RECLAMATION
Managing Water in the West

APPENDIXES
Final Report on Red River Valley Water Needs and Options

U.S. Department of the Interior
Bureau of Reclamation
Dakotas Area Office

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Acronym List

ac-ft-- acre feet
ASR – aquifer storage and recovery
bgals -- billion gallons
CDSS.--.Colorado Decision Support Systems
cfs -- cubic feet per second
Corps – U.S. Army Corps of Engineers
CRWUD -- Cass Rural Water Users District
CWA -- Clean Water Act
DEB -- Doug Emerson basin also DEBs Doug Emerson basins
DEIS -- Draft Environmental Impact Statement
DWRA – Dakota Water Resources Act
EIS -- Environmental Impact Statement
EPA – U.S. Environmental Protection Agency
ESA -- Endangered Species Act
gals/yr – gallons per year
Garrison Diversion – Garrison Diversion Conservancy District
GDU -- Garrison Diversion Unit
GFTWD -- Grand Forks-Traill Water District
GIS -- Geographical Information Systems
gpc/d – gallons per capita per day
gpm -- gallons per minute
IDC – interest during construction
IFIM – Instream Flow Incremental Methodology
mg/L -- milligrams per liter
Mgals -- million gallons
mgd -- million gallons per day
MNDNR – Minnesota Department of Natural Resources
MNGS -- Minnesota Geological Survey
MODNR -- Missouri Department of Natural Resources
MOU -- memorandum of understanding
MPCA – Minnesota Pollution Control Agency
MR&I – municipal, rural, and industrial
NDHD -- North Dakota Health Department
NDSU – North Dakota State University
NDSWC -- North Dakota State Water Commission
Needs and Options Report – *Report on Red River Valley Water Needs and Options*
NEPA -- National Environmental Policy Act
NPDWR – National Primary Drinking Water Regulations
NSDWR -- National Secondary Drinking Water Regulations
OM&R -- operation, maintenance, and replacement
PHABSIM -- Physical Habitat Simulation System
Phase IA report – Reclamation 1998 study
Phase IB report – Reclamation 1999 study
Phase II report – Reclamation 2000 study
Project – Red River Valley Water Supply Project
PSW -- principal supply works
Q90 -- MPCA's 90% exceedance flow guideline
Reclamation – Bureau of Reclamation
Red River – Red River of the North
Red River Basin – Red River of the North Basin
RSRWUD -- Ransom-Sargent Rural Water Users District
RWS – rural water system
SCADA - supervisory control and data acquisition
SCPP -- Snake Creek Pumping Plant
SDWA -- Safe Drinking Water Act
Sheyenne National Grasslands see the Grasslands
SWD – Southeast Water District
TCWD – Tri-County Water District
TDS -- total dissolved solids
the Grasslands -- Sheyenne National Grasslands
TRWD -- Traill Rural Water District
USGS -- United States Geological Survey
WC – water conservation
WCPA -- water conservation potential assessment
WTP -- water treatment plant
WU -- water users
WUA-- water user(s) association

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Appendix A – Needs Assessment

Introduction

This Needs Appendix contains information and analysis used in the development of chapter two, Needs Assessment. The appendix provides detailed information on the methods and analysis that could not reasonably be included in the chapter text. A description of the materials included on the data CD (compact disc) reference materials used in the analyses are also provided in this appendix.

Needs Assessment Materials Included on the Data CD

Prior to release of the Needs and Options Report, a number of technical reports were published in support of the analysis conducted. These were produced by Reclamation and other outside entities. A list of the reports and the source of the report is listed in table 1. Each report is provided in PDF format on the enclosed CD.

Table 1 – Tabulation of Needs and Options Supporting Reports.

Report Title	Source of Report
Report on Red River Valley Water Supply Project Needs and Options, Aquatic Needs Assessment, Instream Flows for Aquatic Life and Riparian Maintenance, Final Report 2003	Bureau of Reclamation
Report on Red River Valley Water Supply Project Needs and Options, Current and Future Population of the Red River Valley Region 2000 through 2050, Final Report 2003/Revised 2005	Bureau of Reclamation
Report on Red River Valley Water Supply Project Needs and Options, Recreation Needs Assessment, Final Report 2003	Bureau of Reclamation
Report on Red River Valley Water Supply Project Needs and Options, Water Quality Needs, Regulatory Overview of the Safe Drinking Water Act, Final Report 2003	Bureau of Reclamation
Report on Red River Valley Water Needs and Options, Assessment of Commercial Needs, Future Business and Industrial Activity in the Red River Valley, Final Report 2004	Bureau of Reclamation
Report on Red River Valley Water Needs and Options, Water Conservation Potential Assessment, Final Report 2004	Bureau of Reclamation
Report on Red River Valley Water Needs and Options, Water System Assessment Executive Summary, Final Report 2004	Bureau of Reclamation
Report on Red River Valley Water Needs and Options, Industrial Needs Assessment: Future Red River Valley Commercial Water Demands, Final Report 2004	Bureau of Reclamation
Red River Valley Industrial Water Needs Assessment, 2004	North Dakota State University, Department of Agribusiness and Applied Economics, Fargo, North Dakota.
Population Projections for Red River Valley Counties and Municipalities, 2000 through 2050, 2003	Northwest Economic Associates

The per capita water demand (gpc/d), annual average and maximum water demands (ac-ft) and peak day water demand (cfs or ac-ft) estimates were generated in the water system water demand computation spreadsheets included in this appendix.

Information presented in tables throughout the needs assessment was originally created in Microsoft Excel as spreadsheets. Original spreadsheets are provided to document the process of estimating water demands. The data CD contains a majority of the tables included in chapter two along with files containing information used to create data for these tables.

Table 2 lists the tables included in chapter two and identifies whether they were originally developed in Microsoft Excel or whether they were developed strictly for the report in Microsoft Word. All data that involved computations are provided in the original Excel format on the CD. There may be slight differences between the Word and Excel tables, relating to format, but all table values are the same. A limited number of figures were developed to display tabular data in the needs assessment and these figures are listed in table 3.

Section 2.1 of the Needs and Options Report provides background information on current water systems in the Red River Valley service area. The section summarizes the following: 1) types and number of water systems presently in the valley; 2) outlines assumptions used to identify which of these water systems would have their own water treatment capability in the future; and 3) identifies the water systems focused on in the analysis. From the report text, only table 2.1.2 and figure 2.1.1 are included in this appendix and on the CD. The remaining tables of the section are not included because they did not include data calculations.

Section 2.2, Water Demand Calculation Methods, contains a number of tables and figures which demonstrate how the needs assessment analysis was conducted. The example using Fargo's historic water use and demand projections were developed in Excel and are included in this appendix and CD, along with the other water systems that were individually analyzed. The example of Fargo's peak day analysis was also developed in Excel in addition to the analysis of each individual water system. This information is included in this appendix and CD.

Section 2.3 of the Needs and Option Report summarizes population projections for municipalities and counties in the Red River Valley through 2050. Population projections are summarized from the *Report on Red River Valley Water Supply Project Needs and Options, Current and Future Population of the Red River Valley Region 2000 through 2050* (Reclamation 2003b). Municipality population projections provided by the water systems in the Red River Valley were also used in the analysis. These population projections were provided to Reclamation in a July 18, 2003, letter from Advanced Engineering and Environmental Services, Inc. (see Attachment 1). Tables in Section 2.3 were developed in Excel using data from the Reclamation and water user projections. This supporting data is summarized in Attachment 2. The population projections for rural water systems are included in section 2.6. Summarized population projection data from the above sources are on the CD.

Section 2.4, Per Capita Water Demands, contains the annual average, maximum year, maximum month and peak day per capita water demand estimates for major water systems in the study area. All of tables in section 2.4 were originally developed in Excel. Historic water demand data presented in the tables were taken from individual water system spreadsheets, which are included in the appendix and CD.

Section 2.5, Water Conservation, includes information summarized from the *Report on Red River Valley Water Supply Project Needs and Options, Water Conservation Potential Assessment Final Report* (Reclamation 2004b). Specific tables included in the report text are not included in this appendix or on the CD; however, the analysis documented in the water conservation report was developed in Excel and is included on the CD.

Sections 2.6, 2.7, 2.8 and 2.9 present the future water demand analysis for municipalities, rural water systems, industries, and consumptive recreational activities, respectively. The analysis was conducted using tabular information developed in previous analysis. The majority of tables included in sections 2.6 - 2.9 were originally developed in Excel. The tables on municipal population were only developed in Word for clarification purposes. An Excel spreadsheet calculating future rural water system populations is included in the appendix and the CD. The majority of the tables in sections 2.6 - 2.9 are included in this appendix and on the CD.

Section 2.10, Other Red River Valley Water Needs, covers non-water demand needs including water quality, aquatic environment, and non-water consumptive recreation. No tables from this section are included in the appendix or CD. However, the original reports documenting the analysis completed are included on the CD.

Section 2.11 presents a summary of the analysis and results of the needs assessment. Most tables included in this section were developed in Excel and are included in this appendix and on the CD.

Table 2 – Needs Assessment Tables.

Table Name	File Name on CD	Tab Name in Excel	Description
2.1.1 – Red River Valley MR&I Systems.	Not Included	N/A	Summarizes how many of each type of water system is in the study area.
2.1.2 – Municipalities Maintaining Water Treatment Facilities through 2050.	Not Included	N/A	Lists municipal water systems that will continue to have their own WTP capability through 2050.
2.1.3 – Breakdown of Municipalities Served by Rural Water Systems.	Chapter 2 Section 2.1 Graphics	Table 2.1.2	Identifies how many water systems will have WTPs by 2050.
2.1.4 – Water Systems Included in Water Demand Analysis.	Not Included	N/A	Table lists all municipal and rural water systems which are individually evaluated in the Needs Assessment.
2.2.1 – Fargo Historic Monthly Raw Water Diversions.	Fargo Demand Calculations (max month) 3-1-05	Demand Analysis	
2.2.2 – Fargo Historic Metered Water Usage (without system losses).	Fargo Demand Calculations (max month) 3-1-05	Demand Analysis	
2.2.3 – Fargo Historic Monthly Metered Water Use Without System Losses.	Fargo Demand Calculations (max month) 3-1-05	Demand Analysis	
2.2.4 – Fargo Historic Summer and Winter Monthly Per Capita Water Use Data without System Losses.	Fargo Demand Calculations (max month) 3-1-05	Demand Analysis	

Table Name	File Name on CD	Tab Name in Excel	Description
2.2.5 – Water Conservation Potential Assessment Results.	Table 2.2.5 not included on CD, but table was developed from data in **Final WCPA Computation Sheets.xls**	Summary Sheet	Table 2.2.5 data from Table 14 in WCPA Final Report.
2.2.6 – Fargo Water Demand Estimates.	Fargo Demand Calculations (max month) 3-1-05	Demand Analysis	
2.2.7 - Ranked Naturalized Annual Flows at Emerson, Manitoba – 1931 – 2001	Nat vs Hist Flow at Emerson 3-1-05	Table 2.2.7	Flow data was originally generated from the StateMod surface water hydrologic model.
2.2.8 – Fargo Average and Maximum Monthly Water Demands (ac-ft).	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Average & Max Monthly Water Demand	Information for Fargo originated from this spreadsheet.
2.2.9 – Fargo Historic Peak Daily Water Use.	Fargo Demand Calculations (max month) 3-1-05	Demand Analysis	
2.2.10 – Estimated Peak Daily Water Demand with WC and Losses.	Fargo Demand Calculations (max month) 3-1-05	Demand Analysis	
2.2.11 – Water Demand and Storage Analysis – City of Fargo – Scenario One.	Peak Day Analysis Municipal and Rural Water Systems 1-20-05	Fargo Scen 1	
2.3.1 – County Population Projections.	Table 2.3.1 is not included, but the table was developed from data in **RRV Population Projections.xls**	County	Original tabular population data came from Reclamation and Northwest Economics Associates reports.
2.3.2 – Municipal Population Projections.	Table 2.3.2 is not included, but the table was developed from data in **RRV Population Projections.xls**	City	Original tabular population data came from Reclamation and Northwest Economics Associates reports.
2.3.3 – Service Area Population Projections Used in Analysis	Not Included	N/A	
2.4.1 – Water Demands for North Dakota Cities with Water Treatment Plants through 2050 (gpc/d).	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Demand Summary	Most data shown in the table were taken from the water system maximum month demand calculation Excel spreadsheets included in the appendix and on the CD.
2.4.2 – Water Demands for Minnesota Cities with Water Treatment Plants through 2050 (gpc/d).	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Demand Summary	Most data shown in the table were taken from the water system maximum month demand calculation Excel spreadsheets include in the appendix and on the CD.
2.4.3 – Water Demands for North Dakota Cities Served by Rural Water Systems (gpc/d).	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Demand Summary	Most data shown in the table were taken from the water system maximum month demand calculation Excel spreadsheets include in the appendix and on the CD.

