non-irrigated farms and farms associated with the irrigation projects. The Navajo Nation Farmboard Plan of Operation allows the Farmboards to collect a water assessment for the operation and maintenance of the irrigation project. This assessment may revert directly to the Farmboard (3 N.N.C. Section 62). The DWR/WMB has worked with the Department of Agricultural and the water users to prepare a Fund Management Plan based on the tribal regulations for nonprofit corporations. The draft Fund Management Plan describes the Farmboards establishing representative water users associations governed by their own bylaws and the articles of incorporation as a nonprofit corporation. This association may, over time and based on the concurrence of the NDWR, take on greater and greater responsibility for operation and maintenance of the irrigation system. This responsibility may include hiring ditch riders to administer water deliveries. Based on the bylaws, the associations will have a representative mechanism for changing assessments and developing penalties for delinquencies.

The Farmboard, through its association, will also hold a Water Use Permit describing the irrigation project's place of use, point of diversion and type of use. This permit will define and protect the irrigators water uses. The proposed Water Use Permit may also describe special conditions protecting the irrigators on the system.

One of the objectives of this study is to compile background information which may help to ensure the Navajo Nation's successful participation in appropriate programs and to identify key management concerns. Based on the literature review and on discussions with water users and managers, some of the key water management concerns are presented.

- Low cropping intensity, low crop values and low operation and maintenance assessments
- A critical need for system wide and on-farm rehabilitation and reconfiguration
- Lack of water control and the need for greater water user participation
- Subdivision of land for home sites
- Seepage and operational losses
- Salinity control
- Compliance with the Endangered Species Act
- Reestablishing Area Seven and other lease areas
- Developing a fee schedule and operating budget
- Poorly defined Right-of-Ways

One of the objectives of this technical memorandum is to present recommendations that can be formulated into specific proposals for the appropriate federal or tribal agency. Most of these recommendations were presented in earlier drafts of this Technical Memorandum. Based on comments received and recent accomplishments, these recommendations are presented as a chronological action plan. The higher priority activities are scheduled earlier and the sequence of recommendations results in a critical path. These recommendations fall into three general categories:

- Recommendations for correcting immediate system deficiencies,
- Recommendations for organizing the water users, and
- Recommendations for developing a rehabilitation plan for congressional authorization in FY2002 as part of the Navajo Nation's interim settlement on the San Juan River.

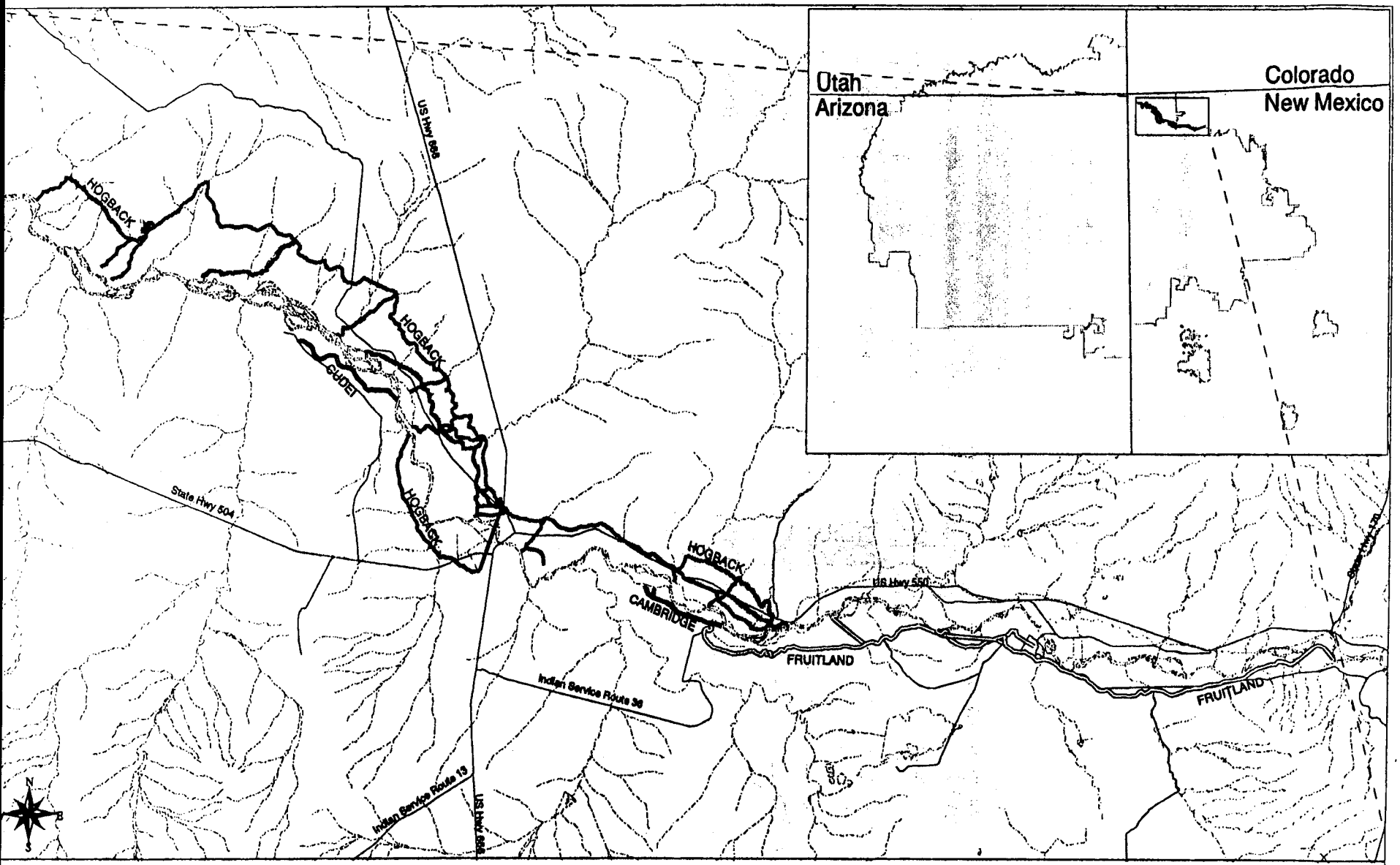
The Plan of Action presented starts with the major activities completed in Fiscal Year 1996. The ability to adhere to this proposed schedule depends largely on the availability of several hundred thousand dollars to complete 27 tasks. These tasks are described in greater detail in Section 12.

1 *INTRODUCTION*

The Navajo (Dine') people irrigated fields along the San Juan River long before non-Indian farmers moved into the region. The Hogback, Fruitland, Cudei and Cambridge irrigation projects divert water directly from the San Juan River in New Mexico. These projects are shown in Figure 1. Projects located in Utah are beyond the scope of this memorandum. Federal participation began in the early 1900's when the United States Indian Irrigation Service (USIIS) expanded the Navajo irrigation projects along the San Juan River and its tributaries. Over subsequent decades the U.S. Bureau of Indian Affairs (BIA) attempted to improve, extend and operate these projects. As a result of Public Law 86-636 (74 Stat. 470), effective October 1, 1962, the BIA explicitly transferred the Hogback, Fruitland and Cudei irrigation projects, and the responsibility for operation and maintenance, to the Navajo Nation. The Cambridge irrigation project is operated by its Navajo water users.

There are several justifications for examining these irrigation projects. First, the crop production and crop intensity of these projects lag far behind the non-Indian projects in the region. Improving the performance of these irrigation projects will benefit the economy of the Shiprock area. Second, as a result of decades of inadequate maintenance, a chronic need has developed for rehabilitating or reconfiguring many of the project facilities. Third, these projects divert water from, and discharge return flow into, the designated critical habitat for the Colorado Squawfish and Razorback sucker. And finally, the Navajo Nation will soon begin to quantify and resolve its water rights within the San Juan River Basin.

Successfully addressing these issues will require an improved understanding of the operation and constraints facing these irrigation projects. This technical memorandum may provide a basis for beginning the work necessary to improve the irrigation systems. But, the water users participation and leadership are critical to the future success of these irrigation projects. These projects will only survive and prosper, if the water users become an integral part of the decision making process.



Cambridge
Cudei
Fruitland
Hogback
Major Roads
Drainages

1:250000

3 0 3 Miles

Figure 1

SHIPROCK IRRIGATION PROJECTS
Location Map
January 07, 1998
Department of Water Resources

2 GOALS AND OBJECTIVES

The primary objective of this technical memorandum is to determine if the current canal capacities are adequate to meet the water demands of the Shiprock irrigators. This study includes field measurements at strategic locations along the irrigation canals. This data was used to estimate canal capacities, develop a water budget, and identify system deficiencies. These measurements, along with the implementation of a systematic data collection plan for the Shiprock irrigation projects will improve the system operation. This information will improve the understanding of the projects' problems and opportunities, and it will be included in a water management plan.

A second objective of this study is to compile background information which may help to ensure the Navajo Nation's successful participation in some of the following programs:

- San Juan River Recovery Implementation Program
- U.S. Bureau of Reclamation (USBOR) Colorado River Basin Salinity Control Program
- USBOR Native American Affairs Office Programs
- USBOR Water Conservation and Management Program
- USDA Environmental Quality Incentive Program (E.Q.I.P.)
- BIA Shiprock Area Office programs
- BIA Gallup Area Office programs
- New Mexico Interstate Stream Commission and other State programs

A third objective is to present a plan of action for improving the operation of the irrigation systems. This plan will describe the initial steps for transferring a greater portion of the system's operational responsibility to the local water users and developing a Rehabilitation Plan that can be submitted to Congress by FY2002.

To achieve these objectives, the Department of Water Resources Water Management Branch (DWR/WMB) completed the following tasks:

- Developed an improved GIS ArcView coverage including the main canals and principal laterals of the four irrigation projects
- Compiled flow and seepage measurements

- Estimated the flow capacity of canal reaches
- Compiled data on the assessed irrigated acreage and used this data to estimate the crop water requirements and diversion requirements
- Determined critical water control points
- Developed recommendations for further investigations and an action plan

3 *SHIPROCK IRRIGATION PROJECT DESCRIPTIONS*

Past documents on these projects frequently include inconsistent data. Several sources were reviewed to develop a reasonable range of project parameters. According to the 1993 BIA Crop Utilization Survey (BIA, 1993) the total acreage of the Hogback. Fruitland and Cudei irrigation projects is 13,680 acres. This 1993 BIA data set was used for this analysis. The project descriptions are based on information compiled from the following reports:

- The Detailed Conservation Soil Survey of the Fruitland Irrigation Project (U.S. Dept. of Interior [USDOI], 1942)
- The Navajo Long Range Program for Navajo Rehabilitation (USDOI, Krug, 1948)
- The BIA Completion Report (BIA, December 1962)
- The Inventory of Navajo Indian Irrigation Projects (United States Department of Agriculture Soils Conservation Service [USDA SCS], 1986)
- Draft Design Proposal, Navajo Indian Irrigation Projects in the Shiprock, New Mexico Area (USBOR, January 1989)
- Navajo Indian Reservation Hogback & Fruitland Irrigation Projects, Crop Utilization Survey (BIA, October 1993)
- Expanding Distribution of Colorado Squawfish in the San Juan River (BIO/WEST Inc., December 1996)

3.1 *The Hogback Irrigation Project*

The Hogback Irrigation Project is shown in Figure 1. The project lands are located on both sides of the San Juan River and extend from the Hogback approximately nine miles east of Shiprock, New Mexico, to about 17 miles northwest of Shiprock, near the Four Corners area. This diversion structure is located at river mile 158.9. Based on the BIA completion report (1962), the federal involvement with the Hogback irrigation canal dates back to 1904.

According to the USBOR Design Proposal (1989), the Hogback Project includes 28.6 miles of concrete and earth lined main canal and 135 miles of field laterals. The system includes 1,990 structures including eight siphons ranging in length from 650 feet to 2,300 feet, and four concrete wasteway structures.

Based on the description prepared by BIO/WEST (1996). the diversion structure is constructed of alluvial fill materials pushed up from the river bed to form a berm across the channel and is routinely damaged and reconstructed with major flow events. The size and configuration vary from year to year. The diversion structure forces water into a side channel where water either passes through radial gates into a canal or returns to the main channel using a side channel as a sluiceway. The headgate is a remanent of an older quarry rock structure. Up to 1,700 cubic feet per second (cfs) of water can be diverted into the inlet bay where the majority of flow passes through a sluiceway back to the main channel. Radial gates in the control structure are used to regulate flow into the irrigation canal. Approximately 300 cfs of water typically passes into the irrigation canal. A second sluiceway, located approximately 1,500 feet down stream returns about 100 cfs back to the main river channel. Approximately 200 cfs continues down the canal for irrigation.

According to the Krug report (USDOI, 1948) 4,832 acres of the Hogback Irrigation Project were "under ditch" and 11,500 acres were ultimately irrigable. According to the BIA 1962 completion plan, the Hogback Project included 9,614 acres of irrigable land. According to the USDA SCS 1986 inventory, this project included 6,460 acres. According to the USBOR design proposal (1989), the project includes 8,869 total acres and 7,795 acres of cropland. Based on the 1993 BIA crop utilization data, the project includes 510 farming plots totaling 8,268 assessed acres.

The Hogback Project includes seven main laterals including the A and B pump Laterals, the NCC Lateral, the NTUA Lateral, the Helium Lateral, the Area 2 Lateral, and the Area 7 Lateral:

- The A and B Laterals are supplied by pumps in the main canal. The A Lateral has ten turnouts and a capacity of 11 cfs. According to the BIA crop utilization data (1993) the lateral provides water to 279 acres. The B Lateral has 15 turnouts and a capacity of 15 cfs. According to the BIA crop utilization data (1993) the lateral provides water to 667 acres.

- Based on a review of aerial photographs, it appears that the NCC Lateral provided water to approximately 40 acres of landscaping on the Dine' College (formerly Navajo Community College) compound. The lateral has also provided water to the 76.4 prime acres on a demonstration farm. For this investigation it was assumed that this lateral needed to provide water to 100 acres.

- According to the 1993 Molzen-Corbin study, the NTUA Lateral currently has a 900 gallons per minute capacity (2 cfs) to gravity feed water from the Hogback Canal to the NTUA Shiprock water treatment plant. Molzen-Corbin projects a maximum demand of 6.6 cfs by the year 2013.

- The Helium Lateral originates at canal mile 9.18, west of Highway 666 on the north bank of the San Juan River. The Helium Lateral turnout is 36 inches in diameter. This lateral passes through approximately 150 feet of open canal, a Parshall flume, 9,500 feet of 40 inch diameter reinforced concrete siphon pipe (which crosses under

the San Juan River to the south bank), and approximately 4.2 miles of earth canal which includes two 40 inch diameter steel siphons and a steel flume for crossing washes. According to information provided by the BIA Shiprock staff which included permitted farm plot data and Navajo Community College lease maps, this lateral serves 999 irrigable acres.

NCC on 2 laterals?

- The Area 2 Lateral is to the west of Highway 666. The length of this lateral is 9.9 miles. According to the BIA crop utilization study (1993), this lateral serves 1,058 irrigable acres.

Can't get a picture of the layout based on these descriptions. How about referring to Reach by Reach Schematic

3.2 *The Fruitland Irrigation Project*

The Fruitland Irrigation Project is shown in Figure 1. The headworks are located two miles west of Farmington, San Juan County, New Mexico, on the southern bank of the San Juan River at river mile 178.5 about 0.4 miles upstream from the confluence of the La Plata River. According to the 1942 USDOI report, the USIIS started to subjugate farm lands along the Navajo irrigation projects in 1937. The diversion structure is located on land which was owned by the Navajo Mission and is now owned by the City of Farmington. !?

Based on the description prepared by BIO/WEST (1996), the diversion structure is a quarry rock structure that is maintained on an as-needed basis. A sluiceway to the river adjacent to the canal can sluice up to 1,000 cfs back to the river through two 10 foot wide gates. During midsummer these gates are operated to allow a flow of 100 to 200 cfs through the sluiceway. The gates are opened wider during periods of higher flows and are left open during the winter. The capacity of the canal is approximately 165 cfs although 120 cfs is considered the likely maximum. With the sluiceway wide open, the water velocity in the sluiceway was between 6.00 and 6.25 fps, with a 2.5 foot difference in the water surface elevation across the structure.

According to the 1962 BIA completion report, the main canal extends from the headworks west approximately 24 miles along the southern bank of the San Juan River. The Fruitland Project includes 24 miles of concrete and earth lined main canal and between 97 and 120 miles of field laterals. According to the USBOR design proposal (1989), the project includes 1,201 structures including three main siphons ranging in length from seventy feet to 9,248 feet and eleven wasteway structures. Yellowman Siphon is the longest of the siphons. Portions of it are very badly rusted. A multi-phase rehabilitation effort is underway and the worst sections have been replaced. This siphon provides water to more than 1,250 acres and more than 100 Navajo families.

According to the Krug report (USDOI, 1948) 3,275 acres of the Fruitland Irrigation Project were "under ditch" and ultimately irrigable. According to the USDA SCS 1986 inventory, the Fruitland Project includes 3,675 acres. According to the USBOR design proposal (1989), the project includes 3,718 total acres and 3,165 acres of cropland. According to the 1993 BIA crop utilization data, the project includes approximately 350 farming plots totaling 3,830 assessed acres.

The 93 BIA data seem to be consistently [illegible] acreage

3.3 *The Cudei Irrigation Project*

The Cudei Irrigation Project is shown in Figure 1. The headworks are located eight miles west of Shiprock, San Juan County, New Mexico, on the southern bank of the San Juan River at River Mile 142.0. The main canal extends from the headworks west along the southern bank of the San Juan River. According to the USBOR design proposal (1989). the project includes 12 miles of earth lined main canal and 16 miles of field laterals. The project contains 50 structures including three sluice gates, 26 turnout gates, and 21 concrete drop/gate structures. According to the Natural Resource Conservation Service (NRCS), federal involvement with this project dates back to 1900.

Based on the description prepared by BIO/WEST (1996), the diversion structure is constructed of quarry rock and can divert approximately 40 cfs. The main sluiceway consists of a five-foot diameter corrugated metal pipe with concrete head wall and control gate. The canal inlet consists of a three-foot diameter corrugated metal pipe with concrete head wall and control gate. The total volume of water remaining beyond the sluiceway is about 20 cfs and can be as high as 30 cfs. The diversion structure is about 800 feet wide with about 430 feet of the total length functioning as an overflow section. The flow through the notch in the center of the dam drops 4.5 feet in about 30 feet at a velocity of 8 feet per section (fps) at low river flows of approximately 1,000 cfs.

According to the Krug report (USDOI, 1948) 600 acres of the Cudei Irrigation Project were "under ditch" and 800 were ultimately irrigable. According to the USDA SCS 1986 inventory, the Cudei Project includes 670 acres. According to the USBOR design proposal (1989), the project includes 670 total acres and 569 acres of cropland. Based on the 1993 BIA crop utilization data, the project includes approximately 46 farming plots totaling 627 assessed acres.

I take back what I said about BIA

3.4 *The Cambridge Irrigation Project*

The Cambridge Irrigation Project is the smallest of the four projects and is shown in Figure 1. Due to a lack of information, it did not receive as much attention as the other projects. The headworks are located upstream of the last Fruitland wasteway and the southern bank of the San Juan River. This project is the oldest and smallest of the four irrigation projects. The system includes a concrete head wall and diversion gate, and approximately four miles of earth-lined canal. The diameter of the headwork gate is 36 inches.

According to the Krug report (USDOI, 1948). 300 acres were under ditch and ultimately irrigable. According to the USDA SCS 1986 inventory, the project includes 160 acres. These irrigated farming plots and their acreage are not assessed. These fields were included as field plots 341 through 350 in the BIA crop utilization report (1993) and totaled 159.9 acres.

4 *PROJECT MAPS AND DIGITAL COVERAGES*

One of the objectives of this investigation is to identify the most useful project maps and to prepare an improved digital coverage of the canals and laterals. Staff from the DWR/WMB attempted to locate copies of the current maps and to use them to improve the digital information. The results of that search are presented in this chapter.

4.1 *Project Maps*

Project maps were collected to determine canal alignments and the location of the fields irrigated by each canal and lateral. Based on the maps that were identified for this investigation, currently available project maps are not adequate for system wide rehabilitation or reconfiguration purposes. The following maps were available:

- USDOI, United States Indian Irrigation Service, A.L. Wathen, Director; H.V. Clotts, Assistant Director; H.C. Neuffer, Supervising Engineer, Fruitland Irrigation Project "As-Builts" for flume, silt-trap & wasteway, headworks, and sluice main, Dated June 26, 1934, Scale: 1"=1', 1"=2', 1"=3', 1"=5', 1"=8', 1"=20', and 1-1/2"=1', Fruitland, New Mexico

- USDOI, United States Indian Service, Navajo Agency Irrigation Division, Fruitland Irrigation Project, Dated: April 4, 1950, Scale: 1"=200', Surveyed: K.J.H., Drawn: B.B.R, Traced: B.B.R, Fruitland, New Mexico

- United States Department of Interior, Branch of Land Operation, Cudei Project, Map traced from aerial photo flight August 15, 1952, Nos. 1-52, 1-104, Cudei, New Mexico

- USDOI BIA, Hogback & Fruitland Irrigation Projects, General Map-Plan view, Dated: August 1961, Scale: 1"=1 mile, Index Map, Fruitland and Shiprock, New Mexico

- USDOI, U.S. Indian Service, Navajo Agency Irrigation Division, Fruitland Irrigation Project, Sheets 1 through 4, Dated: Dec. 1, 1939, Scale: 1"=800', Fruitland, New Mexico, Revision dates: March 26, 1947 & June 4, 1962

- Navajo Nation Division of Water Resources, Planning and Design, Fruitland Irrigation Project, Details and As-Builts, Sheets 1 through 6, Designed by: H.B., Dated: August 1934, Redrawn By: Nelson Begaye, December 1983, Redrawn By: L. Kanuho, Fruitland, New Mexico

- United States Department of Interior, Bureau of Indian Affairs, Shiprock Agency, Hogback and Fruitland Irrigation Projects, Aerial Photographs, Dated: February 8, 1987. Scale: 1"=660', Photographs are not rectified for distortion. Fruitland and Shiprock, New Mexico

- Navajo Nation Division of Water Resources, Water Development Department, Hogback Irrigation Project, Sheets 1 through 13. Project Number: HOGB-1000-86-0001, Shiprock, New Mexico, 1986, 1 in = 650 ft

4.2 *Digital Coverages*

For this investigation, the Water Management Branch digitized the main canals and primary laterals of all four projects. The primary source map for this coverage is the U.S. Geological Survey (USGS) 1:100,000 Farmington, NM (1980). Additional details were derived from the following USGS 1:24,000 quadrangles:

- Hogbck Project - The Hogback North (1966), Chimney Rock (1983), Shiprock (1983), Rattlesnake (1983), Canal Creek (1983), and Sallies Spring (1983)
- Fruitland Project - Kirtland (1966), Fruitland (1966), and The Hogback North (1966)
- Cudei Project - Chimney Rock (1983), and The Hogback North (1966)
- Cambridge Project - Rattlesnake (1983), and Shiprock (1983)

4.3 *Canal Attributes*

Reach numbers, descriptions, and ranks are shown in Tables 4.1, 4.2, 4.3, and 4.4. ArcView schematics are presented in Appendix 1. The attributes in these tables and the GIS digitized coverages are defined in the following sections.

4.3.1 *Canal Reaches*

For this analysis a canal reach is defined as a section of canal which has a uniform lining and presumably a uniform flow capacity. For this analysis, the Hogback Project includes 54 reaches, the Fruitland Project includes 21 reaches, the Cudei Project includes three reaches and the Cambridge Project includes one reach.

4.1
4.1

TABLE 1A
Hogback Irrigation Project - Reach by Reach Attributes

Reach Number	Description	Approx. canal distance (miles)	Rank	Lining
220	Headworks to Sluiceway	0.35	Main Canal	Concrete
215	Sluicway/Wasteway	0.35	Wasteway	Earth
214	Wasteway	0.38	Wasteway	Earth
210	Sluicway to Pumps (Parshall flume)	0.55	Main Canal	Earth
200	B Lateral	0.55	Primary Lateral	Concrete
190	A Lateral	0.55	Primary Lateral	Concrete
187	Pumps to HWY 555 inlet	0.55	Main Canal	Earth
184	Underflow	3.55	Main Canal	Pipe
180	Underflow to Eagle Nest Siphon	3.75	Main Canal	Earth
175	Eagle Nest Siphon (#1)	3.80	Main Canal	Pipe
170	Eagle Nest Siphon to conc. lining	7.10	Main Canal	Earth
160	Conc. lining to Baker Wash Siphon	7.80	Main Canal	Concrete
155	Baker Wash Siphon (#2)	7.81	Main Canal	Pipe
150	Baker Wash Siphon to 135 T.O	9.00	Main Canal	Concrete
147	T.O. 135 to HWY666 Siphon	9.13	Main Canal	Concrete
145	Hwy 666 Siphon	9.13	Main Canal	Pipe
140	Hwy 666 Siphon to Control Gate	9.25	Main Canal	Concrete
135	Lateral	9.00	Primary Lateral	Unk
131	Lateral		Primary Lateral	Unk
130	NTUA Lateral	9.15	Primary Lateral	Pipe
126	Helium Lateral Inlet Channel	9.18	Primary Lateral	Pipe
125	Helium Lateral Siphon		Primary Lateral	Pipe
124	Helium Lateral		Primary Lateral	Earth
121	Lateral	9.20	Primary Lateral	Earth
120	Lateral	9.20	Primary Lateral	Earth
115	NCC Lateral	9.20	Primary Lateral	Concrete
110	Control Gate to Area 2 Lateral T.O.	9.90	Main Canal	Concrete
100	Area 2 Lateral		Primary Lateral	Earth
99	Area 2 Sub-Lateral & Wasteway		Secondary Lateral	Concrete
98	Area 2 Lateral (Washed out pipe)		Primary Lateral	Pipe
90	Area 2 Lateral T.O. to Salt Creek Siphon	11.05	Main Canal	Concrete
85	Salt Creek Wash Siphon (#3)	11.05	Main Canal	Pipe
83	Area 2 Lateral (Alt)	12.60	Primary Lateral	Concrete
80	Salt Creek Wash Siphon to Yellow Arroyo Gt	13.50	Main Canal	Earth
78	Yellow Arroyo gate to Siphon (#4)	13.55	Main Canal	Unk
75	Yellow Arroyo (Jim's Canyon) Siphon (#4)	13.90	Main Canal	Pipe
70	Yellow Arroyo Siphon to Control Gate	16.45	Main Canal	Concrete
60	Control Gate to Malpais Siphon	17.30	Main Canal	Concrete
55	Malpais Arroyo Siphon (#5)	17.95	Main Canal	Pipe
50	Malpais Siphon to Area 2 T.O. & Siphon #6	20.78	Main Canal	Earth
45	Siphon #6	20.80	Main Canal	Pipe
40	Areal 5 Lateral	20.78	Primary Lateral	Earth
35	Siphon #6 to Siphon #7	21.40	Main Canal	Earth
30	Siphon #7	21.60	Main Canal	Pipe
27	Siphon #7 to Underflow	22.00	Main Canal	Earth
25	Underflow	22.40	Main Canal	Pipe
23	Underflow to concrete lining	24.00	Main Canal	Earth
21	Concrete lining at Canal Creek to Siphon #8		Main Canal	Concrete
20	Siphon #8		Main Canal	Pipe
18	Canal to Area 7 Reservoir	26.10	Primary Lateral	Unk
15	Canal from Area 7 Reservoir	26.30	Primary Lateral	Unk
10	Siphon #8 to end of concrete lining		Main Canal	Concrete
5	end of concrete lining to Area 7 Pump		Main Canal	Earth
1	Area 7 pump to end of wasteway		Main Canal	Earth

4.12

TABLE 1B
Fruitland Irrigation Project - Reach by Reach Attributes

Reach Number	Description	Approx. canal distance (miles)	Rank	Lining
110	Headworks to Wasteway #1	0.7	Main Canal	Rock/Cobble
100	Wasteway #1 to Automatic Sluice	1.1	Main Canal	Earth
90	Automatic Sluice to Wasteway #2	6.1	Main Canal	Earth
80	Wasteway #2 to Wasteway #3	8.1	Main Canal	Earth
78	Wasteway #3 to start of concrete	8.3	Main Canal	Earth
76	Start of concrete to start of earth lined	8.4	Main Canal	Concrete
74	Start of earth lined to start of concrete	8.8	Main Canal	Earth
72	Start of concrete to start of earth lined	9.4	Main Canal	Concrete
70	Start of earth lined to Siphon Inlet	9.9	Main Canal	Earth
65	Siphon	9.9	Main Canal	Pipe
60	Siphon Outlet to Yellowman T.O.	9.9	Main Canal	Concrete
56	Yellowman T.O. to Yellowman Lateral	11.2	Primary Lateral	Concrete
55	Yellowman Lateral	11.2	Primary Lateral	UNK
50	Yellowman T.O. to Siphon inlet & Way #5	11.3	Main Canal	Concrete
40	Yellowman Siphon	15.7	Main Canal	Pipe
38	Yellowman Tunnel	16.8	Main Canal	Concrete
35	End of tunel to end of concrete flume	16.8	Main Canal	Concrete
30	End of Concrete Flume to Wasteway #7	16.8	Main Canal	Concrete
25	Lateral	17.4	Primary Lateral	UNK
20	Wasteway #7 to Wasterway #8	17.4	Main Canal	Concrete
10	Wasteway #8 to Wasterway #9	20.8	Main Canal	Concrete

4.3

TABLE 1C

Cudei Irrigation Project - Reach by Reach Attributes

Reach Number	Description	Approx. canal distance (miles)	Rank	Lining
30	Canal Headworks to Wasteway #1	0.46	Main canal	Earth
20	Wasteway #1 to Wasteway #2	1.17	Main canal	Earth
10	Wasteway #2 to Wasteway #3 (SJR)	2.18	Main canal	Earth

4.4

TABLE 1D

Cambridge Irrigation Project - Reach by Reach Attributes

Reach Number	Description	Approx. canal distance (miles)	Rank	Lining
10	Headworks to Wasteway #1	4.00	Main canal	Earth

4.4 *Hydraulic Structure Attributes*

Attributes describing the hydraulic structures were compiled from several previously assembled data sets. The USBOR Phoenix Area Office provided comments on the first draft of this technical memorandum (February 6, 1998). The USBOR staff recommends preparing a database which would include detailed description, location, and the condition of the various individual features (siphons, pipe, pumps, gates, valves, turnout structures, trash racks, and rakes). A similar worksheet has been prepared by the USBOR for the Ganado Irrigation Project. The detailed descriptions will eventually include information on size, capacity, materials, equipment specifications, and drawings. This information is useful for determining features that require major rehabilitation or replacement. This data along with operating procedures of each feature would be useful to determine if a particular feature needs to be enlarged or modified.

Criteria can be developed to address the most critical system needs for the least amount of funding. If the structure density is disproportionately high for a sustainable maintenance program, or if the number of structures needing repair or replacement is great enough, reconfiguring portions of the system may be the most economic alternative.

Future studies will require definition of additional attributes. For instance, an attribute for reach or structure conditions can be developed to establish rehabilitation needs and expenses. Attributes for slope and shape can be used for determining canal capacities and other design parameters. Attributes linking water control features with the number of irrigated acres or idle acres can be used to determine effective ways to improve the systems' response to the needs of the water users. Attributes linking canal reaches with soil properties can be used to identify reaches which may contribute to salinity problems.

5 *CANAL FLOW MEASUREMENTS*

In the 1994 DNR/BOR Reconnaissance Report it is stated that "an accurate knowledge of water flows based on accurate flow monitoring technology is a critical aspect of the system rehabilitation." This Technical Memorandum included two flow measurement tasks. The first task was to compile historic flow measurements from readily available sources. The second task was to recommend additional measurement sites.

5.1 *Historic flow measurements*

The purpose of this task was to utilize historic flow measurements for estimating the maximum flow capacity of the canals. Flow measurements have been sporadically recorded throughout the lives of these projects. However, recent measurements are distressingly sparse. The BIA Area Office in Gallup, New Mexico stores dozens of strip chart records made during the 1950's. They are contained in Box #_____. Reducing these charts was beyond the scope of this investigation. For this investigation, data was compiled from the following sources: Navajo Nation DWR, Keller-Bliessner Engineering (KBE), and Colorado State University's Colorado Institute for Irrigation Management (CSU CIIM). These data collection efforts are described in the following section. Flow measurements are summarized by assigned reach number in Tables 5.1, 5.2, and 5.3. No flow measurements for the Cambridge project were located.

Between 1990 and the summer of 1997, DWR/WMB staff conducted several flow measurements on the Shiprock irrigation projects. For this technical memorandum, DWR/WMB conducted additional flow measurements on the Hogback and Cudei Projects during September and October 1997 and June 1998. These measurements were taken to supplement historic flow data, and to provide additional data for estimating maximum canal capacities. These 1997 and 1998 measurements were made at predefined reaches along the Hogback and Cudei canals utilizing a Marsh-McBirney current meter and float marker methods. When the DWR/WMB staff used current meters to measure flows, United States Geological Service (USGS) standard procedures were followed. Most of these measurements were conducted after the 1997 growing season. To simulate the maximum system capacity, the DWR Shiprock staff set the head gates as close to the maximum "normal" operating levels. These levels were as close to the apparent high water marks as possible. Where possible, a computer spreadsheet developed by the Colorado Water Conservation Board called R2CROSS was used to calculate discharges and plot cross sections for reaches visited in October 1997. The R2CROSS results are presented in Appendix 2.