Table Name	File Name on CD	Tab Name in Excel	Description
2.4.4 – Water Demands for North Dakota Rural Water Systems (gpc/d).	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Demand Summary	Most data shown in the table were taken from the water system maximum month demand calculation Excel spreadsheets include in the appendix and on the CD.
2.4.5 – Prorated Annual Maximum Month and Peak Daily Water Demands of Rural Water Systems including Cities to be Served in the Future.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Demand Summary	
2.5.1 – Specific Water Conservation Measures Evaluated in WCPA.	Not Included	N/A	Same as Table 6 in Water Conservation Potential Assessment (WCPA) report.
2.5.2 – WCPA Summary Results.	Table 2.5.2 is not included, but the table was developed from data in **Final WCPA Computation Sheets.xls**	Summary Sheet	Data from Table 14 in WCPA Final Report.
2.5.3 – Summer and Winter Water Savings.	Table 2.5.3 is not included, but table was developed from data in **Final WCPA Computation Sheets.xls**	Summary Sheet	Data from Table 14 in WCPA Final Report.
2.6.1 – Municipal Current and Future Populations.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Municipal Analysis	
2.6.2 – Municipal Annual Maximum Month and Peak Daily Water Demand.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Municipal Analysis	
2.6.3 – Annual Maximum Month Municipal Water Demand Scenario One Projections (ac-ft).	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Municipal Monthly Demands	
2.6.4 – Annual Maximum Month Municipal Water Demand Scenario Two Projections (ac-ft).	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Municipal Monthly Demands	
2.6.5 – Municipal Water Demands Scenario One.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	
2.6.6– Municipal Water Demands Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	
2.6.7 – Fargo 31-Day Max. Month and Peak Day Water Demand Scenario One.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	31 Day Max Month Scenario One	
2.6.8 – Fargo 31-Day Max. Month and Peak Day Water Demand Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	31 Day Max Month Scenario Two	

Table Name	File Name on CD	Tab Name in Excel	Description
2.7.1 – Rural Water System Current and Future Population Projections.	Table 2.7.1 is not included but data presented in table comes from **Rural Water Population Estimates 2-04-04.xls**	Summary Sheet	Spreadsheet estimates the 2000 and 2050 rural water system populations based on Reclamation county population projections. Analysis assumed that 100% of county residents will be served by RWS.
2.7.2 – Cities Served by Rural Water Systems.	Not Included	N/A	
2.7.3 – Rural Water System Water Demands.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	RWS Analysis	
2.7.4 – Rural Water System Water Demands Scenario One.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	
2.7.5 – Rural Water System Water Demands Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	
2.7.6 – Annual Maximum Month Rural Water System Water Demand Projections Scenario One (ac-ft).	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	RWS Monthly Demands	
2.7.7 – Annual Maximum Month Rural Water System Water Demand Projections Scenario Two (ac-ft).	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	RWS Monthly Demands	
2.8.1 – Historic Industrial Water Use.	Industrial Demand Tables 12-10-04	General	
2.8.2 – Future Annual Red River Valley Commercial Water Demand (ac-ft).	Reclamation Industrial Water Demand Estimate	Tables 2.8.2 & 2.8.3	Water demand data comes from the Reclamation Future Red River Valley Commercial Water Demands report.
2.8.3 – Location of Annual Industrial Water Demands (non agri-processing).	Reclamation Industrial Water Demand Estimate	Tables 2.8.2 & 2.8.3	Water demand data comes from the Reclamation Future Red River Valley Commercial Water Demands report.
2.8.4 – North Dakota 2050 Projected Industrial Water Demand.	Industrial Demand Tables 12-10-04	General	Water demand data summarized from NDSU Industrial Needs Assessment report.
2.8.5 – Allocation of North Dakota 2050 Projected Industrial Water Demands.	Industrial Demand Tables 12-10-04	General	Water demand data summarized from NDSU Industrial Needs Assessment report.
2.8.6 – Redistribution of NDSU Industrial Water Demands.	Industrial Demand Tables 12-10-04	General	
2.8.7 – Monthly and Peak Day Future Industry Water Demands Scenario One.	Industrial Demand Tables 12-10-04	General	
2.8.8 – Monthly and Peak Day Future Industry Water Demands Scenario Two.	Industrial Demand Tables 12-10-04	General	
2.8.9 – Summary of Future Industrial Water Demands Scenario One.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	

Table Name	File Name on CD	Tab Name in Excel	Description
2.8.10 – Summary of Future Industrial Water Demands Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	
2.9.1 – Golf Courses Annual Water Demands Projected through 2050.	RRV Golf Courses Inventory 9-25-03	Tables 1, 2 & 3	
2.9.2 – Annual Maximum Monthly Golf Course Water Demand Projections (ac-ft).	RRV Golf Courses Inventory 9-25-03	Tables 1, 2 & 3	
2.9.3 – Water Demand for Golf Courses.	RRV Golf Courses Inventory 9-25-03	Tables 1, 2 & 3	
2.10.1 – MR&I Water System Data Summary Results.	Not Included	N/A	See *Water System Assessment Executive Summary Final Report* (Reclamation 2004c) for more information.
2.10.2 – Community-based Flow Regime for Sheyenne River and Red River Reference Sites.	Not Included	N/A	
2.10.3 – Estimated Bankfull and Floodflow Flows for Sheyenne River and Red River Reference Sites.	Not Included	N/A	
2.10.4 – USGS Recommended Streamflow for Canoeing in the Sheyenne River	Not Included	N/A	Summarizes recommended flows for canoeing on the Sheyenne River.
2.11.1 – Summary of Water Demands Estimates Scenario One.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	
2.11.2 – Summary Water Demand Estimates Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	
2.11.3 – Summary of 2050 Water Demands Scenario One.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	
2.11.4 – Summary of 2050 Water Demands Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scen 1 & 2 Summary Tables	
2.11.5 – Monthly Distribution of 2050 Maximum Year Water Demands (ac-ft) Scenario One.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scenario 1 Monthly Demands	
2.11.6 – Monthly Distribution of 2050 Maximum Year Water Demands (ac-ft) Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Scenario 2 Monthly Demands	
2.11.7 – Comparison of Current (2005) with Future (2050) Water Demands.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Summary Charts	

Table 3 – Needs Assessment Figures.

Figure Name	File Name on CD	Tab Name in Excel	Description
2.1.1 – Independent Municipalities vs. Municipalities served by Rural Water Systems	Chapter 2 Section 2.1 Graphics	Table 2.1.2	Displays data presented in Table 2.1.2.
2.2.1 - Fargo Historic Per Capita Water Use	Fargo Demand Calculations (max month) 3-1-05	Figure 2.4.1	Displays data presented in Table 2.2.1and 2.2.2.
2.2.2 - Fargo Summer and Winter Historic Per Capita Water Use (without water losses)	Fargo Demand Calculations (max month) 3-1-05	Figure 2.4.2	Displays data presented in Table 2.4.4.
2.2.3 - Estimation of Fargo's Annual Average Water Demand Including Water Conservation and Water Loss.	Not Included	N/A	
2.2.4 - Maximum Month Water Demand Curve – Fargo under Scenario One	Peak Day Analysis Municipal and Rural Water Systems 1-20-05	Fargo Scen 1	Displays data presented in Table 2.2.13.
2.2.5 – Storage Simulation – Fargo under Scenario One	Peak Day Analysis Municipal and Rural Water Systems 1-20-05	Fargo Scen 1	Displays data presented in Table 2.2.13.
2.11.1 – Comparison of Average Annual Water Demand between Scenario One and Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Summary Charts	Displays data from Tables 2.11.1 & 2.11.2.
2.11.2 – Comparison of Maximum Annual Water Demand between Scenario One and Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Summary Charts	Displays data from Tables 2.11.1 & 2.11.2.
2.11.3 – Comparison of Peak Day Water Demand between Scenario One and Scenario Two.	Needs Appendix RRVWSP MR&I Demand Req 1-24-05	Summary Charts	Displays data from Tables 2.11.1 & 2.11.2.

A.1 - Rural Water System Population Estimates

Rural water system population projections are required to estimate future water demands. Population projections were estimated for the Red River Valley on a county and municipality basis (see Table 1 for list of reports), but developing actual rural water system populations requires a combination of both municipal and county population projections. Rural water systems provided their population projections.

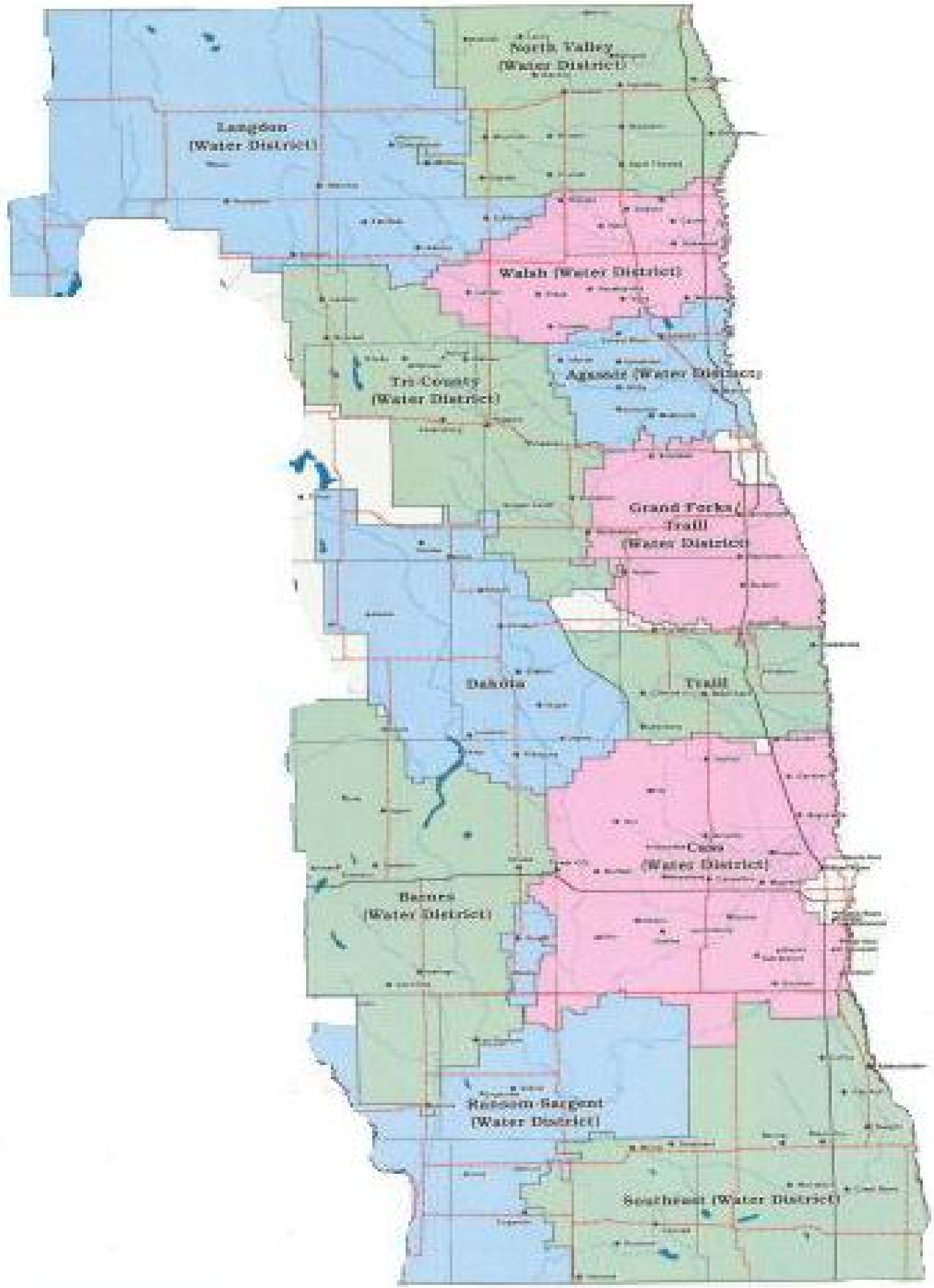
Table A.1.1 shows how 2000 and 2050 population projections for Cass County were used to estimate rural water system potential populations. The 2000 population census for Cass County was 123,138 while Reclamation projected a 2050 population of 254,800. Removing the cities with their own water treatment facilities reduces the remaining population to 15,130 (2000) and 12,670 (2050) which is the estimated rural service population of Cass County. This method was applied to every county in the Red River Valley of North Dakota.

The geographic area of each rural water system was also evaluated to determine what share of each county was covered by which rural water system. A certain amount of judgment was required in this analysis because populations are not distributed evenly throughout a county. Table A.1.2 (Table 2.7.1 in the Needs and Options Report) shows the percentage of each rural water system service area resides in each county. For example, the geographic service area of Agassiz Water Users District includes approximately 35% of Grand Forks County and 20% of Walsh County. Therefore, in estimating the service population for Agassiz Water Users District, 35% of Grand Forks county rural population and 20% of Walsh county rural population were included.

The population of a rural water system can also be adjusted to account for communities in their service area that would be served in the future. Reclamation assumed 10 communities would be served by a rural water system. These communities include Cooperstown, Hankinson, Harwood, Hillsboro, Horace, Lidgerwood, Mayville, Minto, Pembina, and Wyndmere.

Table A.1.3 presents the results of the rural water system population estimates. Populations were estimated based on 2000 county census data as well as Reclamation's 2050 county and city population projections. The last column provides the population projections provided by the rural water systems. Reclamation estimated 88,140 rural residents in the 12 rural water system service areas based on 2000 population levels. Reclamation estimated the population would be reduced to 62,281 by 2050. The decline is due to the reduced population estimated in a majority of the counties served by the 12 rural water systems. The total future population (2050) estimate provided by the rural water systems is 79,578.

Reclamation used two different water demand scenarios for evaluating future water demands and available water sources in the Needs and Options Report. Reclamation's population projection of 62,281 is used in water demand Scenario One and the water users' population projection of 79,578 is used in water demand Scenario Two.



12 Rural Water Systems in the North Dakota Red River Valley Service Area

In an August 14, 2003 memorandum from Houston Engineering to the Garrison Diversion Conservancy District (Attachment 3) regarding unserved rural residents, it was recommended that 95% of a county's population be used to estimate the service population of a rural water system. In developing the population estimates used in the analysis, Reclamation assumed 100% of the rural population would eventually be served by a rural water system because it represented a more conservative approach in evaluating future water supplies. This decision had little influence on the results of the analysis because all of but two of the rural water systems evaluated were determined to have adequate water supplies through 2050.

Table A.1.1 – Example of County Rural Water System Population Estimate – Cass County.

	Population Projection Year	
	2000	**2050**
County Population	123,138	254,800
Major Cities in the County		
Harwood	607	1,120
Horace	915	1,950
Fargo	90,599	204,300
West Fargo	14,940	33,900
Enderlin	947	860
Total Rural Population	**15,130**	**12,670**

Table A.1.2 - Rural Water System Current and Future Population Projections.

Rural Water System	Counties and Cities included in Service Area and Percentage of Rural Population	Reclamation Estimated Potential 2000 Population	Reclamation 2050 Population Projection	Rural System 2050 Population Projection
Agassiz Water Users District	Grand Forks (35%), Walsh (20%)	4,132	5,355	5,300
Barnes Rural Water District	Barnes (70%), Griggs(10%), LaMoure (20%), Ransom (5%)	5,433	2,266	4,897
Cass Rural Water Users District	Barnes (10%), Cass (99%), Richland (10%), Ransom (10%)	18,050	16,244	21,048
Dakota Rural Water District	Barnes (10%), Cass (1%), Griggs (90%), Nelson (25%), Steele (65%)	6,116	3,421	2,600
Grand Forks-Traill Water District	Grand Forks (60%), Steele (15%), Traill (45%)	9,711	12,176	15,000
Langdon Rural Water District	Cavilier (90%), Towner (50%), Ramsey (15%)' Walsh (5%)	4,673	1,568	2,900

Rural Water System	Counties and Cities included in Service Area and Percentage of Rural Population	Reclamation Estimated Potential 2000 Population	Reclamation 2050 Population Projection	Rural System 2050 Population Projection
North Valley Water District	Pembina (100%), Cavalier (10%)	9,091	5,101	8,900
Ransom-Sargent Water Users District	Barnes (10%), Dickey (10%), LaMoure (10%), Ransom (85%), Sargent (30%)	4,727	1,036	2,673
Southeast Water District	Richland (90%), Sargent (70%)	11,425	7,273	7,500
Traill Rural Water District	Steele (20%), Traill (55%)	6,476	4,527	2,800
Tri-County Water District	Grand Forks (5%), Nelson (75%), Ramsey (10%), Walsh (5%)	3,674	2,185	2,800
Walsh Rural Water District	Walsh (70%)	4,634	1,129	3,160
Totals		**88,140**	**62,281**	**79,578**

Table A.1.3 - North Dakota Red River Valley Rural Water System Population Estimates.

Assumed Present (2000) Rural Signup % = 100%
Assumed Future (2050) Rural Signup % = 100%

Rural Water System	Percent of Rural Population	Rural County Population (2000)	Potential Rural Service Population (2000)	Signup Percentage (2000)	Estimated Rural Service Population (2000)		Rural County Population (2050)	Potential Rural Service Population (2050)	Signup Percentage (2050)	Estimated Rural Service Population (2050)		Water User Population Projections (2050)
Agassiz Water Users District												
Grand Forks County	35%	8,558	2,995	100%	2,995		14,918	5,221	100%	5,221		
Walsh County	20%	5,681	1,136	100%	1,136		670	134	100%	134		
Total =						4,131					5,355	5,300
Barnes Rural Water District												
Barnes County	70%	4,949	3,464	100%	3,464		1,360	952	100%	952		
Griggs County	10%	1,701	170	100%	170		560	56	100%	56		
LaMoure County	20%	4,701	940	100%	940		2,694	539	100%	539		
Ransom County	5%	3,463	173	100%	173		670	34	100%	34		
Additional Systems												
Ransom Sargent Water Users					685					685		
Total =						5,432					2,266	4,897
Cass Rural Water Users District												
Barnes County	10%	4,949	495	100%	495		1,360	136	100%	136		
Cass County	99%	15,130	14,979	100%	14,979		12,670	12,543	100%	12,543		
Richland County	10%	7,083	708	100%	708		4,280	428	100%	428		
Ransom County	10%	3,463	346	100%	346		670	67	100%	67		

Rural Water System	Percent of Rural Population	Rural County Population (2000)	Potential Rural Service Population (2000)	Signup Percentage (2000)	Estimated Rural Service Population (2000)		Rural County Population (2050)	Potential Rural Service Population (2050)	Signup Percentage (2050)	Estimated Rural Service Population (2050)		Water User Population Projections (2050)
Additional Cities												
Harwood					607					1,120		
Horace					915					1,950		
Total =						18,050					16,244	21,048
Dakota Rural Water District												
Barnes County	10%	4,949	495	100%	495		1,360	136	100%	136		
Cass County	1%	15,130	151	100%	151		12,670	127	100%	127		
Griggs County	90%	1,701	1,531	100%	1,531		560	504	100%	504		
Nelson County	25%	2,262	566	100%	566		528	132	100%	132		
Steele County	65%	1,743	1,133	100%	1,133		830	540	100%	540		
Additional Cities												
Cooperstown					1,053					840		
Finley					515					470		
McVille					470					470		
Tolna					202					202		
Total =						6,116					3,421	2,600
Grand Forks-Traill Water District												
Grand Forks County	60%	8,558	5,135	100%	5,135		14,918	8,951	100%	8,951		
Steele County	15%	1,743	261	100%	261		830	125	100%	125		
Traill County	45%	3,650	1,643	100%	1,643		310	140	100%	140		
Additional Cities												
Hatton					707					600		

Rural Water System	Percent of Rural Population	Rural County Population (2000)	Potential Rural Service Population (2000)	Signup Percentage (2000)	Estimated Rural Service Population (2000)		Rural County Population (2050)	Potential Rural Service Population (2050)	Signup Percentage (2050)	Estimated Rural Service Population (2050)		Water User Population Projections (2050)
Northwood					959					730		
Thompson					1,006					1,630		
Total =						9,711					12,176	15,000
Langdon Rural Water District												
Cavalier County	90%	2,471	2,224	100%	2,224		110	99	100%	99		
Towner County	50%	2,876	1,438	100%	1,438		1,641	821	100%	821		
Ramsey County	15%	4,844	727	100%	727		4,095	614	100%	614		
Walsh County	5%	5,681	284	100%	284		670	34	100%	34		
Total =						4,673					1,568	2,900
North Valley Water District												
Pembina County	100%	7,943	7,943	100%	7,943		4,260	4,260	100%	4,260		
Cavalier County	10%	2,471	247	100%	247		110	11	100%	11		
Additional Cities												
Milton					85					60		
Osnabrock					174					130		
Pembina					642					640		
Total =						9,091					5,101	8,900
Ransom-Sargent Water Users District												
Barnes County	10%	4,949	495	100%	495		1,360	136	100%	136		

Rural Water System	Percent of Rural Population	Rural County Population (2000)	Potential Rural Service Population (2000)	Signup Percentage (2000)	Estimated Rural Service Population (2000)		Rural County Population (2050)	Potential Rural Service Population (2050)	Signup Percentage (2050)	Estimated Rural Service Population (2050)		Water User Population Projections (2050)
Dickey County	10%	5,757	576	100%	576		4,572	457	100%	457		
Lamoure County	10%	4,701	470	100%	470		2,694	269	100%	269		
Ransom County	85%	3,463	2,944	100%	2,944		670	570	100%	570		
Sargent County	30%	2,212	664	100%	664		70	21	100%	21		
Additional Cities												
Forman					506					510		
RSWU Service by others					-927					-927		
Total =						4,728					1,036	2,673
Southeast Water District												
Richland County	90%	7,083	6,375	100%	6,375		4,280	3,852	100%	3,852		
Sargent County	70%	2,212	1,548	100%	1,548		70	49	100%	49		
Additional Cities												
Hankinson					1,058					1,170		
Lidgerwood					738					680		
Milnor					711					600		
Ransom Sargent Water Users					242					242		
Rutland					220					150		
Wyndmere					533					530		
Total =						11,425					7,273	7,500
Traill Rural Water District												
Steele County	20%	1,743	349	100%	349		830	166	100%	166		

Rural Water System	Percent of Rural Population	Rural County Population (2000)	Potential Rural Service Population (2000)	Signup Percentage (2000)	Estimated Rural Service Population (2000)		Rural County Population (2050)	Potential Rural Service Population (2050)	Signup Percentage (2050)	Estimated Rural Service Population (2050)		Water User Population Projections (2050)
Traill County	55%	3,650	2,008	100%	2,008		310	171	100%	171		
Additional Cities												
Hillsboro					1,563					1,930		
Mayville					1,953					1,660		
Portland					604					600		
Total =						6,476					4,527	2,800
Tri-County Water District												
Grand Forks County	5%	8,558	428	100%	428		14,918	746	100%	746		
Nelson County	75%	2,262	1,697	100%	1,697		528	396	100%	396		
Ramsey County	10%	4,844	484	100%	484		4,095	409	100%	409		
Walsh County	5%	5,681	284	100%	284		670	34	100%	34		
Additional Cities												
Lakota					781					600		
Total =						3,674					2,185	2,800
Walsh Rural Water District												
Walsh County	70%	5,681	3,977	100%	3,977		670	469	100%	469		
Additional Cities												
Minto					657					660		
Totals =						4,634					1,129	3,160
Total RWS Population =						**88,140**					**62,281**	**79,578**

A.2 - Water Demand Computation Sheets

Section 2.2, Water Demand Calculation Methods, provides a description of how water demands were estimated in the Needs and Options Report. Excel spreadsheets included in this appendix are the basis for the water demand analyses conducted (see Attachment 4). Table A.2.1 lists the water systems for which water demand analysis was conducted and the corresponding Excel spreadsheet filename for each water system as included on the enclosed CD. Section 2.3 of the Needs and Options Report describes how these water systems were selected for evaluation. Data used in the analysis of the water demands for the municipal and rural water systems is included in Attachment 4.