During past canal modifications, a 12 foot by 4 foot by 32 foot Parshall flume was installed downstream of the headworks on the Hogback Canal (Reach 210). Based on the dimensions of this flume, a rating curve was developed using the following equation:

$$Q = (3.6875\ W + 2.5)\ Ha\ ^{1.6}$$

Where Q = Flow (cfs)
W = Throat width = 12 feet
Ha = Depth measured approximately 12' upstream of the throat

Periodic measurements taken by DWR staff at the flume verify this rating curve. A stilling well was part of the original flume structure. Rehabilitating this stilling well and installing a recording device is a possible DWR/WMB program priority.

5.2 *Recommended Flow Measurement Sites*

An objective of future investigations will be to develop a systematic data collection plan for the Shiprock irrigation projects which will result in improved system operations. The proposed plan will incorporate the input and expertise from water users, operating staff, and other water management personnel that are familiar with the projects. Developing a final measurement plan was beyond the scope of this memorandum. However, approximately twenty specific measurement points were identified for this Technical Memorandum.

Prior to the 1998 irrigation season, DWR installed ten plates on the Hogback Project, one on the Fruitland Project, and one on the Cudei Project. Staff plates were marked on-site with canal identification codes and the associated reach numbers developed for this technical memorandum. For example, staff plate FSP90 is located on Fruitland Canal, Reach 90. Staff plate numbers, locations, and dates of installation are shown in Table 5.4.

The Water Management Branch, with assistance from Colorado State University, provided in-house training to the Shiprock Irrigation Operation and Maintenance staff regarding the purpose, installation, and monitoring of the staff plates. The Water Management Branch developed a staff plate recording form for the Shiprock Irrigation Operation and Maintenance staff to assist in monitoring water levels in the canals. A series of flow measurements needs to be taken to determine rating curves for these staff plates. Historic flow measurements will be used to help refine rating curves when possible. Once reliable rating curves are developed, operation and maintenance staff will be able to determine flows at a staff plate by reading the water depth at the staff plate and recording the corresponding flow.

DWR staff identified additional staff plate locations for installation after the 1998 irrigation season. Recommended sites on the Hogback Project include Reaches 90 and 100, downstream of the Helium lateral / NTUA area. Recommended sites on the Fruitland Project include the diversion structure and the major laterals. Recommended sites on the Cudei Project include the diversion structure and Reach 30 upstream of the last wasteway before the fields. On the Cambridge Project, recommended sites include the diversion structure. These sites are shown on the Figures in Appendix 1.

Exh 5.1

TABLE 2A

Hogback Irrigation Project - Compilation of known flow measurements

Sources:

Reach Number	Description	Approx. canal distance (miles)	NN DWR 1990-1998 (measured)		KBE (estimated)		CSU IIM 1988 (measured)	
			Q (cfs)	Date	Q (cfs)	Date	Q (cfs)	Date
220	Headworks to Sluiceway	0.35	365	09/25/97				
215	Sluicway/Wasteway	0.35						
214	Wasteway	0.38	180	09/25/97				
			41	10/13/97				
210	Sluicway to Pumps (Parshall flume)	0.55	191	05/05/92	258	06/19/97	255	05/25/88
			263	06/02/94			270	07/30/88
			176	07/25/95			285	07/30/88
			271	09/24/97			285	07/31/88
			207	06/23/98			255	08/05/88
			178	07/07/98			264	08/06/88
200	B Lateral	0.55	10	06/24/98			17	05/25/88
			9	07/07/98			15	07/30/88
190	A Lateral	0.55	9	06/24/98			11	05/25/88
			7	07/08/98			10	07/30/88
187	Pumps to HWY 555 inlet	0.55					266	05/25/88
184	Underflow	3.55						
180	Underflow to Eagle Nest Siphon	3.75	190	06/21/90	246	06/19/97		
			130	09/20/90				
			186	09/24/97				
			203	10/13/97				
175	Eagle Nest Siphon (#1)	3.80						
170	Eagle Nest Siphon to conc. lining	7.10			235	06/19/97		
					155	06/19/97		
160	Conc. lining to Baker Wash Siphon	7.80	198	09/24/97	103	06/19/97		
			173	09/25/97				
			124	07/07/98				
155	Baker Wash Siphon (#2)	7.81	127	10/14/97				
150	Baker Wash Siphon to 135 T.O	9.00	130	09/25/97				
			158	10/14/97				
147	T.O. 135 to HWY666 Siphon	9.13						
145	Hwy 666 Siphon	9.13						
140	Hwy 666 Siphon to Control Gate	9.25						
135	Lateral	9.00	6	10/14/97				
131	Lateral							
130	NTUA Lateral	9.15						
126	Helium Lateral Inlet Channel	9.18	10	09/25/97			7	08/05/88
125	Helium Lateral Siphon							
124	Helium Lateral		23	06/24/98				
			19	07/07/98				
121	Lateral	9.20						
120	Lateral	9.20						
115	NCC Lateral	9.20						
110	Control Gate to Area 2 Lateral T.O.	9.90	123	10/15/97				
100	Area 2 Lateral		12	10/14/97				
99	Area 2 Sub-Lateral & Wasteway		11	10/15/97				
98	Area 2 Lateral (Washed out pipe)							
90	Area 2 Lateral T.O. to Salt Creek Siphon	11.05						
85	Salt Creek Wash Siphon (#3)	11.05						
83	Area 2 Lateral (Alt)	12.60						
80	Salt Creek Wash Siphon to Yellow Arroyo Gt	13.50	79	10/16/97				
78	Yellow Arroyo gate to Siphon (#4)	13.55	69	10/16/97				
75	Yellow Arroyo (Jim's Canyon) Siphon (#4)	13.90						
70	Yellow Arroyo Siphon to Control Gate	16.45						
60	Control Gate to Malpais Siphon	17.30						
55	Malpais Arroyo Siphon (#5)	17.95						
50	Malpais Siphon to Area 2 T.O. & Siphon #6	20.78						
45	Siphon #6	20.80						
40	Areal 5 Lateral	20.78						
35	Siphon #6 to Siphon #7	21.40						
30	Siphon #7	21.60						
27	Siphon #7 to Underflow	22.00						
25	Underflow	22.40						
23	Underflow to concrete lining	24.00						
21	Concrete lining at Canal Creek to Siphon #8							
20	Siphon #8							
18	Canal to Area 7 Reservoir	26.10						
15	Canal from Area 7 Reservoir	26.30						
10	Siphon #8 to end of concrete lining							
5	end of concrete lining to Area 7 Pump							
1	Area 7 pump to end of wasteway							

TABLE 2B

Fruitland Irrigation Project - Compilation of ~~known~~ flow measurements

Reach Number	Description	Approx. canal distance (miles)	Sources: NN DWR 1990-1998 (measured)		CSU IIM 1988 (measured)	
			Q (cfs)	Date	Q (cfs)	Date
110	Headworks to Wasteway #1	0.7			177	07/12/88
100	Wasteway #1 to Automatic Sluice	1.1	108	05/25/90	126	07/12/88
			116	06/22/90		
			113	08/03/90		
90	Automatic Sluice to Wasteway #2	6.1	126	07/08/98	170	05/24/88
					125	06/12/88
					150	05/24/88
					119	07/12/88
80	Wasteway #2 to Wasteway #3	8.1			99	07/18/88
78	Wasteway #3 to start of concrete	8.3				
76	Start of concrete to start of earth lined	8.4				
74	Start of earth lined to start of concrete	8.8				
72	Start of concrete to start of earth lined	9.4				
70	Start of earth lined to Siphon Inlet	9.9				
65	Siphon	9.9				
60	Siphon Outlet to Yellowman T.O.	9.9				
56	Yellowman T.O. to Yellowman Lateral	11.2				
55	Yellowman Lateral	11.2				
50	Yellowman T.O. to Siphon inlet & Way #5	11.3	23	09/01/92		
			29	09/01/93		
			28	06/16/95		
			45	07/01/97		
			5	08/19/97		
			4	08/19/97		
40	Yellowman Siphon	15.7				
38	Yellowman Tunnel	16.8				
35	End of tunel to end of concrete flume	16.8				
30	End of Concrete Flume to Wasteway #7	16.8	64	08/19/97		
25	Lateral	17.4				
20	Wasteway #7 to Wasterway #8	17.4				
10	Wasteway #8 to Wasterway #9	20.8			1	05/27/88

TABLE 2e 5.3

Cudei Irrigation Project - Compilation of ~~known~~ flow measurements

Reach Number	Description	Approx. canal distance (miles)	NN DWR 1990-1998 (measured)		CSU IIM 1988 (measured)	
			Q (cfs)	Date	Q (cfs)	Date
30	Canal Headworks to Wasteway #1	0.46	14.4	06/10/97	29.9	05/26/88
			10.3	10/17/97		
20	Wasteway #1 to Wasteway #2	1.17	24.2	05/24/90		
			6.4	08/02/90		
			7.5	07/25/95		
			13.9	06/18/97		
			28.6	06/23/98		
			19.2	07/08/98		
10	Wasteway #2 to Wasteway #3 (SJR)	2.18	15.2	06/10/97		
			8.3	06/18/97		

~~35.4~~

TABLE ~~xx~~

Shiprock Irrigation Canal Staff Plates

Plate no.	Canal	Location	Date installed
HSP210	Hogback	Reach 210 - at Parshall flume	02/26/98
HSP200	Hogback	Reach 200 - lateral B	03/24/98
HSP190	Hogback	Reach 190 - lateral A	03/24/98
HSP160	Hogback	Reach 160 - on bridge across from Shiprock Fleet Mngt	03/24/98
HSP150	Hogback	Reach 150 - at foot bridge	03/25/98
HSP140	Hogback	Reach 140 - before gates; next to ladder	03/25/98
HSP135	Hogback	Reach 135 - just upstream of plant pipe outlet	03/25/98
HSP125	Hogback	Reach 125 - Helium plant lateral; at Parshall flume	02/26/98
HSP121	Hogback	Reach 121 - small lateral across road from 140	03/26/98
HSP110	Hogback	Reach 110 - downstream of culvert	03/26/98
FSP90	Fruitland	Reach 90 - d/s of last wasteway before fields; foot bridge	03/26/98
CSP20	Cudei	Reach 20 - d/s of last wasteway before fields	03/26/98

6 *ESTIMATED MAXIMUM FLOW CAPACITY*

One of the main objectives for this Technical Memorandum analysis was to estimate the flow capacity of each canal reach. Due to the measurement uncertainties the maximum flow capacity was bounded between theoretical lower and upper flows. These estimates are based on a combination of historic measurements, design documentation, and hydraulic analysis. These items are described in the following sections.

6.1 *Historic Flow Measurements*

The historic flow measurements are presented in the previous section. If these values were greater than either the theoretical or design values, they were used to establish an upper limit on the estimated flow capacity.

6.2 *Design Documentation*

Theoretical estimates of the canal capacities at various reaches were compiled from readily available sources such as DWR documentation, several BIA reports, the BIO/WEST report (1996), the USDA SCS Inventory of Navajo Irrigation Projects (1986), and the Shiprock Irrigation Systems Standard Operating Procedures (SOP) (DRAFT December 1995). Values in these documents are often based on "as-built" design values or theoretical maximums rather than measured maximum flows. Consequently, these values may not accurately reflect current field conditions. For instance, the BIO/WEST (1996) estimates are qualified as "probable normal capacities" based on personal communications with field observers. Estimated maximum capacities from various sources are summarized by assigned reach numbers in Tables 6.1, 6.2, and 6.3.

It should be noted that structural elements such as flumes are frequently "oversized" with respect to capacity to provide efficient measuring performance. For instance two Parshall flumes are on the Hogback project. One is downstream of the headworks on Reach 210 and the other is on the Helium Lateral on Reach 126. The maximum flow through these flumes was determined by the flume dimensions (12 feet and 3 feet, respectively). These capacities exceed the overall system capacity. Many types of structures such as siphons, gates, and crossings are also frequently designed with additional capacity.

6.3 *Hydraulic Analysis*

The flow measurements conducted by DWR/WMB during September and October 1997 were taken with the system set close to its maximum capacity. To analyze maximum canal flow hydraulics at specific reaches, DWR/WMB staff recorded canal slope, high water marks, and cross-sectional profiles at several predetermined reaches. Maximum canal flows presumably correspond

to high water marks on the sides of the canal. However, DWR/WMB staff noted that, depending on the time of the measurement, the flow oscillated above and below the high water mark during sampling. When it was noted in the field documentation that the water level was at the high water mark at the time of measurement, the calculated flows were recorded as maximum capacity flows for that reach. When the water level was below the noted high water mark, DWR/WMB estimated maximum flow capacity at the recorded high water marks using Manning's equation. It should be noted that specific hydraulic structures which may limit maximum flows may have gone undetected.

DWR/WMB summarized the estimated maximum flows by reach. Due to the uncertainty in the data sets, DWR/WMB developed a range for the upper (maximum) and lower (minimum) estimate of the maximum flow capacity. Due to the variety of sources and the lack of precise measurements, some of the estimated maximum flows listed on Tables 5.1, 5.2 and 5.3 are less accurate than others.

The upper range of the estimated maximum canal capacity is based on the largest of the following three values:

- The greatest value for the theoretical design capacity,
- The greatest value historically measured, or
- The greatest value based on Manning's equation.

The lower range of the estimated maximum canal capacity is based on the smallest of the following three values:

- The smallest value for the theoretical design capacity,
- The smallest value based on Manning's equation, or
- The flow must be less than or equal to any upstream main canal maximum estimate.

The ranges of the peak capacities are presented in Tables 6.1, 6.2 and 6.3. The minimum values for the estimated peak capacities are constrained by upstream conditions. These assumptions reflect the fact that if an upstream condition is controlling the volume of flow, then all of the downstream reaches will be limited by that reach.

Because of the importance of hydraulic parameters and accurate flow measurements, DWR/WMB intends to utilize additional models, such as R2CROSS, in future analysis. Model, such as R2CROSS, can be used to determine additional parameters such as average depth, average velocity, and percent wetted perimeters at varying stages.

TABLE 7A

Hogback Irrigation Project - Compilation of estimated maximum / high flow capacities

Sources:

Reach Number	Description	Approx. canal distance (miles)	NN DWR manning's n calculations (1	BIA 1962 completion report (2)	BIO/WEST 1996 (3)	Parshall flume max Q (4)	Shiprock Irrigation SOP 1995 (dft)	BIA Land Ops Inventory 1969	USDA SCS Inventory 198[illegible]	Molzen-Corbin 1993 (5)	BIA Land Ops design sketches 1959-60 (6)
			Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
220	Headworks to Sluiceway	0.35		300	300		300				
215	Sluiceway/Wasteway	0.35									
214	Wasteway	0.38			100						
210	Sluiceway to Pumps (Parshall flume)	0.55			200	347	300		220	220	
200	B Lateral	0.55	10	11							
190	A Lateral	0.55	10	5							
187	Pumps to HWY 555 inlet	0.55									
184	Underflow	3.55									
180	Underflow to Eagle Nest Siphon	3.75	302								
175	Eagle Nest Siphon (#1)	3.80		220							
170	Eagle Nest Siphon to conc. lining	7.10									
160	Conc. lining to Baker Wash Siphon	7.80	146								
155	Baker Wash Siphon (#2)	7.81		180							
150	Baker Wash Siphon to 135 T.O	9.00	158								
147	T.O. 135 to HWY666 Siphon	9.13									
145	Hwy 666 Siphon	9.13		180							180
140	Hwy 666 Siphon to Control Gate	9.25									
135	Lateral	9.00	9								180
131	Lateral										
130	NTUA Lateral	9.15									
126	Helium Lateral Inlet Channel	9.18	30			50				2	
125	Helium Lateral Siphon			40							
124	Helium Lateral			40							
121	Lateral	9.20									
120	Lateral	9.20									
115	NCC Lateral	9.20									
110	Control Gate to Area 2 Lateral T.O.	9.90	159								
100	Area 2 Lateral		34								180
99	Area 2 Sub-Lateral & Wasteway		17								
98	Area 2 Lateral (Washed out pipe)										
90	Area 2 Lateral T.O. to Salt Creek Siphon	11.05									
85	Salt Creek Wash Siphon (#3)	11.05		180							180
83	Area 2 Lateral (Alt)	12.60									
80	Salt Creek Wash Siphon to Yellow Arroyo Gt	13.50									
78	Yellow Arroyo gate to Siphon (#4)	13.55									180
75	Yellow Arroyo (Jim's Canyon) Siphon (#4)	13.90		180							180
70	Yellow Arroyo Siphon to Control Gate	16.45									
60	Control Gate to Malpais Siphon	17.30									
55	Malpais Arroyo Siphon (#5)	17.95		130							
50	Malpais Siphon to Area 2 T.O. & Siphon #6	20.78									130
45	Siphon #6	20.80		80				130			130
40	Areal 5 Lateral	20.78						80			100
35	Siphon #6 to Siphon #7	21.40						21			18
30	Siphon #7	21.60		80				80			80
27	Siphon #7 to Underflow	22.00						80			80
25	Underflow	22.40		80				60			60
23	Underflow to concrete lining	24.00						60			60
21	Concrete lining at Canal Creek to Siphon #8							60			60
20	Siphon #8			60				60			60
18	Canal to Area 7 Reservoir	26.10		60							60
15	Canal from Area 7 Reservoir	26.30		60							60
10	Siphon #8 to end of concrete lining			60				60			60
5	end of concrete lining to Area 7 Pump			60				60			60
1	Area 7 pump to end of wasteway			60							60

Notes:

(1) Calculated flow at high water mark - Based on manning's n calculations using cross-sectional data collected Sept and Oct 1997. Probable error in field record of reach 180 high water mark resulting in higher capacity than expected.