Table A.2.1 – List of Water System Water Demand Computation Sheets.

Water System	Excel Computation Spreadsheet Filename
Agassiz Water Users District	Agassiz Demand Calculations (max month) 3-1-05.xls
Barnes Rural Water District	Barnes RW Demand Calculations (max month) 3-1-05.xls
Breckenridge	Breckenridge Demand Calculations (max month) 3-1-05.xls
Cass Rural Water Users District	Cass RW Demand Calculations (max month) 3-1-05.xls
Cooperstown	Cooperstown Demand Calculations (max month) 7-22-04.xls
Dakota Rural Water District	Dakota Water Users Demand Calculations (max month) 3-1-05.xls
Drayton	Drayton Demand Calculations (max month) 7-22-04.xls
East Grand Forks	East Grand Forks Calculations (max month) 3-1-05.xls
Enderlin	Enderlin Demand Calculations (max month) 3-1-05.xls
Fargo	Fargo Demand Calculations (max month) 3-1-05.xls
Grafton	Grafton Demand Calculations (max month) 3-1-05.xls
Grand Forks	Grand Forks Demand calculations (max month) 3-15-05.xls
Grand Forks-Traill Water District	Grand Forks Demand Calculations (max month) 3-1-05.xls
Gwinner	Gwinner Demand Calculations (max month) 3-1-05.xls
Hankinson	Hankinson Demand Calculations (max month) 7-22-04.xls
Harwood	Harwood Demand Calculations (max month) 7-22-04.xls
Hillsboro	Hillsboro Demand Calculations (max month) 7-22-04.xls
Horace	Horace Demand Calculations (max month) 7-22-04.xls
Langdon	Langdon Demand Calculations (max month) 3-1-05.xls
Langdon Rural Water District	Langdon Rural Water Dist Demand Calculations (max month) 3-1-05.xls
Larimore	Larimore Demand Calculations (max month) 3-1-05.xls
Lidgerwood	Lidgerwood Demand Calculations (max month) 7-27-04.xls
Lisbon	Lisbon Demand Calculations (max month) 7-22-04.xls
Mayville	Mayville Demand Calculations (max month) 7-22-04.xls
Minto	Minto Demand Calculations (max month) 7-22-04.xls
Moorhead	Moorhead Demand Calculations (max month) 3-1-05.xls

Water System	Excel Computation Spreadsheet Filename
North Valley Water District	North Valley Water Users Demand Calculations (max month) 3-1-05.xls
Park River	Park River Demand Calculations (max month) 3-1-05.xls
Pembina	Pembina Demand Calculations (max month) 7-22-04.xls
Ransom-Sargent Water Users District	Ransom-Sargent RWU Demand Calculations (max month) 3-1-05.xls
Southeast Water District	Southeast Water Users Demand Calculations (max month) 3-1-05.xls
Traill Rural Water District	Traill Water Users Demand Calculations (max month) 3-1-05.xls
Tri-County Water District	Tri-County Water Users Demand Calculations (max month) 3-1-05.xls
Valley City	Valley City Demand Calculations (max month) 3-1-05.xls
Wahpeton	Wahpeton Demand Calculations (max month) 3-1-05.xls
Walsh Rural Water District	Walsh Rural Water Dist Demand Calculations (max month) 3-1-05.xls
West Fargo	West Fargo Demand Calculations (max month) 3-1-05.xls
Wyndmere	Wyndmere Demand Calculations (max month) 7-22-04.xls

A.3 - Peak Day Water Demand Computation Sheets

In the Needs and Options Report, section 2.2, Water Demand Calculation Methods, provides a description of how peak day water demands were estimated. The Excel spreadsheets included in this appendix are the basis for the peak day water demand analysis. All of the analysis was conducted in one Excel spreadsheet called "*Peak Day Analysis Municipal and Rural Water Systems 1-20-05.xls*" which is included in the enclosed CD.

Chapter three described the results of surface water hydrologic modeling using StateMod on a monthly time step for the future without the project and the action alternatives considered in the Needs and Options Report. For each action alternative, two models (Scenario One and Two water demands) specific to the alternative were developed and the capacity requirements of its water supply features were determined. Two demand scenarios are evaluated in the Needs and Options Report in recognition of the uncertainty related to estimating future water demands through 2050. Satisfying capacity requirements meant meeting the estimated monthly water demands through 2050.

Daily modeling is required to help understand the water demand and flow variability that is not perceivable from monthly surface water modeling. Daily modeling is required because while monthly modeling assures that demands are met on average over a month, flows may not be adequate on individual days to supply enough water to meet peaking requirements. Daily modeling shows the status of available flow and the ability of daily flows to meet peaking demands.

Evaluating peak day demands for water systems using groundwater is relatively straightforward, assuming the aquifers in question have been adequately assessed prior to issuing water permits. The maximum permitted daily withdrawal is compared to the estimated peak day water demand to determine if the current permit is adequate. Evaluating surface-water-dependent systems is more complicated than evaluating groundwater-dependent systems and requires hydrologic modeling to determine the adequacy of future supplies.

StateMod is capable of performing daily time-step modeling; however, the results from any modeling are only as good as the available input data. There is very little daily 1930s flow data for key locations in the model. Additionally, historic demand data for daily peaking are not readily available for the majority of MR&I systems in the area.

Although StateMod is capable of filling in data gaps by interpolating flow data from nearby gages, monthly modeling results showed zero flow available for nearly all major water users at some point during the modeling period. Adding peaking demands to the system will not provide greater resolution to the model, since the available flow is still zero. This means that an alternative water source must be used not only to meet monthly demand, but also to meet the full requirements of daily peaking demands.

Through consultation with USGS it was agreed that daily modeling in StateMod would not give a higher level of flow resolution and ultimately would introduce an unacceptable level of error into the model. Instead of modeling, it was agreed that spreadsheet analysis of daily peaking requirements for individual water demands would provide answers.

Peak Day Water Demand Analysis Method

Section 2.2 (Water Demand Calculation Methods) describes methods used to evaluate peak day water demand in this report. Three basic methods were investigated for each Red River Valley water system that fully or partially depends on surface water sources and has daily peaking factors that must be met by the alternatives. These methods are additional groundwater capacity, additional storage, or additional capacity of imported water sources. Some water systems have access to groundwater sources that can be used to meet short-term peaking demands if there is adequate withdrawal capacity. All water systems have the potential to develop storage to meet all or part of their daily peaking requirements. Lastly, some alternatives proposed in the Needs and Options Report propose to import new water sources. The capacity of this imported conveyance feature could be increased to meet peak day demand requirements. Table A.3.1 lists the water systems evaluated and which of the available peaking methods were analyzed for each system to meet daily peaking requirements.

Table A.3.1 – Water Systems to be Evaluated for Peak Day Water Demand.

Water Systems	Groundwater	Storage	Import[1]
Cass Rural Water Users District	Yes	Yes	Yes
Drayton	No	Yes	Yes
East Grand Forks	No	Yes	Yes
Fargo	Yes	Yes	Yes
Grafton	No	Yes	Yes
Grand Forks	Yes	Yes	Yes
Grand Forks-Traill Water District	Yes	Yes	Yes
Langdon (City and RWD)	No	Yes	Yes
Moorhead	Yes	Yes	Yes
Valley City	Yes	Yes	Yes
West Fargo	Yes	Yes	Yes

[1] Not all water systems are served via pipeline in the alternatives, but additional pipeline capacity can be considered for these systems to meet their increased surface water flow needs.

Groundwater – Peak Day Water Demand Method

Groundwater can be used to meet peak day water demand requirements if sources of groundwater are available. Seven out of the 11 water systems listed in table A.3.1 have the potential to tap local groundwater sources. The water systems and their potential groundwater sources are listed in table A.3.2. The concept is to increase existing groundwater withdrawal capacity or to develop new groundwater sources to meet peak day demands. The added groundwater is intended for short-term intensive withdrawals, not day-to-day use.

The 31-day scenario for modeling peak day is based on estimated peak day, maximum month, and a 31-day water demand distribution curve. Following are two examples that show the how peak day and maximum month analysis was conducted.

An analysis of Grand Forks historic water use revealed annual groundwater withdrawals to meet peak day averaged about 6% of the annual maximum water demand. This analysis is in Appendix B.

An analysis of Fargo maximum month water demand revealed a water demand of 5,005 ac-ft under Scenario One. Column 8 in table A.3.3 shows Fargo's daily water shortages and surpluses of storage for their maximum month under Scenario One demands. The total shortage is 449.1 ac-ft or 146.3 million gallons (Mgals). That is the amount of water that would be withdrawn from groundwater in the maximum month. The largest daily shortage occurs on the twenty-first day of the month at 77.9 ac-ft (25.4 Mgals) or an equivalent flow capacity of 39.3 cfs. Additional well capacity of 39.3 cfs will be required to meet the peak day water demand for Fargo under Scenario One.

Table A.3.2 – Water Systems with Potential Groundwater Sources.

Water Systems	Groundwater Source Description
Cass Rural Water Users District	Cass Rural Water Users District currently has wells developed in West Fargo North Aquifer, but this study assumes that they will purchase water from Fargo as their primary source of water in the future. There is adequate capacity in the aquifer to meet short-term peaking needs.
Fargo	The West Fargo South Aquifer is located approximately 6 miles south of the city of Fargo. The aquifer is not a good water source candidate for continuous withdrawals; however, it is relatively untapped and could serve the city of Fargo's periodic peak day water demands in the future.
Grand Forks	The Elk Valley Aquifer is located approximately 17 miles west of the city of Grand Forks. The aquifer is heavily permitted, but there is potential to purchase or contract for irrigation water rights to meet peak day water needs.
Grand Forks-Traill Water District	Grand Forks-Traill Water District currently uses the Elk Valley Aquifer as a water source. The aquifer is heavily permitted, but there is potential to purchase or contract for irrigation water rights to meet peak day water needs.
Moorhead	The city of Moorhead currently uses the Buffalo Aquifer as a water source. There is potential to expand their well capacity in the aquifer to meet peak day demands.
Valley City	The city of Valley City currently uses surface water from the Sheyenne River to recharge groundwater via a pond adjacent to the WTP. Their actual water supply comes from wells adjacent to the recharge pond. Well capacity to meet peak day demands would also be included.
West Fargo	An ASR system is planned as the city of West Fargo water source in a drought using the West Fargo North Aquifer. The ASR system would be designed for peak day capacity.

Storage - Peak Day Water Demand Method

Table A.3.3 shows a 31-day maximum month water demand scenario developed for each water system listed in table A.3.1. The Scenario One water demand for the city of Fargo is used as an example in the following discussion. The 31-day scenario was developed based on historic daily water use by the city of Grand Forks because Grand forks had historic data that other systems lacked.

Table A.3.3 shows the estimated water demand in cfs and ac-ft (columns 3 and 4), the daily water delivery in 161.5 ac-ft (column 5), and storage required, which is the difference between the water needed and delivered in ac-ft and Mgals (columns 8 and 9) and net storage (column 10). The net storage is the day-by-day storage volume simulation for the water system. In this example, the city of Fargo's peak daily water demand could be met with 125.3 Mgals of storage.

Figure A.3.1 below shows the water demand curve for Fargo under Scenario One in ac-ft. The peak day occurs on the twenty-first day of the month at a demand of 239.3 ac-ft or 120.7 cfs. Figure A.3.2 shows the storage simulation for the city of Fargo. A total storage of 125.3 Mgals (385 ac-ft) is required to meet peak day water demands during the maximum water demand month. In this simulation, the maximum volume of water required for peaking is achieved on the fifteenth day of the month at 125.3 Mgals, as shown in column 10 of table A.3.3.

This storage method captures excess flows from Lake Ashtabula when its releases are higher than needed during the maximum month. Water is withdrawn from storage on days where river flows (releases from Ashtabula and natural flows) are not adequate to meet peak day demands. Column 5 of table A.3.3 shows the average volume of water (161.5 ac-ft) allocated for Fargo's use during the maximum month scenario. In 16 of the 31 days, the water demand is higher than what is available, based on hydrologic modeling. Approximately 125.3 Mgals of storage has to be drawn these 16 days to meet peaking demands. The other 15 days require less than average maximum month demand (< 161.5 ac-ft) and excess allocated flows to Fargo can be used to recharge the storage reservoir(s).

Table A.3.3 – Water Demand and Storage Analysis – City of Fargo – Scenario One.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Storage Required (ac-ft)	Storage Required (10^6 gallons)	Storage (10^6 gallons)
1	3.37%	84.9	168.5	161.5	168.5	161.5	-7.0	-2.3	57.7
2	2.76%	69.6	138.0	161.5	306.5	322.9	23.5	7.6	65.3
3	2.24%	56.6	112.2	161.5	418.7	484.4	49.3	16.1	81.4
4	2.29%	57.7	114.5	161.5	533.2	645.8	46.9	15.3	96.7
5	3.76%	94.8	188.1	161.5	721.3	807.3	-26.6	-8.7	88.0
6	3.93%	99.1	196.6	161.5	917.9	968.7	-35.2	-11.5	76.5
7	3.28%	82.8	164.2	161.5	1,082.1	1,130.2	-2.7	-0.9	75.7
8	2.99%	75.5	149.7	161.5	1,231.8	1,291.6	11.7	3.8	79.5
9	2.37%	59.7	118.4	161.5	1,350.3	1,453.1	43.0	14.0	93.5
10	2.41%	60.9	120.8	161.5	1,471.1	1,614.5	40.7	13.2	106.7
11	2.99%	75.5	149.7	161.5	1,620.8	1,776.0	11.7	3.8	110.6
12	2.99%	75.5	149.7	161.5	1,770.5	1,937.4	11.7	3.8	114.4
13	2.99%	75.5	149.7	161.5	1,920.3	2,098.9	11.7	3.8	118.2
14	2.99%	75.5	149.7	161.5	2,070.0	2,260.3	11.7	3.8	122.0
15	3.02%	76.3	151.4	161.5	2,221.4	2,421.8	10.1	3.3	125.3
16	3.50%	88.3	175.1	161.5	2,396.4	2,583.2	-13.6	-4.4	120.9
17	3.59%	90.6	179.8	161.5	2,576.2	2,744.7	-18.3	-6.0	114.9
18	3.59%	90.6	179.8	161.5	2,755.9	2,906.1	-18.3	-6.0	108.9
19	3.59%	90.6	179.8	161.5	2,935.7	3,067.6	-18.3	-6.0	103.0
20	3.63%	91.7	181.9	161.5	3,117.6	3,229.0	-20.4	-6.7	96.3
21	4.78%	120.7	239.3	161.5	3,356.9	3,390.5	-77.9	-25.4	70.9
22	4.20%	106.1	210.4	161.5	3,567.3	3,551.9	-48.9	-15.9	55.0
23	3.77%	95.2	188.8	161.5	3,756.1	3,713.4	-27.4	-8.9	46.1
24	3.34%	84.4	167.3	161.5	3,923.4	3,874.8	-5.9	-1.9	44.2
25	3.58%	90.3	179.1	161.5	4,102.5	4,036.3	-17.6	-5.7	38.4
26	4.42%	111.6	221.3	161.5	4,323.8	4,197.7	-59.8	-19.5	18.9
27	4.25%	107.1	212.5	161.5	4,536.3	4,359.2	-51.0	-16.6	2.3
28	2.44%	61.7	122.4	161.5	4,658.6	4,520.6	39.1	12.7	15.0
29	1.38%	34.9	69.2	161.5	4,727.8	4,682.1	92.3	30.1	45.1
30	2.36%	59.5	118.1	161.5	4,845.9	4,843.5	43.4	14.1	59.2
31	3.18%	80.2	159.1	161.5	5,005.0	5,005.0	2.3	0.8	60.0
Totals			5,005.0	5,005.0					

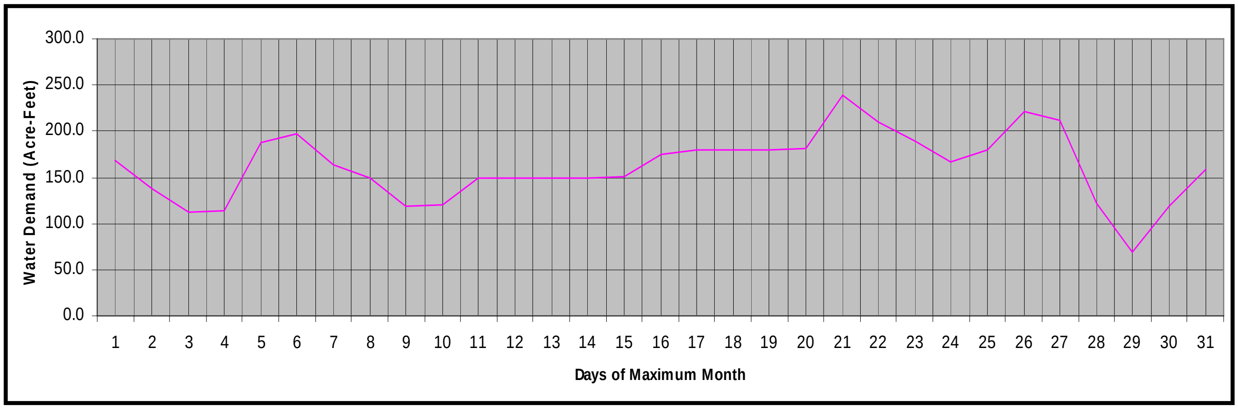


Figure A.3.1 – Maximum Month Water Demand Curve – Fargo under Scenario One.

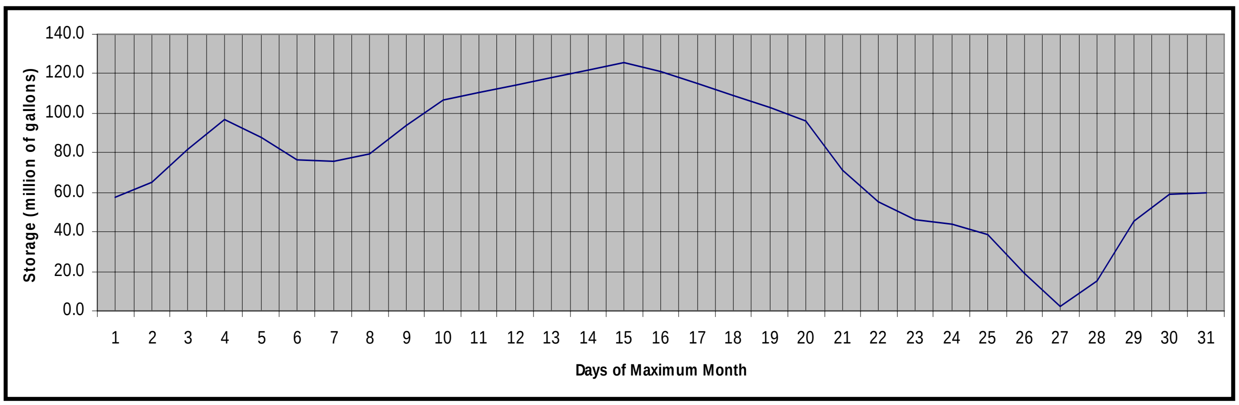


Figure A.3.2 – Storage Simulation – Fargo under Scenario One.

Additional Pipeline Capacity - Peak Day Water Demand Method

Some alternatives involve importing water from outside the Red River Valley. Water imports include water from the Missouri River, Lake of the Woods and Minnesota groundwater. The conveyance pipeline system's capacity from each of these water sources can be increased to meet peak day requirements. For example, for Fargo under Scenario One, the difference between average water allocation during the maximum month (161.5 ac-ft) and Fargo's peak day water demand (239.3 ac-ft) is 77.9 ac-ft or 25.4 Mgals. That is equivalent to 39.3 cfs flow over a one-day period. Therefore, the import feature to serve Fargo can be increased in capacity by 39.3 cfs to meet peak day water demands. The results are the same capacity requirements as discussed for groundwater. These values are highlighted in table A.3.3.

Peak Day Water Demand Analysis Results

Tables A.3.4 and A.3.5 show the results of peak day water demand analysis for water demand Scenario One or Scenario Two. The tables show the required increase in capacity in cfs from groundwater sources, storage in millions of gallons, and added pipeline capacity in cfs for imports. Groundwater capacity in the table represents the added capacity required above what is needed to meet average day demand during a maximum month. Storage volume in the table represents the volume in Mgals required to meet peak day above a water system's requirements for normal operational flows and fire flows. Added pipeline capacity in cfs is the added capacity required above results generated in the monthly hydrologic model that are based on maximum month. Detailed analysis for each of the water systems appears in Attachment 5.

A combination of two or all three of these peak day demand methods can be employed by a water system to meet peak day. For example, the city of Moorhead has all three methods available, so some combination may be preferable to using one method exclusively. Table A.3.2 identifies the peak day methods available to individual systems. If one method is more cost effective than the other two, the full capability of that method may be used before the other two are considered.

Table A.3.4 – Peak Day Water Demand Results - Scenario One.

Water Systems	Scenario One Well Capacity (cfs)	Scenario One Storage Capacity (millions of gallons)	Scenario One Added Pipeline Capacity (cfs)
Cass Rural Water Users District	0.56	2.78	0.56
Drayton	NA	1.86	0.45
East Grand Forks	NA	7.90	3.79
Fargo	39.26	125.30	39.26
Grafton	NA	2.69	0.52
Grand Forks	27.05	65.37	27.05
Grand Forks-Traill Water District	1.29	4.12	1.29
Langdon (City and Rural Water System)	NA	2.45	0.92
Moorhead	5.12	24.01	5.12
Valley City	1.53	3.36	1.53
West Fargo	3.56	15.99	3.56

NA - This method of meeting peak day demand is not available

Table A.3.5 – Peak Day Water Demand Results - Scenario Two.

Water Systems	Scenario Two Well Capacity (cfs)	Scenario Two Storage Capacity (millions of gallons)	Scenario Two Added Pipeline Capacity (cfs)
Cass Rural Water Users District	0.85	4.27	0.85
Drayton	NA	1.86	0.45
East Grand Forks	NA	10.41	5.27
Fargo	46.72	147.69	46.72
Grafton	NA	3.81	0.79
Grand Forks	28.67	69.50	28.67
Grand Forks-Traill Water District	1.86	5.85	1.86
Langdon (City and Rural Water System)	NA	2.75	1.08
Moorhead	6.42	30.04	6.42
Valley City	1.97	4.26	1.97
West Fargo	3.64	16.18	3.64

NA - This method of meeting peak day demand is not available

Peak Day Results for Alternatives

All action alternatives need to meet peak day water demands for the alternatives or options in order to meet the comprehensive water needs of the Red River Valley. Table A.3.6 lists each alternative and the peak day method or methods employed for that alternative. Tables A.3.7 and A.3.8 show the peak day water demand methods used and results for each of the action alternatives under Scenario One and Scenario Two, respectively. The GDU Water Supply

Replacement Pipeline alternative is not listed in the table because it was originally designed to meet peak day demands, so no additional capacity was added to this alternative.

Table A.3.6 – Alternatives and Peak Day Water Demand Methods Used.

Alternative	Peaking Factor Method(s)
North Dakota In-Basin	Groundwater and Storage
Red River Basin	Groundwater and Storage
Lake of the Woods	Groundwater and Storage
GDU Import to Sheyenne River	Peak day releases from Lake Ashtabula to meet downstream peak day demands
GDU Import Pipeline	Import pipeline capacity increased
Missouri River to Red River Valley Import	Groundwater and Storage

Each water system has a peaking method shown with the associated capacity requirement for each of the six supplement alternatives. Capacity values for groundwater and pipeline are in cfs units, while capacity requirements for storage are in Mgals. Selecting which peak day methods to use in which alternative was somewhat subjective, with the main goal to use all peak day methods at least once in the alternatives.

Four of the six alternatives primarily use groundwater, with some storage to meet their peak day demands. The GDU Import Pipeline alternative uses increased import pipeline capacity and some limited storage to meet peak day. The GDU Import to Sheyenne River alternative also has increased pipeline capacity as its primary method of meeting peak day demands. But rather than adding 82.5 cfs (Scenario One) or 95.7 cfs (Scenario Two) increased pipeline capacity, the increase was smaller because of efficiencies associated with using Lake Ashtabula as a re-regulating reservoir. Storage was used to meet peak day demands in some alternatives for Drayton, Grafton, Langdon (city and rural water system), and East Grand Forks.