(2) Based on design

(3) Based on Blickenstaff personal communication - probable "normal" capacity

(4) Based on dimension of flume

(5) Molzen-Corbin states a potential projected peak daily NTUA capacity of 3% of Hogback's capacity (220 cfs), or 6.6 cfs, by the year 2013.

(6) Document's "Siphon #4" is DWR/WMB Siphon #6 (Reach 45); Area 2 T.O. (below Reach 50) at 50 cfs

TABLE 3B

Fruitland Irrigation Project - Compilation of estimated maximum / high flow capacities

Sources:

Reach Number	Description	Approx. canal distance (miles)	Shiprock Irrigation SOP 1995 (dft)	BIO/WEST 1996 (1)	USDA SCS Inventory 1986	(Parshall) flume max Q (2)
			Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
110	Headworks to Wasteway #1	0.7	330	200		
100	Wasteway #1 to Automatic Sluice	1.1	330	200		
90	Automatic Sluice to Wasteway #2	6.1	155	165	165	
				120		
80	Wasteway #2 to Wasteway #3	8.1	135			
78	Wasteway #3 to start of concrete	8.3	135			
76	Start of concrete to start of earth lined	8.4	110			
74	Start of earth lined to start of concrete	8.8	135			
72	Start of concrete to start of earth lined	9.4	110			
70	Start of earth lined to Siphon Inlet	9.9	135			
65	Siphon	9.9	65 (approx)			
60	Siphon Outlet to Yellowman T.O.	9.9	120			
56	Yellowman T.O. to Yellowman Lateral	11.2				
55	Yellowman Lateral	11.2	120			
50	Yellowman T.O. to Siphon inlet & Way #	11.3				
40	Yellowman Siphon	15.7	35 (approx)			
38	Yellowman Tunnel	16.8	50 (approx)			
35	End of tunel to end of concrete flume	16.8	40			103
30	End of Concrete Flume to Wasteway #7	16.8	40			
25	Lateral	17.4				
20	Wasteway #7 to Wasterway #8	17.4	40			
10	Wasteway #8 to Wasterway #9	20.8	20			

NOTES: (1) Report states" Capacity of canal is approximately 165 cfs, although 120 cfs is the likely maximum"; based on personal communication with Bliestner.

(2) Based on dimension of flume (6' throat)

TABLE 3C 46.3

Cudei Irrigation Project - Compilation of estimated maximum / high flow capacities

Sources:

Reach Number	Description	Approx. canal distance (miles)	BIO/WEST 1996	BIA Shiprock memo 08/29/83	USDA SCS Inventory 1986
			Q (cfs)	Q (cfs)	Q (cfs)
30	Canal Headworks to Wasteway #1	0.46	40		30
20	Wasteway #1 to Wasteway #2	1.17	20	20	
			30		
10	Wasteway #2 to Wasteway #3 (SJR)	2.18	10		
			15		

TABLE 3D 46.4

Cambridge Irrigation Project - Compilation of estimated maximum / high flow capacities

Sources:

Reach Number	Description	Approx. canal distance (miles)	USDA SCS inventory 1986
			Q (cfs)
10	Headworks to Wasteway #1	4.0	4.5

7 *ESTIMATED WATER DEMAND*

To determine if the canal reaches have adequate capacity, the peak water demands were determined. The peak water diversion requirements for the Shiprock irrigation projects depend on the number of irrigated or irrigable acres, the crop irrigation requirement, and the overall irrigation efficiency. Unfortunately, precise crop records and water measurements are not available for the Shiprock irrigation systems. Consequently, assumptions have been made to bound the upper and lower limits of the water demands. These assumptions and the resulting values are presented in the following sections.

7.1 *Irrigated and Irrigable acreage*

Different data sources report different irrigated acreages. Some differences are due to different definitions and field assessment methodologies. For instance, the distinction between fields which are fallow, idle, or abandoned may not be immediately apparent. Nor are distinctions between irrigated pasture and alfalfa always evident. It was beyond the scope of this memorandum to reconcile differences between different reported values. It was also beyond the scope to field verify various reports. For determining the acreage irrigated by each canal reach, the BIA's 1993 crop utilization survey was used. A data set based on 1994 aerial photography was also reviewed.

7.1.1 *Acreage based on the 1993 BIA Crop Utilization Data*

The BIA surveyed the extent of utilization of irrigated land during September and October of 1993. For the analysis presented in this technical memorandum, the 1993 BIA crop utilization survey was used. This data set is based on a field observation of each land use permit. Unpermitted land which was irrigated in 1993 may have been omitted from the survey. Project acreage was categorized based on the crop types of corn, alfalfa, produce, pasture, idle or abandoned. Standard definitions were developed for each category. This data is summarized in Table 7.1 and a complete tabulation is presented in Appendix 3. Reconciling the numeric discrepancies evident in Table 7.1 was beyond the scope of this memorandum. Using the 1993 BIA data, a reach by reach tabulation of the irrigated acres is presented in Tables 8.1, 8.2, and 8.3 in the next section.

Based on the 1993 BIA crop utilization data on the Hogback Project, there were 2,545 acres of irrigated corn, alfalfa, produce or pasture; 3,453 acres were idle; and 2,565 acres were abandoned. On the Fruitland Project, there were 2,380 acres of irrigated corn, alfalfa, produce or pasture; 828 acres were idle; and 311 acres were abandoned. On the Cudei Project, 244 acres were irrigating corn, alfalfa, produce or pasture; 340 acres were idle; and 32 acres were abandoned. The Cambridge Project was included with the Fruitland data set in the 1993 BIA survey.

Table 7.1
Summary of 1993 BIA Crop Utilization Data (Acres)

Crop Category	Hogback	Fruitland & Cambridge	Cudei	Total
Corn	692	450	64	1,206
Alfalfa	1,298	1,417	148	2,863
Produce	74	120	1	195
Pasture	481	393	31	905
Irrigated Crops Subtotal	2,545	2,380	244	5,169
Idle	3,453	828	340	4,621
Abandoned	2,565	311	32	2,908
Total Irrigable Acreage	8,286	3,335	543	12,164
Total Project Acreage	9,223	3,830	627	13,680

A project's cropping intensity for a given year is typically defined as the irrigated acreage divided by the project acreage that can be irrigated. Based on the 1993 BIA data, the overall cropping intensity for the Hogback Project is 30 percent, for the Fruitland Project it is 67 percent and for the Cudei Project it is 40 percent. These figures indicate a very significant decline in cropping intensity between the early 1960's and the early 1990's.

The primary conclusion of the BIA 1993 crop utilization survey is that an alarming amount of acreage was categorized as idle or abandoned. For instance, idle or abandoned land amounts to 73 percent of the total irrigated acreage on the Hogback Project. Removing expired agricultural leases from the calculation reduces this value to 63 percent of the irrigated acreage. According to BIA personnel, this situation is a recurring problem. The BIA staff speculates as to the cause of these idle and abandoned lands. Evidently, a significant number of permittees have farm configurations that differ significantly from the original surveys for the original permits. Several areas farmed do not have permits. These comments indicate that it would be appropriate to re-designate project land. Re-designation is the process of reviewing assessed project acreage to insure that the assessment databases accurately and fairly reflect current field conditions. Re-designation would be an opportunity to make these adjustments in a manner which does not negatively impact the overall projects.

The theoretical upper limit for the water demand would be based on a cropping intensity of 100 percent. However, due to crop rotations and fallowing, a more realistic water demand is based on a potential cropping intensity of 80 percent. Consequently, the project diversion requirements are based on a cropping intensity that is 80 percent.

7.1.2 *Acreage based on the 1994 San Juan Basin Water Related Land Use Inventory*

In 1994 the USBOR conducted a San Juan Basin Water Related Land Use Inventory for New Mexico as part of its Upper Colorado Irrigated Lands Assessment. This data is used by the USBOR to determine the depletions in various portions of the Upper Basin. Staff from DWR accompanied USBOR personnel to field verify the interpretation of the aerial photography in the Shiprock area.

The New Mexico Interstate Stream Commission (ISC) attempted to estimate the historic irrigated acreage for the years 1970 to 1994 in the San Juan Basin in New Mexico. The ISC has proposed using the results of that analysis for water operations models in the San Juan Basin. This data set was summarized by the ISC in technical memorandums dated June 12th and June 13th, 1997. Data summarized by the ISC and presented in their technical memorandums are presented in Table 7.2.

Table 7.2
1994 Crop Acreage Data From the ISC (Acres)

Crop	East Hogback	West Hogback	Fruitland	Cudei	Total
Corn	257	390	394	83	1,124
Grains	76	59	100	0	235
Alfalfa	469	883	1,145	156	2,653
Vegetable	85	131	135	11	362
Orchard	0	8	7	0	15
Pasture	197	541	514	86	1,338
Irrigation Crops	1,084	2,012	2,295	336	5,727
Not Irrigated	1,050	2,220	1,039	276	4,585
Total	2,124	4,232	3,334	612	10,302

Based on the 1994 data, there were 3,086 acres of irrigated corn, grains, alfalfa, vegetables, orchards or pasture, and 3,270 acres were not irrigated on the Hogback Project. On the Fruitland Project, there were 2,295 acres of irrigated corn, grains, alfalfa, vegetables, orchards or pasture, and 1,039 acres were not irrigated. On the Cudei Project, there were 336 acres of irrigated corn, grains, alfalfa, vegetables, orchards or pasture, and 276 acres were not irrigated. The Cambridge Project is included within the Fruitland statistics.

The ISC also tabulated data from the 1965 USDA SCS report entitled "Upper Colorado Region, Type I Survey, New Mexico, Water Resources, Present Water Use, Irrigated Acreage by Evaluation Areas, Crops and Full and Short Water Supply, the 1965 Type I Comprehensive Framework Study." According to this USDA SCS report, 8,900 acres out of 11,000 were irrigated in 1965. Based on the USBOR data, only 5,717 acres out of 10,302 were irrigated in 1994. If these numbers are accurate, the cropping intensity declined over the last thirty years from approximately 80 percent in the early 1960's to 55 percent in the 1990's. In future studies the DWR/WMB intends to further assess the 1994 data and verify the ISC results.

The most notable discrepancy between the 1993 and 1994 data is that the 1994 data indicates 541 fewer irrigated acres. However, reconciling data discrepancies between data sets was beyond the scope of this investigation.

7.2 *Crop Irrigation Requirements*

Keller-Bliessner Engineering (KBE) is under contract to the BIA Navajo Indian Irrigation Project (NIIP) to perform a variety of hydrologic and agronomic analysis. In 1995 KBE conducted a needs assessment of the Gallegos Reservoir for NIIP. In that report KBE tabulated the maximum daily evapotranspiration (ET) based on several references which included peak values calculated during an unusually warm and dry period in the 1950's. For the purposes of this DWR/WMB investigation alfalfa is the reference crop. Based on the KBE analyses, the maximum daily ET for alfalfa is approximately 0.29 inches per day. A crop mix of alfalfa, beans, corn, grass or potatoes would have a maximum daily ET of 0.28 inches per day. This rate would translate into a seasonal peak consumptive irrigation demand of approximately 5.3 gallons per minute per acre (0.0118 cfs per acre). Comments received from the Shiprock BIA staff indicated that a range of six to 12 gallons per minute is an appropriate range for planning and design purposes.

7.3 *Peak Diversion Requirements*

Not all of the water diverted by an irrigation project is available to meet the crop water requirements. A portion of the water diverted is lost at the system level due operational spills and transportation losses. These losses are often accounted for by the conveyance efficiency. Additional losses occur on-farm. The diversion requirement is the crop water requirement divided by the conveyance efficiency and the on-farm efficiency. Unfortunately, flow data from the Shiprock diversions, wasteways and on-farm laterals are not adequate to accurately calculate the overall project efficiencies. Consequently, the efficiencies can only be estimated.

7.3.1 *Conveyance Efficiencies*

Data from the Hammond Conservancy District may provide a reasonable benchmark for the conveyance efficiency. In 1994 the annual conveyance efficiency of the Hammond Conservancy District was 40 percent. During the month of July, the Hammond conveyance efficiency increased to 47 percent. It is unlikely that the Shiprock Irrigation Projects have an efficiency greater than Hammond Project's. In the BIO/WEST study, the Shiprock conveyance efficiency is estimated to be approximately 50 percent (BIO/WEST, 1996). For this analysis the conveyance efficiency is assumed to be approximately 50 percent.

7.3.2 *On-Farm Efficiencies*

Data from other studies may provide reasonable benchmarks for estimating on-farm efficiencies. Depending on the type of on-farm irrigation method, the on-farm application or irrigation efficiency will be different. For instance, according to KBE, at NAPI the application efficiencies of the center pivot sprinkler systems are approximately 75 percent. The most common method of on-farm irrigation on the Shiprock Irrigation Projects, uncontrolled flooding, is also the least efficient. The second most common method, furrow irrigation is also relatively inefficient. The more efficient sprinklers and gated pipe methods are rarely utilized.

On similar run-of-the-river Indian irrigation systems in Wyoming, the USDA SCS estimated on-farm efficiency to be approximately 27 percent. The USDA SCS proposed an integrated water management program that was projected to increase on-farm efficiency to 35 percent. With a system wide on-farm program to increase the use of gated pipe and other irrigation techniques, the on-farm efficiency was projected to increase to 65 percent. In the Navajo Nation Division of Natural Resources / BOR reconnaissance report (DNR/BOR, 1994), the on-farm efficiency is estimated to be 40 percent. For this technical memorandum, the low range of the on-farm irrigation losses is 40 percent based on the DNR/BOR report. The high range for the on-farm efficiency is 60 percent because this level could be reasonably achieved with an on-farm program.

As shown in Table 7.3 the overall irrigation efficiency ranges from a low of 16 percent to a high of 36 percent. Based on this approach the estimated diversion requirements range from a low of 14.7 g.p.m. per acre (or 0.033 cfs per acre) to a high of 33.1 g.p.m. per acre (or 0.077 cfs per acre). In the 1994 DNR/BOR reconnaissance report, the diversion requirement is estimated to be 14 g.p.m. per acre. For this technical memorandum, the ranges were limited from a low of 17.7 g.p.m. per acre (or 0.039 cfs per acre) to a high of 26.5 g.p.m. per acre (or 0.059 cfs per acre).

8 *REACH BY REACH ASSESSMENT OF WATER CONTROL*

The primary objective of this technical memorandum is to determine if the current canal capacities are adequate to meet the demands of the Shiprock irrigators. To determine if the canal capacities are adequate, a reach by reach assessment was made of the capacity and demand. Another tool used to identify problem reaches was to interview water users, operators and other DWR staff familiar with the projects. Comments from reports produced by the USBOR and BIA are also included.

8.1 *Reach by reach assessment of the capacity and demand*

Using the BIA 1993 crop utilization data and the KBE crop water requirements, the water demand for each reach and the aggregate water demand downstream of each reach is presented in Tables 8.1, 8.2, and 8.3.

The maximum estimate of the peak water demand is based on:

- A relatively low overall irrigation efficiency of 20 percent is based on a conveyance efficiency of 50 percent and an on-farm efficiency of 40 percent, and
- The total project acreage as reported in the 1993 BIA study with 20 percent of that acreage idle or fallow.