Table A.3.7 – Alternative Peak Day Method and Capacity Requirement – Scenario One.

Water Systems	Options					
	ND In-Basin	Red River Basin	Lake of the Woods	GDU Import to Sheyenne River	GDU Import Pipeline	Missouri River to Red River Valley Import
Cass Rural Water Users District	Groundwater	Groundwater	Groundwater	Purchased [1]	Purchased [1]	Groundwater
	0.56 cfs	0.56 cfs	0.56 cfs	0.56 cfs	0.56 cfs	0.56 cfs
Drayton	Storage	Storage	Storage	In River [2]	In River [2]	Storage
	1.86 mg	1.86 mg	1.86 mg	0.45 cfs	0.45 cfs	1.86 mg
East Grand Forks	Storage	Storage	Storage	In River [2]	Pipeline	Storage
	7.90 mg	7.90 mg	7.90 mg	3.79 cfs	3.79 cfs	7.90 mg
Fargo	Groundwater	Groundwater	Groundwater	In River [2]	Pipeline	Groundwater
	39.26 cfs	39.26 cfs	39.26 cfs	39.26 cfs	39.26 cfs	39.26 cfs
Grafton	Storage	Storage	Storage	In River [2]	In River [2]	Storage
	2.69 mg	2.69 mg	2.69 mg	0.52 cfs	0.52 cfs	2.69 mg
Grand Forks	Groundwater	Groundwater	Groundwater	In River [2]	Pipeline	Groundwater
	27.05 cfs	27.05 cfs	27.05 cfs	27.05 cfs	27.05 cfs	27.05 cfs
Grand Forks-Traill Water District	Groundwater	Groundwater	Groundwater	Purchased [1]	Purchased [1]	Groundwater
	1.29 cfs	1.29 cfs	1.29 cfs	1.29 cfs	1.29 cfs	1.29 cfs
Langdon (City and Rural)	Storage	Storage	Storage	In River [2]	In River [2]	Storage
	2.45 mg	2.45 mg	2.45 mg	0.92 cfs	0.92 cfs	2.45 mg
Moorhead	Groundwater	Groundwater	Groundwater	In River [2]	Pipeline	Groundwater
	5.12 cfs	5.12 cfs	5.12 cfs	5.12 cfs	5.12 cfs	5.12 cfs
Valley City	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
	1.53 cfs	1.53 cfs	1.53 cfs	1.53 cfs	1.53 cfs	1.53 cfs
West Fargo	Groundwater	Groundwater	Groundwater	In River [2]	Pipeline	Groundwater
	3.56 cfs	3.56 cfs	3.56 cfs	3.56 cfs	3.56 cfs	3.56 cfs
Groundwater Capacity (cfs)	78.4 cfs	78.4 cfs	78.4 cfs	1.5 cfs	1.5 cfs	78.4 cfs
Storage Capacity (mg)	14.9 mg	14.9 mg	14.9 mg	0.0 mg	0.0 mg	14.9 mg
Pipeline Capacity (cfs)	0.0 cfs	0.0 cfs	0.0 cfs	82.5 cfs	82.5 cfs	0.0 cfs

[1] The water to meet peak day demands would be actually purchased from Fargo or Grand Forks for these rural systems
[2] Peak day demand met by additional flows in river

Table A.3.8 - Alternative Peak Day Method and Capacity Requirement – Scenario Two.

Water Systems	Alternatives					
	North Dakota In-Basin	Red River Basin	Lake of the Woods	GDU to Sheyenne River Import	GDU Import Pipeline	Missouri River to Red River Valley Import
Cass Rural Water Users District	Groundwater	Groundwater	Groundwater	Purchased [1]	Purchased [1]	Groundwater
	0.85	0.85	0.85	0.85	0.85	0.85
Drayton	Storage	Storage	Storage	In River [2]	In River [2]	Storage
	1.86	1.86	1.86	0.45	0.45	1.86
East Grand Forks	Storage	Storage	Storage	In River [2]	Pipeline	Storage
	10.41	10.41	10.41	5.27	5.27	10.41
Fargo	Groundwater	Groundwater	Groundwater	In River [2]	Pipeline	Groundwater
	46.72	46.72	46.72	46.72	46.72	46.72
Grafton	Storage	Storage	Storage	In River [2]	In River [2]	Storage
	3.81	3.81	3.81	0.79	0.79	3.81
Grand Forks	Groundwater	Groundwater	Groundwater	In River [2]	Pipeline	Groundwater
	28.67	28.67	28.67	28.67	28.67	28.67
Grand Forks-Traill Water District	Groundwater	Groundwater	Groundwater	Purchased [1]	Purchased [1]	Groundwater
	1.86	1.86	1.86	1.86	1.86	1.86
Langdon (City and RWS)	Storage	Storage	Storage	In River [2]	In River [2]	Storage
	2.75	2.75	2.75	1.08	1.08	2.75
Moorhead	Groundwater	Groundwater	Groundwater	In River [2]	Pipeline	Groundwater
	6.42	6.42	6.42	6.42	6.42	6.42
Valley City	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
	1.97	1.97	1.97	1.97	1.97	1.97
West Fargo	Groundwater	Groundwater	Groundwater	In River [2]	Pipeline	Groundwater
	3.64	3.64	3.64	3.64	3.64	3.64
Groundwater Capacity (cfs)	90.1	90.1	90.1	2.0	2.0	90.1
Storage Capacity (mgd)	18.8	18.8	18.8	0.0	0.0	18.8
Pipeline, Purchased or in River Capacity (cfs)	0.0	0.0	0.0	95.7	95.7	0.0

[1] The water to meet peak day demands would be actually purchased from Fargo or Grand Forks for these rural systems
[2] Peak day demand met by additional flows in river

Appendix A – Attachment 1

July 18, 2003 Letter from Advanced Engineering and Environmental Service, Inc. Regarding Population Projections

www.ae2s.com

July 18, 2003

Ms. J. Signe Snortland
Dakotas Area Office
Bureau of Reclamation
304 E. Broadway
P.O. Box 1017
Bismarck, ND 58502

Re: **Comments on Population Projections**
Red River Valley Water Supply Study

Dear Signe:

As the engineering representative for Eastern Dakota Water Users (EDWU) and members of the Technical Team for the Red River Valley Water Supply (RRVWS) Project, we have reviewed the draft population projection document prepared by the Bureau of Reclamation (Reclamation) entitled *Current and Future Population of the Red River Valley Region 2000 through 2050* dated May 2003. We have also reviewed the document prepared by Northwest Economic Associates (NEA) entitled *Population Projections for Red River Valley Counties and Municipalities, 2000 through 2050* dated May 23, 2003.

As you are aware, we were involved in assisting with the presentation on the City of Fargo's behalf at the Public Scoping meeting in Fargo on June 25, 2003 regarding the above referenced population projection documents. In addition, we are also familiar with the written comments on the population projections provided by the City of Fargo and the City of Grand Forks. We agree with these comments and have attached them as support for our position.

The differences between the population projections prepared by Reclamation/NEA and the City of Fargo and the City of Grand Forks were relatively significant. The comment letters submitted by the City of Fargo and the City of Grand Forks raise concerns associated with underestimating the population of the two largest municipalities in the Red River Valley over the 50-year planning horizon, which could ultimately lead to inadequately sized infrastructure during the implementation of a RRVWS Project. To that end, the City of Fargo and the City of Grand Forks address this issue by requesting the consideration of the projections they provided to date for the Needs Assessment data gathering process and suggesting the inclusion of a Cohort analysis that utilizes a reasonable set of increasing trend possibilities.

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Advanced Engineering and Environmental Services, Inc.
2016 Washington Street South • Grand Forks, ND 58201 • (t) 701-746-8087 • (f) 701-746-0370

Ms. J. Signe Snortland
Bureau of Reclamation
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This comment letter is intended to support a set of population projections for the remaining municipalities included in the RRVWS Project. In aggregate, the remaining municipalities comprise a substantial portion of the Red River Valley population. Underestimating the future population and/or providing a limited range of growth estimates for these municipalities raise similar concerns noted above with respect to the implementation of a RRVWS Project. Therefore, it is imperative that a higher range of population projections be considered for the remaining municipalities in similar fashion to that requested by the City of Fargo and the City of Grand Forks.

EDWU Supported Population Projections for North Dakota Municipalities

When considering population projections for the remaining municipalities, participant information and the population projections prepared by Reclamation and NEA were relied upon for justification. It was also recognized that some municipalities could be influenced by such factors as metropolitan growth, industrial presence, institutional presence, economic development indications, etc. As such, the municipalities listed in the documentation prepared by Reclamation and NEA were categorized according to the methodology that appears to provide reasonable, higher population projections with respect to concerns associated with the potential for inadequately sized infrastructure under the RRVWS Project. EDWU supports the following categorization strategies:

RECLAMATION 2050 POPULATION PROJECTIONS

MUNICIPALITY	2050 POPULATION	JUSTIFICATION
Cavalier	1,710	Approx. 0.2% growth
Drayton	920	Stable population; industrial presence
Forman	510	Stable population; regional industrial presence
Harwood	1,120	Approx. 1.2% growth; Fargo influence
Hillsboro	1,930	Approx. 0.4% growth; industrial presence; I-29 corridor; Fargo/Grand Forks influence
Langdon	2,100	Stable population
Lisbon	2,530	Approx. 0.2% growth; regional industrial presence
McVille	470	Stable population
Park River	1,540	Stable population
Pembina	640	Stable population; industrial presence
Portland	600	Stable population; institutional presence (Mayville)
Thompson	1,630	Approx. 1.0% growth; Grand Forks influence
Wahpeton	12,140	Approx. 0.7% growth; industrial presence

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NEA COHORT ZERO MIGRATION 2050 POPULATION PROJECTIONS

MUNICIPALITY	2050 POPULATION	JUSTIFICATION
Mayville	2,066	Approx. 0.1% growth; institutional presence

NEA COHORT TREND MIGRATION 2050 POPULATION PROJECTIONS

MUNICIPALITY	2050 POPULATION	JUSTIFICATION
Arthur	603	Approx. 0.8% growth
Casselton	3,160	Approx. 1.1% growth; Fargo influence
Gwinner	1,254	Approx. 1.1% growth; industrial presence
Horace	3,132	Approx. 2.5% growth; Fargo influence
Minto	896	Approx. 0.6% growth; Grand Forks influence
Wyndmere	697	Approx. 0.5% growth; regional industrial presence

PARTICIPANT 2050 POPULATION PROJECTIONS

MUNICIPALITY	2050 POPULATION	JUSTIFICATION
Cooperstown	1,053	Stable population
Enderlin	947	Stable population; industrial presence
Fargo	243,073	2.0% growth; trend analysis
Finley	515	Stable population
Grafton	6,244	0.65% growth; positive economic indicators
Grand Forks	89,631	1.2% growth; trend analysis
Hankinson	1,058	Stable population
Hatton	707	Stable population
Lakota	781	Stable population
Larimore	1,839	0.5% growth; Grand Forks/GFAFB influence
Lidgerwood	738	Stable population
Mapleton	997	1.0% growth; Fargo influence
Northwood	959	Stable population
Valley City	7,500	Barnes County Development Corporation
Walhalla	1,057	Stable population; industrial presence
West Fargo	34,705	Approx. 1.7% growth; Fargo/Moorhead/West Fargo Metro area

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It is interesting to note that the population projections completed by Reclamation and NEA include some municipalities that currently have a population less than or about 500 (Arthur, Forman, and McVille) or are presently served by rural water systems (Casselton, Cavalier, Finley, Hatton, Mapleton, Northwood, Portland, Thompson, and Walhalla). To the best of our knowledge, information was not collected from these municipalities during the Needs Assessment data collection process completed to date, which was likely due to interpretation of the Specific Plan of Study and the rural water systems being able to provide the water source, water usage, and water quality data.

The population projections for these municipalities could easily be incorporated into the population projections and future water demands for the rural water systems. However, the Needs Assessment data collected from rural water systems will likely not include water system storage and distribution system needs anticipated over the 50-year planning horizon for bulk service customers. Based on the list of projects on the draft 2003 Drinking Water State Revolving Fund (DWSRF) loan program Intended Use Plan (IUP), it appears that a number of relatively small communities are concerned about storage and distribution system age and/or condition. Therefore, it would be prudent for Reclamation to assume a range of costs as appropriate for such improvements based on the water system summary reports completed for the rural water systems, if such improvements are intended to address water loss reduction and/or conservation.