The minimum estimate of the peak water demand is based on:

- A relatively high overall irrigation efficiency of 30 percent is based on a conveyance efficiency of 50 percent and an on-farm efficiency of 60 percent, and
- The irrigated acreage as reported in the 1993 BIA study with 20 percent of that acreage idle or fallow.

Using a combination of reported theoretical values, measured values and the Manning's equation, the DWR/WMB estimated a lower and upper value for the estimated maximum capacity for each reach. To identify which reaches may not have adequate capacity, the ranges of water demands for each reach were compared to the ranges of estimated capacity. The water demand and maximum capacity data is presented in Tables 8.1, 8.2, and 8.3.

It appears that on the Hogback and Fruitland Projects, some canal reaches may not have adequate capacity to provide the peak seasonal water demands for lands which, according to the 1993 BIA crop utilization survey, are being irrigated. There are several explanations for how these water users are coping with inadequate capacities.

- First, much of the irrigated land may be deficit irrigated. However, deficit irrigation results in greater stress on the crops and lower yields.

- Second, the majority of the farmers are producing lower value crops that can withstand periods of stress. Higher value crops are not common. To insure the survival through the summer, farmers can pre-irrigate their hay, pasture and alfalfa fields.

- Third, the water users appear to be concentrating crops on fields that have more reliable water supply.

- Finally, the current canal capacities are barely adequate for the lands which the 1994 BIA crop utilization survey identified with one of the five irrigated crop categories. This result is obvious given the fact that the lands which are currently irrigated must be receiving at least a modestly adequate water supply to survive.

Uncertainty surrounding the water requirements and demands makes it difficult to reach definitive system wide conclusions regarding the capacity. However, given the current overall irrigation efficiency and the current condition of the water delivery system, it will be difficult for these projects to irrigate anything close to 80 percent of their assessed acreage. The data assembled in Tables 8.1, 8.2, and 8.3 can be used to identify reaches that may be of special concern.

From the data presented in Table 8.1, on the Hogback Project it appears that the reaches upstream from the siphon under Highway 666 are not passing enough water. This section includes Reaches 140 through 175. Measurements made during September and October of 1997 were conducted when the canal was set at a normal maximum. These measurements indicate that the flow in those reaches was less than 160 cfs while the minimum estimate of the peak demand was greater than 200 cfs. Unfortunately, it is not immediately obvious which of the hydraulic control structures may be causing this problem.

Overall, it appears that most of the Fruitland and Cudei reaches have adequate capacity. However, from the data presented in Table 8.2, on the Fruitland Project it appears that the reaches downstream from Reach 40, the Yellowman Siphon Turn Out are just barely adequate to meet existing demands.

8-1

TABLE 8A

Hogback Irrigation Project - Reach by Reach Assessment of Capacity and Demand

Reach Number	Comments	Distance	Project Acreage Per Reach	Irrigated Acreage Per Reach	Aggregate Project Acreage Per Reach	Aggregate Irrigated Acreage Per Reach	Water Demand (Min)	Water Demand (Max)	Estimated Maximum Capacity (Min)	Estimated Maximum Capacity (Max)
		Miles	Acres		Acres		CFS		CFS	
220	Headworks to Sluiceway	0.35	0.0	0.0	9644.4	8745.1	275.2	455.2	300	365
215	Sluicway/Wasteway	0.35	0.0	0.0	0.0	0.0	0.0	0.0		
214	Westeway	0.38	0.0	0.0	0.0	0.0	0.0	0.0	100	180
210	Sluicway to Pumps (Parshall flume)	0.55	0.0	0.0	9644.4	8745.1	275.2	455.2	200	300
200	B Lateral	0.55	707.2	667.8	707.2	667.8	21.0	33.4	11	17
190	A Lateral	0.55	280.7	279.3	280.7	279.3	8.8	13.2	5	11
187	Pumps to HWY 555 inlet	0.55	511.2	425.8	8656.5	7798.0	245.4	408.6	266	266
184	Underflow	3.55	0.0	0.0	8145.3	7372.2	232.0	384.5		
180	Underflow to Eagle Nest Siphon	3.75	0.0	0.0	8145.3	7372.2	232.0	384.5	300	302
175	Eagle Nest Siphon (#1)	3.80	0.0	0.0	8145.3	7372.2	232.0	384.5	220	220
170	Eagle Nest Siphon to conc. lining	7.10	395.4	292.7	8145.3	7372.2	232.0	384.5	220	235
160	Conc. lining to Baker Wash Siphon	7.80	502.1	419.2	7749.9	7079.5	222.8	365.8	146	198
155	Baker Wash Siphon (#2)	7.81	0.0	0.0	7247.8	6660.3	209.6	342.1	180	180
150	Baker Wash Siphon to 135 T.O.	9.00	121.6	69.2	7247.8	6660.3	209.6	342.1	158	158
147	T.O. 135 to HWY666 Siphon	9.13	0.0	0.0	7126.2	6591.1	207.4	336.4	158	158
145	Hwy 666 Siphon	9.13	0.0	0.0	7126.2	6591.1	207.4	336.4	158	158
140	Hwy 666 Siphon to Control Gate	9.25	0.0	0.0	7126.2	6591.1	207.4	336.4	158	158
135	Lateral	9.00	0.0	0.0	0.0	0.0	0.0	0.0	9	9
131	Lateral		0.0	0.0	0.0	0.0	0.0	0.0		
130	NTUA Lateral	9.15	0.0	0.0	0.0	0.0	2.0	6.0	2	6
126	Helium Lateral Inlet Channel	9.18	0.0	0.0	999.0	999.0	31.4	47.2	30	30
125	Helium Lateral Siphon		0.0	0.0	999.0	999.0	31.4	47.2	30	40
124	Helium Lateral		999.0	999.0	999.0	999.0	31.4	47.2	30	40
121	Lateral	9.20	0.0	0.0	261.4	260.8	8.2	12.3		
120	Lateral	9.20	261.4	260.8	261.4	260.8	8.2	12.3		
115	NCC Lateral	9.20	100.0	100.0	100.0	100.0	3.1	4.7		
110	Control Gate to Area 2 Lateral T.O.	9.90	712	646	5766	5231	164.6	272.1	158	159
100	Area 2 Lateral		1058.5	985.9	1058.5	985.9	31.0	50.0	34	34
99	Area 2 Sub-Lateral & Wasteway		0.0	0.0	0.0	0.0	0.0	0.0	17	17
98	Area 2 Lateral (Washed out pipe)		0.0	0.0	0.0	0.0	0.0	0.0		
90	Area 2 Lateral T.O. to Salt Creek Siphon	11.05	200.7	200.7	3995.5	3599.5	113.3	188.6		
85	Salt Creek Wash Siphon (#3)	11.05	0.0	0.0	3794.8	3398.8	106.9	179.1	158	159
83	Area 2 Lateral (Alt)	12.60	650.8	598.8	650.8	598.8	18.8	30.7		
80	Salt Creek Wash Siphon to Yellow Arroyo Gt	13.50	0.0	0.0	3144.0	2800.0	88.1	148.4	159	159
78	Yellow Arroyo gate to Siphon (#4)	13.55	0.0	0.0	3144.0	2800.0	88.1	148.4	159	159
75	Yellow Arroyo (Jim's Canyon) Siphon (#4)	13.90	0.0	0.0	3144.0	2800.0	88.1	148.4	159	159
70	Yellow Arroyo Siphon to Control Gate	16.45	495.0	447.0	3144.0	2800.0	88.1	148.4		
60	Control Gate to Malpais Siphon	17.30	121.0	121.0	2649.0	2353.0	74.0	125.0		
55	Malpais Arroyo Siphon (#5)	17.95	0.0	0.0	2528.0	2232.0	70.2	119.3	130	130
50	Malpais Siphon to Area 2 T.O. & Siphon #6	20.78	322	196	2528	2232	70.2	119.3	130	130
45	Siphon #6	20.80	0.0	0.0	2206.0	2036.0	64.1	104.1	80	100
40	Areal 5 Lateral	20.78	195.0	186.0	195.0	186.0	5.9	9.2	18	21
35	Siphon #6 to Siphon #7	21.40	2011.0	1850.0	2011.0	1850.0	58.2	94.9	80	80
30	Siphon #7	21.60	0.0	0.0	0.0	0.0	0.0	0.0	80	80
27	Siphon #7 to Underflow	22.00	0.0	0.0	0.0	0.0	0.0	0.0	60	60
25	Underflow	22.40	0.0	0.0	0.0	0.0	0.0	0.0	60	60
23	Underflow to concrete lining	24.00	0.0	0.0	0.0	0.0	0.0	0.0	60	60
21	Concrete lining at Canal Creek to Siphon #8		0.0	0.0	0.0	0.0	0.0	0.0	60	60
20	Siphon #8		0.0	0.0	0.0	0.0	0.0	0.0	60	60
18	Canal to Area 7 Reservoir	26.10	0.0	0.0	0.0	0.0	0.0	0.0	60	60
15	Canal from Area 7 Reservoir	26.30	0.0	0.0	0.0	0.0	0.0	0.0	60	60
10	Siphon #8 to end of concrete lining		0.0	0.0	0.0	0.0	0.0	0.0	60	60
5	end of concrete lining to Area 7 Pump		0.0	0.0	0.0	0.0	0.0	0.0	60	60
1	Area 7 pump to end of wasteway									
Total			9644.4	8745.1						

Notes:

(1) The peak crop water requirement is 0.0118 cfs/acre

(2) The on-farm efficieny is between 40 and 60 percent

(3) The conveyance efficiency is 50 percent

(4) The cropping intensity is 80 percent

(5) Assume that the Helium Lateral Acreage is 999 acres

(6) Assume that the NTUA lateral uses between 2 and 6 cfs and the NCC lateral irrigated 100 acres

(7) Molzen-Corbin states a potential projected peak daily NTUA capacity of 3% of Hogback's capacity (220 cfs), or 6.6 cfs, by the year 2013.

TABLE 8B 82

Fruitland Irrigation Project - Reach by Reach Assessment of Capacity and Demand

Reach Number	Comments	Distance	Project Acreage Per Reach	Irrigated Acreage Per Reach	Aggregate Project Acreage Per Reach	Aggregate Irrigated Acreage Per Reach	Water Demand (Min)	Water Demand (Max)	Estimated Maximum Capacity (Min)	Estimated Maximum Capacity (Max)
		Miles	Acres	Acres	Acres	Acres	CFS	CFS	CFS	CFS
110	Headworks to Wasteway #1	0.7	0	0	3830	3336	105.0	180.8	200	330
100	Wasteway #1 to Automatic Sluice	1.1	0	0	3830	3336	105.0	180.8	200	330
90	Automatic Sluice to Wasteway #2	6.1	805	678	3830	3336	105.0	180.8	120	170
80	Wasteway #2 to Wasteway #3	8.1	608	568	3025	2658	83.6	142.8	135	135
78	Wasteway #3 to start of concrete	8.3	0	0	2417	2090	65.8	114.1	135	135
76	Start of concrete to start of earth lined	8.4	0	0	2417	2090	65.8	114.1	110	110
74	Start of earth lined to start of concrete	8.8	0	0	2417	2090	65.8	114.1	135	135
72	Start of concrete to start of earth lined	9.4	0	0	2417	2090	65.8	114.1	110	110
70	Start of earth lined to Siphon Inlet	9.9	0	0	2417	2090	65.8	114.1	135	135
65	Siphon	9.9	0	0	2417	2090	65.8	114.1	65	65
60	Siphon Outlet to Yellowman T.O.	9.9	321	277	2417	2090	65.8	114.1	65	120
56	Yellowman T.O. to Yellowman Lateral	11.2	0	0	2097	1814	57.1	99.0		
55	Yellowman Lateral	11.2	363	335	2097	1814	57.1	99.0	65	120
50	Yellowman T.O. to Siphon inlet & Way #5	11.3	25	21	1733	1479	46.5	81.8	45	45
40	Yellowman Siphon	15.7	324	298	1708	1457	45.9	80.6	35	35
38	Yellowman Tunnel	16.8	0	0	1385	1160	36.5	65.3	35	50
35	End of tunel to end of concrete flume	16.8	0	0	1385	1160	36.5	65.3	35	40
30	End of Concrete Flume to Wasteway #7	16.8	376	357	1385	1160	36.5	65.3	35	64
25	Lateral	17.4	0	0	1009	803	25.3	47.6		
20	Wasteway #7 to Wasterway #8	17.4	613	458	1009	803	25.3	47.6	35	40
10	Wasteway #8 to Wasterway #9	20.8	396	345	396	345	10.8	18.7	20	20
Total			3830.0	3335.8						

Notes:

(1) The peak crop water requirement is 0.0118 cfs/acre

(2) Assume the on-farm efficieny is between 40 and 60 percent

(3) Assume the conveyance efficiency is 50 percent

(4) Assume the cropping intensity is 80 percent

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TABLE 8c-7

Cudei Irrigation Project - Reach by Reach Assessment of Capacity and Demand

Reach Number	Description	Distance	Project Acreage Per Reach	Irrigated Acreage Per Reach	Aggregate Acreage Per Reach	Aggregate Irrigated Acreage Per Reach	Water Demand (Min)	Water Demand (Max)	Estimated Maximum Capacity (Min)	Estimated Maximum Capacity (Max)
		Miles	Acres	Acres	Acres	Acres	CFS	CFS	CFS	CFS
30	Canal Headworks to Wasteway #1	0.46	0	0	627	544	17	30	3[illegible]	40
20	Wasteway #1 to Wasteway #2	1.17	242	203	627	544	17	30	2[illegible]	30
10	Wasteway #2 to Wasteway #3 (SJR)	2.18	386	341	386	341	11	18	[illegible]	15
Total			627	544						

Notes:

(1) The crop water requirements is 0.0118 cfs/acre
(2) The on-farm efficiency is between 40 and 60 percent
(3) The conveyance efficieny is 50 percent
(4) The cropping intensity is 80 percent

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8.2 *Comments of Water Users, DWR Staff, and USBOR and BIA Reports*

Water users, operators and other staff familiar with the operation of the Shiprock irrigation projects were interviewed to identify additional reaches of concern. Additional interviews were conducted at a Farmboard meeting on February 10, 1998 to further document areas of the system that the water users believe need attention. For completeness, all of the comments received from the water users were included. These comments and the reaches cited will be further investigated to develop a better hydraulic understanding of the problems and possible solutions.

These comments primarily reflect a lack of system resources to keep up with deferred system maintenance. When compared to the other irrigation projects in the area, the Shiprock system operators only have a fraction of the dollars available to maintain their facilities. The resulting comments have been grouped by project and, where appropriate, include reference to previous studies.

8.2.1 *Hogback Irrigation Project*

The Hogback Irrigation Project includes 28.6 miles of concrete and earth lined canals and 135 miles of field laterals. For this analysis the Hogback system has been defined by 54 reaches. The numbering system begins at the tail of the system (Reach 10) and stops at the diversion structure (Reach 220).

8.2.1.1 *Modify the Hogback diversion structure and sediment basin (Reach 220)*

According to the 1989 USBOR Design Proposal, the sediment basin needs to be enlarged to four times its current size. After high spring flows, the earth and rock portions of the diversion structure frequently need to be rebuilt. According to the 1994 DNR/BOR Reconnaissance Report, $43,000 dollars were spent rebuilding the diversion berm due to late winter floods in 1993. This type of rebuilding is required almost every year. Several water users also stated that a permanent diversion structure should be constructed and that the current structure is used as a low water crossing across the San Juan River.

8.2.1.2 *Repair or replace the sluiceway below the settling basin (Reaches 214 and 215)*

According to the 1989 USBOR Design Proposal, the sluiceway is inoperable. This situation makes it difficult to make adjustments to control the flow velocity and sediment discharges. In their comments on the draft Technical Memorandum, the USBOR suggests that inoperable sluice ways make it difficult to control the amount of water flowing further downstream on the irrigation system and may account for the inability to increase the flows through the main canal.

8.2.1.3 *Hogback A and B Laterals (Reaches 190 and 200)*

The pumps on the Hogback A and B Laterals (Reaches 190 and 200) have a reputation for being unreliable. For instance, flow measurements during the 1987 irrigation season indicate that the pumps were inoperable throughout most of August. The USBOR noted in the 1989 Design Proposal that the pumps have a tendency to fail. Sand material reaches the pump sump and is pumped by the pump. Improving the diversion's ability to control and manage sediment may improve this situation. The pumps are also expensive to operate. During the irrigation season, power costs approximately $3,000 per month with a $300 per month stand by fee. It might be possible to develop an additional assessment for the operation and maintenance of these pumps. NRCS may also be able to provide assistance. It has also been noted that if there is a breakdown it can take many weeks to get parts through the tribal procurement process.