EDWU Supported Population Projections for Rural Water Systems

Of the 12 rural water systems included in the RRVWS Project, information provided by Reclamation suggests that only five (5) of these systems provided population projection information through 2050. It is recognized that some of the information provided by the rural water systems may have been received after the information was presented by Reclamation. The following information is intended to summarize the population projections for all of the rural water systems included in the RRVWS Project. As noted above, the population projections for the rural water systems may need to be revised according to the projections prepared for municipalities that are presently being served by rural water systems. The future population projections for various rural water systems may also need to be adjusted to include municipalities that presently operate independent water systems but would likely rely upon a regional system in the future for bulk water service.

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RURAL WATER SYSTEM 2050 POPULATION PROJECTIONS

RURAL WATER SYSTEM	2050 POPULATION	JUSTIFICATION
Agassiz Water Users, Inc.	5,300	Moderate system growth of 30-40 people per year due to development areas in the Grand Forks area
Barnes Rural Water District	3,785	Approx. 0.5% growth based on present number of non-served rural residences within district boundary
Cass Rural Water Users District	19,533	Population projections provided during the Needs Assessment process – influence from Fargo
Dakota Water Users, Inc.	2,600	Stable population through 2050; could add Binford, Sibley, and Hannaford as bulk services – resulting population served would be approximately 3,025
Grand Forks-Traill Water District	15,000	Population projections provided during the Needs Assessment process – influence from Grand Forks
Langdon Rural Water District	2,900	Stable population through 2050; increase from 2,100 includes on-going Phase IV expansion
North Valley Water District	8,900	Stable population through 2050; this value includes anticipated system expansion in 2004 and Pembina
Ransom-Sargent Water Users District	3,600	Population projections provided during the Needs Assessment process
Southeast Water Users District	7,500	Population projections provided during the Needs Assessment process; could add Lidgerwood, Wyndmere, and Hankinson as bulk services – resulting population served would approach 10,000
Traill County Water Users	2,800	Stable population through 2050; could add Hillsboro, Galesburg, and Mayville as bulk services – resulting population would be approximately 6,950
Tri-County Rural Water District	2,800	Stable population through 2050; increase from 2,538 includes on-going system expansion
Walsh Rural Water District	3,160	Stable population through 2050

EDWU Supported Population Projections for Minnesota Municipalities

With the inclusion of the Minnesota communities of Breckenridge, Moorhead, and East Grand Forks in the RRVWS Project, Reclamation and NEA have prepared population projections accordingly. Each of the Minnesota municipalities included in the RRVWS Project border a North Dakota municipality with relatively large populations and projections for growth. Based on the respective influence of the respective metropolitan

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areas, EDWU supports the following population projections for Breckenridge, Moorhead, and East Grand Forks:

MINNESOTA MUNICIPALITY 2050 POPULATION PROJECTIONS

MUNICIPALITY	2050 POPULATION	JUSTIFICATION
Breckenridge	3,601	Cohort Zero Migration (NEA); Wahpeton influence
Moorhead	58,421	1.2% growth; Fargo/Moorhead/West Fargo Metro area
East Grand Forks	13,619	1.2% growth; Grand Forks/East Grand Forks Metropolitan Planning Organization

Although not directly included in the RRVWS Project study effort, other Minnesota systems and potential industrial water users could increase the overall water demand on the RRVWS Project alternatives. Such systems include Fergus Falls and Thief River Falls. Consideration should therefore be given towards the future population projections of appropriate Minnesota communities and other potential developments that could impact the availability of water for entities included in the RRVWS Project.

Thank you for the opportunity to provide comments on the population projection documents prepared to date for the RRVWS Project. Due to the potential impact of the population projections on the alternatives developed for the RRVWS Project, we trust that the population projections recommended by EDWU will be considered to represent a higher set of data with which to adequately plan for the potential water needs of the Red River Valley. If you have any questions regarding my comments, please do not hesitate to contact me.

Sincerely,

Advanced Engineering and Environmental Services, Inc.

Steve L. Burian, P.E.

Steve L. Burian, P.E.
Chief Executive Officer

Attachments

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c: Pat Zavoral, City of Fargo
Mark Bittner, P.E., City of Fargo
Bruce Grubb, P.E., City of Fargo
Al Grasser, P.E., City of Grand Forks
Todd Feland, City of Grand Forks
Hazel Fetters-Sletten, City of Grand Forks
Jerry Blomeke, Cass Rural Water Users District
Cliff McLain, P.E, City of Moorhead
Dan Boyce, City of East Grand Forks
Dave Koland, Garrison Diversion Conservancy District
Dave Johnson, P.E., Garrison Diversion Conservancy District
Rick St. Germain, P.E., Houston Engineering, Inc.

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Appendix A – Attachment 2

Red River Valley Population Projection Summary Spreadsheets

RED RIVER VALLEY WATER SUPPLY PROJECT
2050 COUNTY POPULATION PROJECTIONS

		Reclamation Draft Population Projections (May 2003)				Northwest Economics Associates (May 2003)		Reclamation Revised Population Estimates in Response to Comments (August 2003)	Reclamation Final Population Estimates (September 2003)
County	**2000 Census**	**ND Data Center & MN Demographic Center**	**US Census Bureau**	**Cohort Comp. Zero Migration**	**Cohort Comp. Past Net Migration**	**Cohort Comp. Zero Migration**	**Cohort Comp. Trend Migration**	**Best Estimate Red River Valley Counties**	**Best Estimate Red River Valley Counties**
		2050	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**
North Dakota									
Barnes	11,775	11,879	5,862	11,592	10,080	11,049	8,750	10,100	7,200
Cass	123,138	192,757	191,242	214,055	227,546	141,900	244,545	270,300	254,800
Cavalier	4,831	2,060	0	3,968	3,367	3,832	1,577	3,400	2,400
Grand Forks	66,109	71,622	101,788	81,066	107,135	79,407	85,459	107,100	107,100
Griggs	2,754	1,181	42	2,209	1,861	2,135	1,095	1,900	1,400
Nelson	3,715	3,422	0	2,853	2,400	2,744	1,695	2,400	1,800
Pembina	8,585	6,922	2,806	7,861	6,775	7,613	6,082	6,800	4,900
Ransom	5,890	5,852	2,685	5,325	4,594	5,179	5,302	4,600	3,300
Richland	17,998	16,222	16,635	18,767	16,536	18,439	16,978	18,800	18,800
Sargent	4,366	4,302	781	3,974	3,437	3,894	3,782	3,400	2,500
Steele	2,258	1,840	0	2,072	1,796	2,019	1,878	1,800	1,300
Traill	8,477	6,787	5,917	8,274	7,209	8,049	6,612	7,200	5,100
Walsh	12,389	7,768	7,038	11,322	9,757	10,974	6,766	9,800	7,000
North Dakota Totals	**272,285**	**332,614**	**334,796**	**373,338**	**402,493**	**297,234**	**390,521**	**447,600**	**417,600**
Minnesota									
Clay	51,313	54,384	65,669	56,296	56,194	61,053	58,286	65,100	83,600
Kittson	5,263	5,297	1,471	4,558	5,557	4,609	3,431	5,600	3,600
Marshall	10,114	8,435	4,459	9,388	9,020	9,135	6,204	9,400	6,900
Norman	7,434	7,076	2,542	7,251	6,151	6,713	5,602	7,300	5,100
Otter Tail	57,222	93,072	65,810	51,100	98,248	51,329	69,845	98,200	81,700
Polk	31,352	32,255	25,194	32,379	26,530	31,044	26,211	34,700	32,400
Traverse	4,119	3,568	0	3,935	3,238	3,553	3,180	3,900	2,800
Wilken	7,133	7,134	2,851	7,966	5,705	7,216	6,587	8,000	4,900
Minnesota Totals	**173,950**	**211,221**	**167,996**	**172,873**	**210,643**	**174,652**	**179,346**	**232,200**	**221,000**
Regional Totals	**446,235**	**543,835**	**502,792**	**546,211**	**613,136**	**471,886**	**569,867**	**679,800**	**638,600**

RED RIVER VALLEY WATER SUPPLY PROJECT
2050 MUNICIPAL POPULATION PROJECTIONS

		Source of Population Projections					
		Reclamation	Northwest Economics Associates		Water Users [2]	Reclamation	Reclamation
Municipality	2000 Census	Draft 2050 Population Projection[1] (May 2003)	Cohort Comp. Zero Migration	Cohort Comp. Trend Migration	2050 Population Estimate	Reclamation Revised Population Estimates in Response to Comments (August 2003)	Reclamation Final Population (September 2003)
North Dakota							
Arthur	402	400	380	603	603	400	400
Casselton	1,855	2,380	1,979	3,160	3,160	2,380	2,380
Cavalier	1,537	1,710	1,335	1,389	1,710	1,710	1,710
Cooperstown	1,053	840	778	437	1,053	840	840
Drayton	913	920	833	642	920	920	920
Enderlin	947	860	761	776	947	860	860
Fargo	90,599	167,420	106,386	190,743	243,073	207,100	204,300
Finley	515	470	470	418	515	470	470
Forman	506	510	386	169	510	510	510
Grafton	4,516	4,130	4,169	2,722	6,244	4,130	4,130
Grand Forks	49,321	69,390	59,999	63,471	89,631	83,800	83,800
Gwinner	717	1,170	721	1,254	1,254	1,170	1,170
Hankinson	1,058	970	835	1,023	1,058	970	970
Harwood	607	1,120	697	433	1,120	1,120	1,120
Hatton	707	600	598	348	707	600	600
Hillsboro	1,563	1,930	1,413	809	1,930	1,930	1,930
Horace	915	1,950	1,255	3,132	3,132	1,950	1,950
Lakota	781	600	525	185	781	600	600
Langdon	2,101	2,100	1,642	1,137	2,100	2,100	2,100
Larimore	1,433	1,190	1,408	1,398	1,839	1,190	1,190
Lidgerwood	738	680	547	619	738	680	680
Lisbon	2,292	2,530	1,804	2,013	2,530	2,530	2,530
Mapleton	606	610	801	381	997	610	610
Mayville	1,953	1,660	2,066	1,319	2,066	1,660	1,660
McVille	470	470	316	234	470	470	470
Minto	657	660	595	896	896	660	660
Northwood	959	730	686	280	959	730	730
Park River	1,535	1,540	1,210	763	1,540	1,540	1,540
Pembina	642	640	671	574	640	640	640
Portland	604	600	479	339	600	600	600
Thompson	1,006	1,630	1,169	1,150	1,630	1,630	1,630
Valley City	6,826	5,840	6,503	5,225	7,500	5,840	5,840
Wahpeton	8,586	12,140	9,685	7,892	12,140	12,140	12,140
Walhalla	1,057	970	876	706	1,057	970	970
West Fargo	14,940	27,610	17,343	26,632	34,705	34,400	33,900
Wyndmere	533	530	516	697	697	530	530
Total for North Dakota	**205,450**	**319,500**	**231,837**	**323,969**	**431,452**	**380,380**	**377,080**
Minnesota							
Breckenridge	3,559	2,540	3,601	3,258	3,601	2,540	2,540
East Grand Forks	7,501	7,500	8,338	7,466	13,619	9,800	9,800
Moorhead	32,177	35,360	41,758	32,895	58,421	44,200	44,200
Total for Minnesota	**43,237**	**45,400**	**53,697**	**43,619**	**75,641**	**56,540**	**56,540**
Grand Total	**248,687**	**364,900**	**285,534**	**367,588**	**507,093**	**436,920**	**433,620**

[1] Each city population projection was estimated using one of the methods discussed on page 9 of the Reclamation Population Projection Repo

[2] Water User population projections were provided by Steve Burian acting as an engineering representative for the Eastern Dakota Water Users organization in Advanced Engineering and Environmental Services, Inc. letter dated July 18, 2003.