8.2.1.4 *Hogback Turnouts upstream from Highway 666 (Reach 187)*

The water users have indicated that the elevations of their turn outs are too high. Consequently, the system operators are forced to raise the water level in the canal to allow for the water users to divert adequate water. Constricting the flow downstream from these turnouts to raise the water level downstream for this reach may reduce the flow available for downstream water users and it may result in increasing the wasteway discharges

8.2.1.5 *Reach 160*

The headgate near Mr. Yazzie's plot is gone. It is difficult to divert water to farms because the water in the canal is not at an adequate elevation. Daisy Martin would like to develop a farm plot which was previously planned. A new lateral would need to be constructed to this plot.

8.2.1.6 *Reach 150*

The water users have indicated that at Plot 89 canal seepage ruined a mobile home and that a replacement mobile home is now in jeopardy. At Plots 202 and 203 farm drainages are plugged and the water table has risen. A nearby house is being ruined and water seeps into the septic tank. The water users indicated that the laterals do not seem to be big enough to serve the number of farms which rely on it. John C. Begay, who lives at the end of the lateral can only irrigate once or twice a season. The Hogback System below the second wash does not have enough water during the summer time. Additional laterals need to be built to six farms.

8.2.1.7 *Reach 147*

The water users have indicated that there is not enough water downstream from the boarding school. Seepage from the main canal has resulted in heavy concentrations of salt in previously good fields north of the old chapter house. This is an eyesore. The water users indicated that this situation could be improved with drainage pipes.

8.2.1.8 *Siphon under Highway 666 (Reach 145)*

The siphon under Highway 666 (Reach 145) poses several unanswered questions. Operating staff has indicated that this siphon may be a constraint on the system. Based on the descriptions, the siphon may be submerged much of the time. It is not possible to determine whether the limiting structure is the siphon, the downstream control gates or the downstream canal. These reported observations appear to be verified through the reach by reach assessment of capacity and demand and with the observation of the water users.

8.2.1.9 *Sub-laterals from Reach 135 (Reach 135)*

Water users have noted that a number of the ditch culverts under roads may have inadequate cover. Consequently, they are subject to frequent damage.

8.2.1.10 *Area 2 Lateral (Reach 100)*

Water users have noted problems with the Area 2 Lateral. During the 1997 irrigation season farmers constructed temporary weirs in the canal to raise the water in order to divert water to their fields. Farmers in the Little Mesa area noted that little or no water was available for the down stream irrigators (Field Numbers 262,263, 264, 267, and 273). The water shortages result in fights between water users. One suggestion was to line the laterals to reduce seepage losses. One water user indicated that the engineering resulted in an inadequate canal slope and that the canal needed widening and lining.

8.2.1.11 *Area 2 Lateral Culvert (Reach 93)*

The Area 2 Lateral culvert over the Salt Creek Wash has washed out. In response to this damage, the irrigators are using other reaches to reroute water around the washed out structure.

8.2.1.12 *Downstream Reach of Area 2 Lateral (Reach 83)*

Water users commented that the capacity of the downstream sections of the Area 2 Lateral was inadequate.

8.2.1.13 *Control structures above Salt Creek Siphon (Reach 85)*

According to the 1989 USBOR Design Proposal. the control gate above the Salt Creek Siphon is in need of repair. The main canal near Area Three has major silting problems near the bends.

8.2.2 *Fruitland Irrigation Project*

The Fruitland Irrigation Project includes approximately 24 miles of concrete and earth lined canals and between 97 and 120 miles of field laterals. For this analysis the Fruitland system has been defined by 21 reaches. The numbering system begins at the tail of the system (Reach 10) and stops at the diversion structure (Reach 110).

8.2.2.1 *Diversion Structure (Reach 110)*

In the 1994 DNR/BOR Reconnaissance Report, it was noted that the diversion structures have reached the end of their design lives. Water users noted that the automatic sluice is not working. This structure may also need to be modified in response to endangered species concerns. The diversion structure is on land owned by the City of Farmington.

8.2.2.2 *Main canal (Reaches 90 and 100)*

The culvert crossing Red Mule Wash is at risk of washing out.

8.2.2.3 *Main canal (Reaches 80 and 90)*

The road along the concrete lined canal is lower than the canal. The dirt along the outer bank is eroding away.

8.2.2.10 *Main canal (Reach 20)*

In the San Juan Chapter approximately 12 farmers with new fields need water and new laterals. Two or three new headgates are needed. This area has problems with erosion of soil into the existing canals. The Denison's farm which is at the end of the system only gets a trickle of water.

8.2.3 *Cudei Irrigation Project*

The Cudei Irrigation Project includes approximately 4 miles of earth lined canals. For this analysis the Cudei system has been defined by three reaches. The numbering system begins at the tail of the system (Reach 10) and stops at the diversion structure (Reach 30).

8.2.3.1 *Cudei Diversion Structure (Reach 10)*

The 1989 USBOR Design Proposal outlined four options for the Cudei Diversion Structure. The first option is to redesign and rebuild diversion works to reduce sediment related maintenance. The second option is to bring a siphon from the Hogback Canal. This siphon would provide pressure for sprinkler irrigation. The third option is to collect water utilizing an intake gallery. And, the fourth option is to drill a series of tube wells into the San Juan River alluvium. These modifications will address endangered species needs as well as improve water delivery to the water users.

8.2.3.2 *Main canal (Reaches 20 and 30)*

The culverts and siphons have holes and are filled with debris. There are drainage problems throughout the system. Weeds and Russian Olives are growing in the canals. Headgates need repair. The canal may need to be lined.

9 *OPERATION OF THE SHIPROCK IRRIGATION PROJECTS*

In the comments provided by the USBOR Phoenix Area Office, the reviewers noted that the original draft of this technical memorandum included essentially no information on the operation of the project. This section was added to the final draft to provide overall operational information. This section includes information on the staff and budget, project equipment and project operation.

9.1 *Staff and Budget*

The Navajo Branch of Operation and Maintenance is responsible for the operation of the Shiprock Irrigation Projects. The Branch is part of the Navajo Department of Water Resources which is part of the Navajo Division of Natural Resources. In 1998 the Operation and Maintenance Branch received approximately $215,000 of Tribal General Funds for the Shiprock Irrigation Projects. The budget included approximately $144,000 for seven full time employees, $10,000 for vehicles, $42,000 for supplies. No funding was available for equipment repair or consultant fees.

The current assessment from the water users is $1.50 per acre. With no delinquencies, the assessment would generate approximately $30,000 for the operation of the projects. The water users drop off checks at the Shiprock Irrigation Office. The checks are then hand delivered to the Department of Water Resources in Fort Defiance where administrative staff deposits them into the Tribal Revolving Account set up for tribal irrigation projects. The revolving accounts do not accrue any interest payment. These budgets require annual review through the Tribes "164" Signature Authorization Sheet process and the approval of the full Navajo Tribal Council is required.

The Shiprock irrigation staff includes five permanent employees and two part time employees. The staff consists of a supervisor, a clerk, four equipment operators and a welder. At the present time there is no ditch rider position. Irrigation staff alternates weekends on-call in the case of an emergency. Low salaries and personnel policies were cited as obstacles to modifying the staffing system. The current personnel policies make it difficult to provide delivery services over the weekend, which is when most of the water users prefer to irrigate.

9.2 *Project Equipment*

Based on information proved by the Shiprock Irrigation Office, the office maintains approximately 16 pieces of heavy equipment. An equipment list is shown in Table 9. During the summer of 1998, about half of that equipment was down. As noted in the budget, the irrigation budget has no funding for equipment repairs.

Table 9.1
Shiprock Office Heavy Equipment

Equipment	Condition
J.D. 410B Backhoe	Fair
Case 580 Backhoe	Good
J.D. 850 Bull Dozer	Good
J.D. 790 Excavator	Down
J.D. 544A Front end Loader	Down
Samsung SE280LC Excavator	Down
Case/Drott 45R Excavator	Down
Caterpillar 12E Motor Grader	Down
Caterpillar 613 Scraper	Down
Bobcat 743 Skid Steer Loader	Good
White GMC #9083 Truck	Down
Chief Lowboy Trailer	Fair
Pintlle Hook Flatbed Trailer	Fair
Walton Goose neck Trailer	Good
MCT 20 Yard End Dump Truck	Fair
Miller Big 20 Welding Machine	Good

9.4 *Revised Plan of Operational for the San Juan Farmboard*

The Navajo Nation farmboards are a division of Chapter government. They are responsible for a wide variety of farming activities including input on land use permitting, non-irrigated farms and farms associated with the irrigation projects. The Navajo Nation Farmboard Plan of Operation allows the Farmboards to collect a water assessment for the operation and maintenance of the irrigation project. This assessment may revert directly to the Farmboard (3 N.N.C. Section 62). The DWR/WMB has worked with the Department of Agricultural and the water users to prepare a Fund Management Plan based on the tribal regulations for nonprofit corporations.

The draft Fund Management Plan describes the Farmboards establishing representative water users associations governed by their own bylaws and the articles of incorporation as a nonprofit corporation. This association may, over time and based on the concurrence of the NDWR, take on greater and greater responsibility for operation and maintenance of the irrigation system. This responsibility may include hiring ditch riders to administer water deliveries. Based on the bylaws, the associations will have a representative mechanism for changing assessments and developing penalties for delinquencies.

The Farmboard, through its association, will also hold a Water Use Permit describing the irrigation project's place of use, point of diversion and type of use. This permit will define and protect the irrigators water uses. The proposed Water Use Permit may also describe special conditions protecting the use of the irrigators on the system.

10 *COMPARISON BETWEEN THE SHIPROCK AND OTHER IRRIGATION PROJECTS*

The USBOR maintains records on dozens of irrigation projects in the Western United States. Based on these statistics, it is possible to develop values for various irrigation project performance parameters. These parameters provide indicators which can be used to determine potential problems facing projects, and to suggest strategies for addressing the problems. These indicators include gross crop values, project assessment rates, irrigated land per mile of canal and the structure density.

10.1 *Gross crop values and low crop intensity*

As shown in Table 10.1, the gross crop value for the irrigated fields on the Shiprock irrigation projects is approximately 189 dollars per acre. In comparison, the gross crop value on the Hammond Irrigation Project is approximately 341 dollars per acre. The overall cropping intensity is below 50 percent while the cropping intensity on the non-Indian projects is between 80 and 90 percent. These low crop values combined with low cropping intensity make it very difficult to achieve a self sustaining irrigation system.

Studies of irrigation projects indicate that typical operation and maintenance assessments are about 6 percent of the gross crop values. As shown in Table 10.2, for the 21 projects utilized in a recent USBOR study, the average operation and maintenance was approximately 9 percent of the gross crop value. Based on Tables 10.1 and Table 10.2, it appears that the Shiprock Irrigators may only be able to afford an assessment between $11 and $17 per acre. Assessments greater than $17 per acre may not be possible until crop values increase or a modified rate schedule is implemented.

10.2 *Project assessment rates*

The average assessment rate for the 21 projects in the USBOR database is approximately 20 dollars per acre while the assessment rate for the Shiprock Projects is $1.50 per acre. This low assessment rate combined with the higher canal density generates only $60 per mile. Including $215,728 of Tribal General Funds the available annual funding is $692 per mile. On other irrigation projects in the western United States the water users typically spend $3,000 dollars per mile. The current resources are adequate to operate and maintain about 70 miles of canal and laterals, not the 350 miles on the three irrigation projects. These numbers are skewed by the major portions on the conveyance system which are no longer in operation. And, a small part of this shortfall is made up by a variety of tribal, state, BIA and USBOR funds.

This lack of resources results in deferred maintenance and general deterioration of the structures and canals. The resulting loss of water control decreases the reliability of the water and the value of the water to the water users. This same conclusion was noted in the 1994 DNR/BOR Reconnaissance Report. Increasing the assessment to $17 per acre would theoretically generate an additional $600 per mile of canal and lateral.

10-2

TABLE 6

Comparison of Irrigation Project Performance Indicators

PERFORMANCE INDICATORS	Navajo Shiprock Irrigation Projects				Non-Indian Irrigation Projects		
	Fruitland Irrigation Project	Hogback Irrigation Project	Cudei Irrigation Project	Cambridge Irrigation Project	Hammond Conservancy District	Farmers Mutual Ditch Company	Twenty One Project Average
Irrigable acres	3335	8286	543	300	3933	4174	31974
Irrigated acres	2380	2545	244	160	3402	3756	28340
Cropping Intensity	71.36%	30.71%	44.94%	53.33%	86.50%	89.99%	88.63%
Diversion Capacity (CFS)	165	220	30	20	90	40	
Total Diversion (acre-feet)					30198		
Operational Spills (acre-feet)					11954		
Transportation Losses (acre-feet)					6879		
Irrigable acres/canal mile	23.50	51.29	114.32	85.71	105.73	208.70	
Irrigated acres/canal mile	16.77	15.75	51.37	45.71	91.45	187.80	160.00
Crop value/irrigated acre ($)	$189.00	$189.00	$189.00	$189.00	$341.00	$341.00	$243.29
O & M assessment ($/acre)	$1.50	$1.50	$1.50	$0.00	$34.25	$20.00	$18.98
O & M assessment/crop value	0.79%	0.79%	0.79%	0.00%	10.04%	5.87%	7.80%
O & M assessment/canal mile ($)	$25.16	$23.63	$77.05	$0.00	$3,132.22	$3,756.00	$3,285.04
Main Canals (Miles)	21.90	26.55	4.75	3.50	26.95	20.00	
Laterals (Miles)	120.00	135.00	0.00	0.00	10.25	0.00	
Canal mile/total delivery mile	0.15	0.16	1.00	1.00	0.72	1.00	0.35
Lateral mile/total delivery mile	0.85	0.84	0.00	0.00	0.28	0.00	0.65

Notes

(1) Navajo Shiprock project acreages based on the 1993 BIA Crop Utilization Study

(2) Hammond Conservancy District values from: 1. Crop production and utilization report Feb 17, 1995 and San Juan River Unit- Colorado River Water Quality Improvement Program Reprot January 1993

(3) Farmers Mutaul Ditch data from the 1988 Financial Report

(4) Twenty one project average from "Wind River Irrigation Project Assessment and Plan" (NRCE, June 23, 1994)

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(5) INCLUDING ~~$0~~ $215,728 OF TRIBAL GOVERNMENT FUNDS MADE OEM TO TRIBE DOLLARS PER MILE TO $692 PER MILE.

Table 10.1
Average Crop Yield for the Shiprock Area

Crop	Percent	Yield	Value (Dollars/unit)	Gross Crop Value (Dollars/acre)
Corn (bu/ac)	19	30.0	3.00	90.00
Grains (bu/ac)	4	30.0	3.00	90.00
Alfalfa (Ton/ac)	46	2.0	119.00	238.00
Vegetables (bu/ac)	6		503.00	503.00
Orchards (bu/ac)	2		503.00	503.00
Pasture (AUM/ac)	23	2.9	28.00	81.20
Average crop Value based on 1994 crop mix				189.10

Source: Crop values from the 1993 USBOR Crop Production and Water Utilization Survey Hammond Conservancy District - February 17, 1995

10.3 *Irrigated land per mile of canal or lateral*

As a general guideline, the USBOR generally suggests that an irrigation project needs approximately 140 acres per mile of canal to be economically self-sufficient. As shown in Table10.2, the Shiprock irrigation projects irrigate approximately 40 acres per mile of canal and lateral. These values are somewhat skewed by the conveyance system to Area 7 which is no longer in operation. Even so, the acreage base may be inadequate to support all 300 miles of canals and laterals. Based on these performance indicators, the Shiprock Irrigation Projects may only be able to satisfactorily maintain about 100 miles of canals and laterals. The Project may need to decommission some canal reaches.

10.4 *The high structure density*

Based on the USBOR 1989 Design Proposal, the Hogback Project has 1,990 structures, the Fruitland project has 1,201 structures and the Cudei Project has 50 structures. This system acreage results in approximately eight irrigable acres per structure. This situation results in a very high structure density and a high maintenance burden. On response to this problem is to reconfigure portions of the system to eliminate, or reduce, open canals and structures.

11 *WATER MANAGEMENT CONCERNS*

One of the objectives of this study is to compile background information which may help to ensure the Navajo Nation's successful participation in appropriate programs and to identify key management concerns. Based on the literature review and on discussions with water users and managers, some of the key water management concerns are presented.

11.1 *Low cropping intensity, low crop value and low assessments*

Low cropping intensity, low crop values and low assessment rates are interrelated. The 1993 Crop Utilization investigation indicates that low cropping intensity and low crop values have plagued these projects for decades. The overall cropping intensity is less than 50 percent while the non-Indian systems in the area have cropping intensities between 80 and 90 percent. The gross crop values are 40 percent less than on the non-Indian systems in the area. The studies cited by the ISC indicate that cropping intensity has fallen over the last thirty years. This poor on-farm performance results in a lack of resources to maintain the system. As maintenance is deferred, the reliability and value of the water declines.

All of the Shiprock projects have significantly lower cropping intensities toward the ends of the canals and the laterals. This result indicates that water control progressively declines further down the systems. Assuming little or no operation and maintenance subsidy, idles lands must be reduced and crop values must increase because idle lands negatively impact all of the remaining water users. Breaking this cycle will require the active participation and direction of the water users. It also requires adequate resources to reconfigure the irrigation projects and to restore the on-farm systems in ways that make them sustainable.

11.2 *A critical need for system wide and on-farm rehabilitation and reconfiguration*

Rehabilitation generally implies replacement in kind. As recommended by the USBOR, a hydraulic structure table needs to be developed. This data base can be utilized to develop a structure by structure assessment of all project facilities. Each structure and canal reach can be categorized based on its condition and the cost of replacement and/or repairs. If the rehabilitation expense is sufficiently large, it may be more cost effective to reconfigure portions of the project.

There are several approaches to closing the gap between the current situation and what the projects needs to be self-sustaining. Based on the performance indicators cited in the previous section, conventional rehabilitation may not restore or create a viable project. Comparisons between the Shiprock projects and other irrigation projects reveal some of the potential problems that must be addressed through reconfiguration. Regardless of whether the water users are operating commercial or noncommercial farms, certain economic realities must be incorporated into the

operation of an irrigation system. One goal of reconfiguring the project is to reduce the operation and maintenance expense so that the water users will be able to afford the annual upkeep.

Another approach is to lower the overall operation and maintenance expense. This goal can be achieved by reducing the number of miles of canals and laterals that must be maintained. One strategy is to convert open ditches to closed pipes. Pipe systems are able to traverse contours and, according to USBOR studies, the maintenance is reduced to approximately one fourth of the cost of open canals. Closed pipe systems may also be designed to enable farmers to take advantage of system pressure.

Another strategy is to systematically decommission laterals which cannot be effectively operated by the project. These decommissioned laterals may either be operated by a subgroup of water users or abandoned. These strategies are not easy to implement. They require strong leadership, direction and participation of the water users and the technical information so that the water users can make informed decisions.

11.3 *Improving water control and increasing the role of the water users*

Much of the recent literature on irrigation management points out that rehabilitation on poorly performing irrigation systems is not simply a matter of reconstructing physical facilities. The effectiveness of an irrigation project is a function of the organization which rehabilitates, operates, and maintains the facilities, as well as resolve conflicts between water users. Irrigation organizations in the western United States have typically adhered to several general principles including among others, linking the delivery of benefits to the acceptance of obligations, and accountable leadership. Without an accountable water users association enforcing these principles, it is very difficult for an agency to effectively supply irrigation water. Overlapping layers of bureaucracy reduce accountability and hinder the efficient delivery of services to water users.

In Fiscal Years 1997, 1998 and 1999 the Navajo Nation and Colorado State University's Colorado Institute of Irrigation Management (CSU CIIM) were awarded Water Management and Conservation grants from the USBOR to work with the Shiprock Farm board on developing a water users association. CSU CIIM has suggested that the water users association would manage detailed water deliveries and financial accounting programs maintained by a small employed staff. The water users association would be a self-financed association whose employed staff and annual operation and maintenance costs would be paid through irrigation services charged for water service provided to association members. The association would operate at cost, meaning that it would be a nonprofit association. Revenue collected through irrigation service fees would be sufficient to cover all operational expenses, debt serving on loans or notes for special works, and cash reserve needs and approved by the water users board of directors for emergency and contingency purposes. The annual budget would be voted on and approved by all association members at an annual meeting.

11.4 *Subdivision of land for home sites and other land uses*

Several reports indicate that subdivision of land for home sites may be a serious problem. It was not within the scope of this study to address concerns over home sites within the irrigated lands. However, aerial photos of the area from the 1970's and 1990's are available. One recommended study is to review these photos to determine the extent and the rate of homesite development. If these results indicate that this problem is serious, a number of measures including, among others, variable water rates, and zoning will be presented.

11.5 *Seepage and other operational losses*

To help assess conveyance losses, in 1993 the USBOR and BIA conducted ponding test and seepage rate determinations on the main Hogback and Upper Fruitland canals. The USBOR normally expresses seepage loss in terms of cubic feet of water passing through one square foot of wetted canal surface per day. For the 1993 study two sites on the Fruitland canal and four sites on the Hogback canal were measured. The investigation yielded the following results:

- The first Hogback site is 1 mile downstream of the San Juan River diversion. The section is unlined and the seepage was 0.07 cubic feet per square foot per day (Reach 187).

- The second Hogback site is 2.7 miles east of Shiprock. The section had an asphalt paper membrane and the seepage rate was 0.06 cubic feet per square foot per day (Reach 170).

- The third Hogback site is 0.2 miles west of Highway 666. The section is lined with concrete in a deteriorated condition and the seepage rate was 0.15 cubic feet per square foot per day (Reach 140).

- The fourth Hogback site is 0.5 miles upstream from the siphon at Salt Creek Wash. The section is lined with concrete and in good condition. The seepage rate was .05 cubic feet per square foot per day (Reach 90).

- The first Fruitland site is 4.0 miles east of County Road 6675. The section is in a cut and the seepage rate was 0.09 cubic feet per square foot per day (Reach 80).

- The second Fruitland site is on a steep escarpment 2.2 miles east of County Road 6675. The seepage rate was 0.14 cubic feet per square foot per day (Reach 72).

These tests indicate a low rate of seepage for both the Hogback and Upper Fruitland canals in the Shiprock area. These seepage rates are similar to those of concrete lined canals with good joint fillers. Based on these results, the USBOR concluded that these canals are not major

contributors of salinity to the San Juan River. The USBOR theorized that silt being transported into the canals from the San Juan River is a major factor in the low seepage rates. This theory may explain why seepage rates appear to increase immediately after the canal banks are reworked.

Many of the reported seepage problems are associated with the project laterals, not the main canals. For instance, it has been reported that near the beginning of the Area 2 Lateral the drainage ditches running parallel to the canal are pooled with water seeping from the lateral. Follow-up work is needed to further quantify seepage losses.

11.6 *Salinity and selenium control*

Salinity and selenium issues are closely related to seepage losses. The United States Geological Service (USGS) records indicate that approximately 157,000 tons of salt are discharged annually into the San Juan River from the Fruitland, Hogback, and Cudei Irrigation areas in the Navajo Nation. In a 1993 study, the USDA indicates that nearly 50,000 tons of salt, in addition to nutrients and pesticides, may be picked up annually by excess irrigation water returning to the San Juan River.

The Fruitland, Hogback, and Cudei irrigation projects were constructed to provide water to approximately 12,000 acres of land through 304 miles of largely unlined canals and laterals. The irrigation delivery and return systems cross terrain composed of rocks from the salt bearing Mancos shale or from soils derived from that rock. The USDA estimated that approximately 14,000 tons of salt are picked up due to "off-farm" canal seepage and 34,000 tons of salt are picked up due to on-farm water use. However, these ponding tests produced inconclusive results.

In the 1993 study, the USDA proposed pipe or concrete lining to repair about 200 miles, or two thirds, of the irrigation project canals and laterals. The USDA also recommended an on-farm program to improve about 80 percent of the furrow and flood irrigated fields. Recommended treatments include ditch lining, gated pipes, surge valves, water control structures, land leveling and irrigation water management. The NRCS recommended a flexible approach to treatment depending on the on-farm circumstances and the potential for salinity reduction. Demonstration projects were encouraged.

The BIA Navajo Area Office prepared a summary of the chemical and physical data for soils along the Hogback, Cudei, Cambridge and Fruitland irrigation canals in the Shiprock area. This analysis was presented to WMB into memorandums, dated 11/24/97 and 11/26/97. For this analysis the canal reaches were examined from the following perspectives:

1. Rapid soil permeability which indicates that canals should be lined - These map units are tabulated in Table 1 of Appendix 4.

2. Corrosion hazards to concrete and steel which indicate limitations for structural materials and that requires special design attention - These map units are tabulated in Table 1 of Appendix 4.

3. Shrink-swell potentials which can affect the canal grade stability especially if pipe and/or concrete liners are used - These map units are tabulated in Table 1 of Appendix 4.

4. Sources of selenium hazards - The potential selenium hazard can come from one or more contributing factors: type of parent material, depth to bedrock strata containing selenium, and depth to the capillary fringe and seasonal ground water table. These map units are tabulated in Table 3 of Appendix 4.

A reach by reach analysis which identifies reach numbers, lining attributes, and soil units are presented in Table 2 of Appendix 4. DWR/WMB intends to overlay the soils data provided by the BIA onto our developing GIS coverages in future phases of this study. DWR/WMB will then generate a matrix tabulating the length of earth-lined canals that passes through soils of varying permeability, corrosion hazard, shrink-swell potential, and selenium sources. This more detailed analysis will then be used to define reaches of the various soil types underlying the canals.

It should be noted that not all of the 300 miles of the Shiprock unlined canal and laterals were within the scope of this study. As improved GIS coverages of these projects are developed, it will be possible to assess a greater percentage of the canals. The soil analysis and other types of analyses in this report need to be extended to the project laterals as well as to the on-farm irrigation systems.

11.7 *Compliance with the Endangered Species Act*

The Shiprock irrigation projects divert water from, and discharge into, designated critical habitats for at least two endangered species. In 1996 the Biology Committee of the San Juan River Recovery Implementation Program directed BIO/WEST to study the feasibility of expanding the distribution of Colorado Squawfish in the San Juan River. According to the BIO/WEST investigation, diversion structures on the San Juan River represent substantial obstructions in the main channel that impede, block, or intercept local and migratory movement of Squawfish. Further investigations conducted in October 1997 conclusively demonstrated that the Cudei diversion structure is capable of entraining young Squawfish. Another concern is that the frequent reconstruction of the Hogback diversion berm after high water events may have detrimental effects on critical habitats.

Project return flows may degrade the water quality of the San Juan River. Biologists believe selenium, a potentially toxic element plentiful in some San Juan River irrigation return flows, could be compounding the effects of chemicals from oil and gas wells.

As well as addressing environmental concerns, reconfiguring the diversion structures would provide substantial benefits to the water users. First, the reconfigured diversion structures will be much less likely to be damaged during high flow events. This would reduce or eliminate program expenditures on rebuilding the diversion works. Second, the reconfigured diversion structures would be much more effective on controlling sediment. Eliminating or reducing the sediment load in the canals will greatly reduce the maintenance burden. Finally, the reconfigured structures could be operated much more efficiently. This would result in fewer operational discharges and an increased ability to responded quickly to water demands. The USBOR conducted site investigations and a drilling program during the winter of 1998 low flows, and began design work in 1999.

11.8 *Reestablishing Area 7 and other lease areas*

Area 7 encompasses approximately 2,000 acres of land that was irrigated during the 1970's. For a variety of agronomic and institutional reasons, Area 7 was abandoned. Reestablishing irrigation in Area 7 could improve the financial base for the Shiprock project operation and maintenance. A study should be conducted to determine agricultural opportunities and evaluate the risk. This effort may result in cost estimates which could be incorporated into settlement discussions or into a request for proposals.

11.9 *Fee schedule including NTUA's Hogback diversion*

A new fee schedule needs to be developed balancing the various water uses and the need for a balanced operational budget. This budget should identify the major operational expenses.

The Navajo Tribal Utility Authority (NTUA) diverts water from the Hogback Canal for municipal purposes. The point of the diversion is approximately 10 miles downstream from the headworks, and is immediately downstream from the siphon under Highway 666. According to a study conducted by Molzen-Corbin (1993), NTUA currently has the diversion capacity of 900 gallons per minute, or 2 cfs. This water is diverted to a 500,000 gallon surge tank which is part of NTUA's water treatment plant. This diversion capacity would result in a theoretical diversion capacity of 1,450 acre-feet per year. However, the system does not operate during the winter months. Based on Moslem-Corbin's estimates, NTUA can currently only utilize approximately 1,000 acre-feet per year. An additional 1,500 gallons per minute can be pumped to the treatment plant directly from the San Juan River.

According to Molzen-Corbin (1993), projected population growth in the Shiprock area dictates a potential need to increase the capacity of the NTUA diversion. Molzen-Corbin estimates that the NTUA projected peak day requirements for the year 2013 would be at most 3 percent of the Hogback Canal's design capacity of 220 cfs, or 6.6 cfs. Using canal water rather than an alternative water source to increase the capacity to 6.6 cfs provides several advantages for NTUA. First, by the time the water reaches the NTUA turn out, much of the sediment has settled and the water is less

turbid. This makes the water easier to treat than water diverted directly out of the San Juan River. The canal can also provide up to 70 percent of the treatment plant's capacity without pumping. Another advantage is that the Hogback Canal provides water to the NTUA system during the peak summer demand periods.

This arrangement has some disadvantages for NTUA. The primary disadvantage is that the facility cannot deliver water year round. According to the 1994 DNR/BOR Reconnaissance Report, the Hogback system was kept in service through severe winter conditions to accommodate NTUA, resulting in severe frost damage to the canal linings. Because of this limitation, a significant portion of the Shiprock area municipal water demands must be met by other sources. Another disadvantage is that the NTUA diversion is subject to interruptions if the canal is unexpectedly shut down for maintenance or repair.

Molzen-Corbin notes in their report that there is no existing agreement between NTUA and the DWR for sharing canal maintenance costs. A formal agreement would provide benefits to both the NTUA water users and to the Shiprock irrigators. Molzen-Corbin refers to discussions between NTUA and DWR during which a range of charges from $3,000 to $40,000 were considered. According to Molzen-Corbin, a $40,000 charge would be $0.125 per thousand gallons or 40 dollars per acre-foot. This rate is twice the cost of pumping directly from the San Juan River. From a cost avoidance standpoint, a charge of up to $25,000 per year could be justified.

Another approach would be to prorate a reasonable canal operation and maintenance fee for NTUA. The USBOR prepared envelope cost curves for estimated canal operation and maintenance costs per mile. Based on these curves, the cost for a 250 cfs canal ranges from 1,000 to 4,000 dollars per mile depending on local conditions. Using a different USBOR data source based on 21 irrigation projects, the typical irrigation project spends approximately 3,200 dollars per mile of canal for maintenance. NTUA benefits from approximately 10 miles of canal, and utilizes 3 percent of the canal's capacity. NTUA also benefits from the efforts to maintain and operate the Hogback diversion structure. These cost components result in an annual fee between $2,000 and $3,000 per year.

When considering an appropriate fee structure, municipal water has a much higher commercial and economic value than agricultural water. Consequently, the municipal water user's ability to pay is greater. For instance, the USBOR's Colorado River Storage Project's repayment obligation for industrial water users is approximately $50 dollars per acre foot while the repayment obligation for irrigation is only $10 per acre-foot.

Another consideration is that on most water systems, all of the water users share some common benefits and some common responsibility for the entire water delivery system. If one assumes that the Shiprock Irrigation Project's required operating expenses are approximately 400,000 dollars per year, and that NTUA utilizes between two and 4 percent of the systems diversions or depletions, then the annual fee would be between $4,000 and $12,000.

NTUA and DWR have agreed to an annual payment of $25,000 dollars per year which is approximately $0.24 per thousand gallons. This fee is a significant source of funding for the operation and maintenance of the irrigation systems. This fee is about the same as the cost of pumping water directly from the San Juan River. This fee still keeps the NTUA Hogback water delivery option in a financially attractive range.

11.10 *The system right-of-ways are poorly defined*

The system right-of-ways are not clearly established. The aerial photographs produced in 1999 will by useful in reestablishing the right-of-ways.

12 *RECOMMENDATIONS FOR A PLAN OF ACTION*

One of the objectives of this technical memorandum is to present recommendations that can be formulated into specific proposals for the appropriate federal or tribal agency. Most of these recommendations were presented in earlier drafts of this Technical Memorandum. Based on comments received and recent accomplishments, these recommendations are presented as a chronological action plan. The higher priority activities are scheduled earlier and the sequence of recommendations results in a critical path. These recommendations fall into three general categories:

- Recommendations for correcting immediate system deficiencies,
- Recommendations for organizing the water users, and
- Recommendations for developing a rehabilitation plan for congressional authorization in FY2002 as part of the Navajo Nation's interim settlement on the San Juan River.

The Plan of Action presented starts with the major activities completed in Fiscal Year 1996. The ability to adhere to this proposed schedule depends largely on the availability of funds.

12.1 *Fiscal Year 1996 Activities*

12.1.1 *Yellowman Siphon Emergency Reconstruction*

In the 1996 USBOR, and ~~State~~ funding was provided to complete the emergency reconstruction of the Yellowman Siphon on the Fruitland system.

12.1.2 *Colorado State University Irrigation Training*

A USBOR cooperative agreement entitled *Water Management and Conservation Education Program for Navajo Water Users in the San Juan River Basin* funded an irrigation training for the water users. This technical workshop was conducted by the Colorado Institute of Irrigation Management. It increased awareness of water management issues and improved water management practices.

12.2 *Fiscal Year 1997 Activities*

12.2.1 *Yellowman Siphon Reconstruction Phase I*

In the 1997 USBOR and State funding was provided to reconstruct ~~2,000~~ feet of the Yellowman Siphon. Materials were procured and construction was ~~initiated in 1998~~.

12.2.2 *Colorado State University Water Users Association Training*

A USBOR grant entitled *Water Management and Conservation Education Program for Navajo Water Users in the San Juan River Basin* funded an irrigation training for the water users. This program included public education. It targeted the general public of the Navajo Nation to help them participate in the water management and planning activities currently taking place.

12.2.3 *A and B Lateral Irrigation Demonstration*

A USBOR grant entitled *Hogback B-Line Irrigation Project Improvement Program* to improve the system and overall management of the Hogback B-Line Irrigation Project. Work will consist of an evaluation of the existing system, assessments of farm plot soils, gated pipe and sprinkler trial runs, and pump testing. A demonstration project is also planned to promote good irrigation practices. This program will also include Area 3.

12.3 *Fiscal Year 1998 Activities*

12.3.1 *Completion of "An Appraisal Level Study of the Capacity Constraints and Water Demands of the Shiprock Irrigation Projects"*

In 1998 the USBIA provided funding to complete this technical memorandum entitled *"An Appraisal Level Study of the Capacity Constraints and Water Demands of the Shiprock Irrigation Projects"*.

12.3.2 *Colorado State University Ditch Rider/Water Users Training and Field Trips*

A USBOR cooperative agreement entitled *Navajo Irrigator's Initiative with the Navajo Nation* and *Water Management Education Program for Navajo Water Users* funded a program to initiate a management transfer program designed to eventually turn over the operation and management of the systems to water users organizations. The agreements will be used to provide technical assistance to develop plans, educate farmers, ditch riders and other personnel. The program funded field trips for water users and for ditch riders, and also funded Chapter meetings to present the development of water users associations on the Shiprock projects.

Using funds provided by the USBOR and the DWR/WMB two pilot ditch rides were established. The objective of these demonstration rides was to collect data on the water supply, improve the water delivery services, and provide additional information on the resources needed to establish rides on a permanent basis.

12.3.3 *Drilling investigation for the Hogback Diversion Project*

In the 1994 DNR/BOR Reconnaissance Report, it was noted that the three diversion structures should be replaced. The Hogback Project diversion structure should be reconfigured to improve sediment control and provide for more efficient water delivery. An improved structure would also reduce or eliminate the annual need to rebuild the diversion structure. The re-configured structure would also address endangered species concerns by eliminating an impediment to fish movement and entrainment.

The USBOR provided approximately $75,000 of FY1998 Native American Affairs Office (NAAO) funds to conduct the drilling and pre-design investigations of the Hogback Diversion structure. This drilling program occurred during late February 1998 when the irrigators did not need water and when the San Juan River flows were low. The 11,000 foot cross section of the proposed site indicated that at the deepest point the unconsolidated

deposits are less than thirty feet deep. Beneath the unconsolidated deposits is soft to moderately soft sandy shale and fine grained sandstone.

12.3.4 *Dine College/Colorado State University demonstration*

In 1998 the USBOR Water Management and Conservation program is considering funding a demonstration farm project at Dine College (formerly Navajo Community College). This project was delayed due to a fire at the College.

12.4 *Fiscal Year 1999 Plans*

12.4.1 *Complete high resolution aerial photogrametery*

Without adequate maps it is difficult to address system wide problems. In its Design Proposal the USBOR notes the need for original project data and specifications for all project features. Developing an adequate map base with traditional ground surveying techniques, or digitizing the locations of project facilities using existing conflicting maps requires excessive amounts of man power. Reconciling the precise location of structures using the existing maps is extremely difficult.

Due to the discrepancies between the various map sources, the DWR/WMB recommended developing new 1:5000 base maps with 2 foot contour intervals. The USBOR recommended utilizing aerial photogrametery. With USBOR assistance, the DWR/WMB intends to develop a digitized coverage of the canals, farm ditches, waste ways, drains, and structures.

This product, with appropriate ground control, will result in a base map adequate for rehabilitation design purposes. This product will also be useful to economically carry out a number of the recommendations presented in this technical memorandum. This product including ground control, aerial photography, and triangulation will cost approximately $140,000. The aerial photography will be largely funded using USBOR Native American Affairs Office funding. Limited data reduction should provide an accurate schematic for planning purposes.

12.4.2 *Survey of the Fruitland Diversion Structure*

The Fruitland Diversion is located on land that belongs to the City of Farmington. The Department intends to conduct an accurate survey of the canal alignment and present a proposal to the City to transfer the ownership of the alignment and an access right-of-way for the diversion structure and the canal.

12.4.3 *Yellowman Siphon Reconstruction Phase II*

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In 1999 USBOR and State funding may be provided to reconstruct an additional ~~2,000~~ feet of the Yellowman Siphon on the Fruitland system.

BADLY DETERIORATED PLANS & SPEC COMPLETED, HOPE COMPLETION

12.4.4 *Rehabilitation Plan Scope of Work*

A Scope of Work for the rehabilitation plan should be developed. This scope of work will outline the required investigations and propose a construction, design and authorization schedule. One proposed schedule would be for studies during the 2000 and 2001 fiscal years with authorization in 2002. This schedule might be associated with an interim settlement of the Navajo Nation's federally reserved water rights in the San Juan River Basin. The 1989 USBOR Design Proposal and the 1994 DNR/BOR Reconnaissance Report are excellent starting points.

12.4.5 *Establish a Water Users entity through the Farmboard*

An effective water users organization is one of the key factors for successfully operating an irrigation project. CSU CIIM has worked with the Shiprock Farmboard to determine how a water users association similar to a water district or ditch company can be established. The water users, DWR staff and others familiar with the projects are working together on this initiative. USBOR Water Conservation Management FY1997 and FY1998 funds have been used for this effort.

The new Farmboard Plan of Operation allows the farmboards to the water users fees for the operation and maintenance of the system. In 1999 the DWR/WMB will work with the Farmboard to develop a Fund Management Plan, incorporate as nonprofit agricultural corporation, and develop bylaws for a water users association. To improve the water delivery services permanent ditch riders may be established during FY1999. CIIM will work with the water users to develop goals and objectives for the ditches, reasonable fee schedules, cost sharing opportunities, and other services.

12.4.6 *Design and Construction of the Hogback Diversion Structure*

Partly in response to the need to recover endangered fish species, and partly to improve the reliability of water delivery, NIIP will partially fund the reconfiguration of the Hogback

Diversion structure. The new structure will be more permanent, have better sediment and water control and improve the fish passage. The USBOR will provide approximately $75,000 of Native American Affairs Office funding in FY1999 to complete the design. Construction funds may be available from NIIP.

12.4.7 *Prepare an Memoradnum of Understanding (MOU) between the irrigation partners*

To improve the cooperation and coordination between the various agencies and the water users, an MOU will be prepared describing the missions of the various entities and the efforts that each entity anticipates bringing to the irrigation projects. Special attention needs to be provided to the close working relationship between the USBIA, USBOR, and NRCS.

12.4.8 *Establish a new Fee Structure*

In 1999 the DWR/WMB recommends developing a new fee structure and irrigation project budget for the Shiprock Irrigation Projects.

12.4.9 *Establish an improved water management program*

In FY 1999 the USBOR Water Management and Conservation Program will fund CIIM to work directly with the operation and maintenance staff for an extended period of time during the 1999 irrigation season. This activity will bring specialized water management skills to the irrigation system. It will also include distributing computers to the Farmboard.

12.5 *Fiscal Year 2000 Plans*

12.5.1 *Complete the comprehensive project base maps*

Due to the discrepancies between the various map sources, the DWR/WMB recommended developing new 1:5000 base maps with 2 foot contour intervals. The USBOR recommended utilizing aerial photogrametery to develop these maps. The aerial photographs will be completed in FY1999. With USBOR assistance, the DWR/WMB intends to develop this digital map product during FY 2000. Depending on the themes developed, these maps may cost between $100,000 and $200,000.

12.5.2 *Begin two year Rehabilitation Planning Study*

For congressional authorization in FY2002, the rehabilitation study should no later than FY2000. This plan should result in an Engineering Feasibility Report which would include cost estimates and an evaluation of alternatives This schedule might be associated with an interim settlement of the Navajo Nation's federally reserved water rights in the San Juan River Basin. This study may cost $400,000.

As part of the rehabilitation plan, the designation and description of the reaches must be refined. This effort will require additional interviews and review of maps and reports. The proposed aerial photogrammetry would be extremely useful for this effort. This improved designation would also include information on specific reach conditions. As part of the rehabilitation plan, the hydraulic structures database needs to be refined. This database will be used to establish an evaluation criterion for rehabilitation based on structure condition, acres of land served and overall cost.

12.5.3 *Complete the Hogback Diversion and the preliminary design of the Cudei Diversion*

Based on the completed USBOR design, construction of the new Hogback Diversion Structure should be completed in the year 2000. This project may be funded by NIIP as part of its compliance with the Endangered Species Act. The Cudei Diversion has four reconfiguration options including redesigning the existing diversion, building a siphon from the Hogback Canal, building an intake gallery and designing wells in the alluvium. These options need to be further evaluated and design work completed in the year 2000.

The reach by reach comparison between the capacity and the demand presented in the Technical Memorandum indicates that the reaches upstream from the Siphon under Highway 666 are a cause for concern. The underlying flow constraints need to be identified, and corrected before the Cudei options can be resolved.

12.5.4 *Begin Right of Way layout*

According to the BIA, the project right-of-ways have not been clearly established. Establishing the right-of-ways will be needed for the Project rehabilitation. Well defined right-of-ways are critical for system reconfiguration and daily operation and maintenance. The BIA has estimated that this effort will cost $200,000 for the canals and access easements. The aerial photogrametery will be essential for this work.

12.5.5 *Begin land re-designation, and reconciling acreage databases*

Due to changing land status, it is appropriate to redesignate irrigation project lands every ten years. This process can be used to insure that the assessed lands are correctly assessed. The proposed aerial photogrametery will be essential for this work. This effort will also take advantage of the NRCS soils classification. It will be an opportunity to rectify assessed acres that are abandoned, idle, or too alkaline to be irrigated. It will be possible to recalibrate the irrigated area associated with each farm plot, and remove project lands that have been committed to non-irrigation purposes. It would also be possible to develop some criteria for including new lands. The BIA has estimated that this effort will cost $400,000 for fencing the farm areas.

The differences between the various acreage databases need to be reconciled. The proposed aerial photogrammetry would be extremely useful for this effort. Because the ISC has recommended utilizing the 1994 data for San Juan River Basin modeling, it is especially critical to reconcile the differences between the 1994 and 1993 data. This data may be suitable for the Hydrographic Survey Report.

12.5.6 *Set up five to six additional ditch entities*

To improve the water delivery services additional permanent ditch riders may be established during FY1999. CIIM will work with the water users to develop goals and objectives for the ditches, reasonable fee schedules, cost sharing opportunities, and other services.

12.5.7 *Yellowman Siphon Reconstruction Phase III*

The DWR is attempting to identify funding to complete the third phase of the Yellowman Siphon reconstruction. INCLUDES DESIGN, CONSTR SPECS, PURCHASE MATERIALS & CONSTRUCT THE REMAINING 5200 FEET. COST OF MATERIALS IS $382,000. NRCS ESTIMATES INSTALLATION AND ENGINEERS COSTS TO BE $425000.

12.5.8 *Prepare an E.Q.I.P. proposal*

An Environmental Quality Improvement Program proposal will be prepared for the USDA to consider for funding in FY2000. The Shiprock Area's recent designation as an enterprise zone should assist the ranking of an E.Q.I.P Proposal.

12.5.9 *Prepare a technical memorandum on the subdivision of irrigated lands*

A study will determine the extent and the rate of homesite development and subdivision. Aerial photos from the 1970's, 1980's and 1990's will be reviewed to determine changes over the last ten, twenty and thirty years. The proposed aerial photogrammetry will be extremely useful for this effort.

The homesite developments identified in the various photo series would be transferred to a common digital base map. Depending on the extent of the problem. strategies could be identified. For instance a conveyance fee structure for commercial, agriculture, grazing, industrial and domestic purposes could be developed.

12.5.10 *Prepare a Salinity Control Proposal*

A more extensive study of seepage and salinity issues on the Shiprock irrigation canals is needed. This investigation identified laterals and unlined sections of main canals in problematic soils. A more refined investigation would include a greater portion of the project laterals and additional seepage measurements. The proposed aerial photogrammetry will be extremely useful for this effort. This proposal will be submitted to the USBOR in FY2000 anticipating FY2001 funding.

12.5.11 *Complete the Fruitland Standard Operating Procedures*

In 1995, DWR began developing standard operating procedures (SOP) for the Fruitland Irrigation Project. These procedures were approximately 90 percent completed when the work was discontinued. It will require approximately six weeks to be completed. Given the time that has been invested into that document, completing it would be a worthwhile expenditure and it may serve as a prototype for the other Navajo irrigation projects.

12.6 *Fiscal Year 2001 Plans*

12.6.1 *Complete the Shiprock Irrigation Project Rehabilitation Study*

The DWR will work with the technical staff from the USBOR and the USBIA to complete the Shiprock Irrigation Rehabilitation Study in 2001. This study will need to be adequate for submission to the Department of Interior and to Congress.

12.6.2 *Complete Right of Way survey, Land re-designation, and reconcile acreages*

The right of way and land designation surveys should be completed in 2001.

12.6.3 *Prepare a Technical memorandum on Area Seven*

Area 7 is an asset of the Navajo Nation that should be reestablished if possible. A technical memorandum should be prepared to review the agronomic potential of Area 7 and the other lease areas. This memorandum might serve as the basis for a request for proposals from potential interests. It might also serve the Nation's water rights protection effort.

12.6.4 *Set up an additional five to six ditch entities for a total of 10 to 12*

To improve the water delivery services additional permanent ditch riders may be established during FY2001. CIIM will work with the water users to develop goals and objectives for the ditches, reasonable fee schedules, cost sharing opportunities, and other services.

12.6.5 *Develop a weed control proposal*

Several water users noted the problem with weed control. Some varieties are especially invasive and it will require significant efforts to reclaim arable land. A weed abatement district or providing resources the existing weed abatement programs may improve the conditions of the ditches and of the farmland, drains and canals.

12.6.6 *Assess the condition of the project drains and develop a drainage plan*

Do to limited resources the existing drains have received very little attention over the years. An improved drainage plan will help to ensure that the lands currently irrigated will not fall out of production due to poor drainage. This task may be incorporated into the overall rehabilitation plan.

12.7 *Fiscal Year 2002 Plans*

12.7.1 *Authorization of Shiprock Rehabilitation as part of Navajo interim settlement*

The primary goal of this strategy is to have a workable rehabilitation plan for congressional authorization in FY2002. Rehabilitation of the Shiprock Irrigation Projects may be a significant part of a San Juan River interim settlement of the Navajo Nation's unquantified federally reserved water rights. The goal of the DWR/WMB is to have the wet water projects adequately defined for consideration by the Navajo Nation and Congress for an interim settlement in FY2002.

13 *CONCLUSIONS*

One fundamental question that must be resolved is whether or not the Shiprock Irrigation Projects are viable. Can the federal government, tribal government and local water users create projects that will be self sustaining in the next century? Can the parties justify the investment required to enable the projects to become self sustaining? One grim scenario is that the systems will continue to deteriorate, cropping intensity will continue to decline, and interest in irrigation will dissipate. If this grim scenario occurs, a precious Navajo asset will disappear. Technical memorandums cannot answer these questions, nor predict the future. They can only provide a data resource to assist the water users in formulating a plan of action.

Clearly a very valuable Navajo asset is at risk. Based on the data assembled in this technical memorandum, a critical mass of farm land exists that should be able to sustain the Shiprock Irrigation Projects. It does appear that if these projects were developed to their full assessed acreage, there may be some significant canal capacity constraints. Higher cropping intensity can only be accomplished with improved on-farm irrigation efficiency combined with improvements at the project level. Consequently, on-farm improvements need to coincide with system improvements. Successful project rehabilitation can only occur if the water users are intimately involved with, and ultimately take ownership of, the process.

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