RED RIVER VALLEY WATER SUPPLY PROJECT
PARTICIPANT PROVIDED 2050 POPULATION PROJECTIONS
FOR RURAL WATER SYSTEMS

Rural Water System	2050 Population Projections from RWS [1]
Agassiz Water Users District	5,300
Barnes Rural Water District	3,785
Cass Rural Water Users District	19,533
Dakota Rural Water District	2,600
Grand Forks-Traill Water District	15,000
Langdon Rural Water District	2,900
North Valley Water District	8,900
Ransom-Sargent Water Users District	3,600
Southeast Water District	7,500
Traill Rural Water District	2,800
Tri-County Water District	2,800
Walsh Rural Water District	3,160
Total	77,878

[1] Water User population projections were provided by Steve Burian acting as an engineering representative for the Eastern Dakota Water Users organization in Advanced Engineering and Environmental Services, Inc. letter dated July 18, 2003.

Appendix A – Attachment 3

August 14, 2003 Letter from Houston Engineering Regarding Rural Population Projections

2505 N. Univ. Dr., PO Box 5054 Fargo, ND 58105
Phone (701) 237-5065 Fax (701) 237-5101

Houston Engineering, Inc.

Memo

To: GDCD

From: Gregg Thielman

Date: August 14, 2003

Re: Needs 3.2 - Unserved Rural Residents

Needs Task 3.2 involved conducting research on existing rural water systems to determine the percentage of rural residents that ultimately are served by rural water systems. Two types of rural water systems were investigated; rural systems near large metro areas (such as Fargo) and more "rural" water systems, such as Barnes Rural Water. At least three rural water systems of each type were documented. This task involved only rural residents and did not include cities served by rural water systems.

The rural water systems near metro areas that were evaluated included Grand Forks Traill Water Users, Cass Rural Water System, and Agassiz Water Users. The more "rural" water systems that were evaluated included North Valley Water District, Barnes Rural Water, and Dakota Water Users.

Metro Area Systems:

Grand Forks Traill Water Users: Do not have a formal study or calculations. Randy Loeslie, the system manager, indicated there are very few unserved rural residents within the system boundary. He estimated 95% of the residents are served by rural water. He indicated the only holdouts are people who did not participate in the original signup or trailer houses, etc. that moved in after the rural water system was installed.

Cass Rural Water Users: Do not have a formal study or calculations. Jerry Blomeke, the system manager, indicated that roughly 75% of the residents in the geographic service area for Cass Rural Water are system members. A more detailed breakdown for rural residents and cities was not available. Jerry expects this number to eventually approach 90-95% of the residents.

Agassiz Water Users Inc.: Representatives from Agassiz Water Users indicated there are very few rural residents in their service area who do not receive rural water due to the poor quality of groundwater in the area. Therefore, they estimate the percentage of rural residents served to be 90% or higher.

Rural Area Systems:

North Valley Water District: Gordon Johnson, the system manager, indicated that excluding the City of Pembina, the population in the North Valley Water District service area is 8,258 people. Of these, approximately 458 people are not served. Based on these numbers, approximately 94.5% of the rural residents within the service area for the North Valley Water District are served by rural water.

Barnes Rural Water District: Paul Lacina, the system manager, indicated that there are no good numbers for the percentage of residents served by the Barnes Rural Water District.

Dakota Water Users: Larry Amundson, the system manager, indicated that after a recent expansion, a majority of the residents within the service area for Dakota Water Users are served by rural water. He estimated the percentage of rural residents served to be 90% or higher.

Conclusions:

Most of the rural water systems that were evaluated did not have detailed numbers for the percent of rural residents served. Based on our discussions with the system managers, it appears a large majority of the rural residents in the Red River Valley receive water from rural water systems. The percentage exceeds 90% in most cases. It is unlikely this number will ultimately reach 100% for a majority of the systems. It is reasonable to assume this percentage will approach 95% though.

Appendix A – Attachment 4

Municipal and Rural Water Demand Computation Data Sheets

Agassiz RWS Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	15.2	16.2	14.0	17.0	19.2	22.7	20.3	20.8	16.7	14.6	13.5	14.1	204	4,181	11.7%	2.0	134
1989	8.7	7.4	9.3	10.3	12.9	12.0	15.8	12.5	9.4	10.2	9.4	10.0	128	4,181	11.7%	1.3	84
1990	11.4	11.4	14.4	13.9	21.6	17.0	17.6	20.0	16.0	14.6	13.1	8.6	180	4,181	11.7%	1.8	118
1991	8.9	10.1	13.8	15.2	17.5	16.4	15.8	14.5	9.2	10.5	8.9	8.6	149	4,181	11.7%	1.5	98
1992	10.7	9.5	11.1	13.8	16.3	17.1	11.6	11.9	13.0	12.1	12.8	10.9	151	4,181	32.5%	4.1	99
1993	13.7	12.4	12.3	11.6	20.1	18.5	16.0	15.3	15.5	15.4	11.3	15.2	177	4,181	37.4%	5.5	116
1994	7.7	7.6	8.1	10.4	12.5	10.5	11.9	11.5	9.8	7.9	10.0	10.0	118	4,181	1.4%	0.1	77
1995	8.3	8.8	11.3	9.1	12.5	11.6	11.7	14.4	11.2	7.2	11.3	11.4	129	4,181	1.3%	0.1	84
1996	8.5	8.6	10.4	8.4	9.7	14.9	12.9	14.6	12.4	9.1	8.3	9.7	127	4,181	0.8%	0.1	84
1997	9.8	5.9	9.7	16.5	21.7	16.7	11.8	13.3	10.5	9.1	10.4	7.9	143	4,181	11.7%	1.4	94
1998	8.1	8.1	10.7	9.4	13.3	15.6	13.5	13.6	13.3	9.2	8.2	14.4	137	4,181	0.8%	0.1	90
1999	8.7	8.7	11.0	9.2	11.1	13.4	15.6	13.9	10.5	11.3	9.5	8.0	131	4,181	2.4%	0.3	86
2000	8.2	10.1	8.4	11.7	16.4	19.1	12.4	15.5	13.6	12.4	9.7	9.1	147	4,181	12.7%	1.5	96
2001	10.8	11.6	10.4	10.8	13.6	15.0	14.9	13.1	11.2	13.1	8.6	10.7	144	4,181	16.5%	2.0	94
Average	9.9	9.7	11.1	12.0	15.6	15.8	14.4	14.6	12.3	11.2	10.4	10.6	148		11.7%		96.7

[1] Unaccounted for losses data was not available from 1988 - 1991 so average losses from later years was used in the analysis

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	13.2	14.2	12.0	15.0	17.2	20.7	18.3	18.8	14.7	12.6	11.5	12.1	180	4,181	118	20.7	165
1989	7.4	6.2	8.1	9.1	11.7	10.8	14.6	11.2	8.1	8.9	8.1	8.7	113	4,181	74	14.6	116
1990	9.6	9.6	12.7	12.1	19.9	15.2	15.9	18.2	14.2	12.9	11.3	6.8	158	4,181	104	19.9	158
1991	7.4	8.7	12.3	13.7	16.1	15.0	14.3	13.1	7.8	9.0	7.5	7.1	132	4,181	86	16.1	128
1992	6.7	5.4	7.0	9.7	12.3	13.0	7.6	7.8	8.9	8.0	8.7	6.8	102	4,181	67	13.0	104
1993	8.2	6.8	6.7	6.1	14.6	13.0	10.4	9.8	10.0	9.9	5.8	9.7	111	4,181	73	14.6	116
1994	7.5	7.5	8.0	10.3	12.4	10.3	11.7	11.3	9.6	7.8	9.9	9.9	116	4,181	76	12.4	99
1995	8.1	8.6	11.1	9.0	12.4	11.5	11.6	14.2	11.0	7.0	11.2	11.2	127	4,181	83	14.2	113
1996	8.4	8.5	10.3	8.3	9.6	14.8	12.8	14.5	12.3	9.0	8.2	9.6	126	4,181	83	14.8	118
1997	8.4	4.5	8.3	15.1	20.3	15.3	10.4	11.9	9.1	7.7	9.0	6.5	127	4,181	83	20.3	162
1998	8.0	8.0	10.6	9.3	13.2	15.5	13.4	13.5	13.2	9.1	8.1	14.3	136	4,181	89	15.5	123
1999	8.5	8.4	10.7	8.9	10.8	13.1	15.4	13.6	10.2	11.0	9.3	7.7	128	4,181	84	15.4	123
2000	6.7	8.6	6.9	10.2	14.9	17.6	10.8	14.0	12.0	10.9	8.1	7.6	128	4,181	84	17.6	140
2001	8.9	9.7	8.4	8.9	11.6	13.0	12.9	11.1	9.3	11.2	6.6	8.7	120	4,181	79	13.0	104
Average	8.4	8.2	9.5	10.4	14.1	14.2	12.9	13.1	10.7	9.6	8.8	9.1	129		84.5	15.9	126.5
% Distrib.	6.5%	6.4%	7.4%	8.1%	10.9%	11.0%	10.0%	10.1%	8.3%	7.5%	6.8%	7.0%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990	No				
1991	Daily				
1992	Peaking				
1993	Data				
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
Average	0	0	0	0	0.00

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	
W. Conservation Reduction =	
Subtotal =	
Peak Daily Demand with WC and Water Losses =	
Peak Daily Demand Factor with WC and Water Losses =	

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	102	121	93	120	133	165	141	145	117	97	91	93	4181	168.0
1989	57	53	62	72	90	86	112	86	65	69	65	67	4,181	103.3
1990	74	82	98	97	153	121	122	141	113	99	90	53	4,181	142.5
1991	57	74	95	109	124	119	111	101	62	69	60	55	4,181	116.6
1992	51	46	54	78	95	104	58	60	71	62	70	53	4,181	88.6
1993	63	58	52	48	113	103	81	75	80	77	46	75	4,181	94.9
1994	58	64	62	82	96	82	91	87	77	60	79	76	4,181	97.8
1995	63	74	86	72	95	92	90	110	88	54	89	87	4,181	105.2
1996	65	72	80	66	74	118	99	112	98	69	65	74	4,181	103.0
1997	65	39	64	121	156	122	81	92	72	59	72	50	4,181	101.6
1998	62	68	82	74	102	123	103	104	106	70	65	110	4,181	107.7
1999	65	72	83	71	84	105	119	105	82	85	74	60	4,181	99.5
2000	51	73	53	81	115	140	83	108	96	84	65	59	4,181	98.3
2001	68	83	65	71	90	104	100	86	74	86	53	67	4,181	90.9
Average	64	70	73	83	108	113	99	101	86	74	70	70		108.4

Agassiz RWS Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = **Summer =**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	102	121	93	120	133	165	141	145	117	97	91	93	4,181	103	133
1989	57	53	62	72	90	86	112	86	65	69	65	67	4,181	63	85
1990	74	82	98	97	153	121	122	141	113	99	90	53	4,181	82	125
1991	57	74	95	109	124	119	111	101	62	69	60	55	4,181	75	98
1992	51	46	54	78	95	104	58	60	71	62	70	53	4,181	59	75
1993	63	58	52	48	113	103	81	75	80	77	46	75	4,181	57	88
1994	58	64	62	82	96	82	91	87	77	60	79	76	4,181	70	82
1995	63	74	86	72	95	92	90	110	88	54	89	87	4,181	78	88
1996	65	72	80	66	74	118	99	112	98	69	65	74	4,181	70	95
1997	65	39	64	121	156	122	81	92	72	59	72	50	4,181	68	97
1998	62	68	82	74	102	123	103	104	106	70	65	110	4,181	77	101
1999	65	72	83	71	84	105	119	105	82	85	74	60	4,181	71	96
2000	51	73	53	81	115	140	83	108	96	84	65	59	4,181	64	104
2001	68	83	65	71	90	104	100	86	74	86	53	67	4,181	68	90
Average	64	70	73	83	108	113	99	101	86	74	70	70		71.8	97.0

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	103
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Max Year Monthly Demand w/o System Losses (gpc/d) =	165
Estimated Water Losses (%) =	12%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	64	70	73	83	108	113	99	101	86	74	70	70	84.5
Average Monthly Demand w/ WC (gpc/d)	56	62	65	75	99	104	90	91	76	65	62	62	75.7
Average Monthly Demand w/ WC and Losses (gpc/d)	**64**	**70**	**74**	**85**	**112**	**118**	**102**	**104**	**86**	**74**	**70**	**70**	**85.7**
Max Month Data w/o Losses (gpc/d)	102	121	98	121	156	165	141	145	117	99	91	110	122.2
Max Month Data w/ Losses (gpc/d)	**115**	**137**	**111**	**137**	**177**	**187**	**160**	**164**	**132**	**113**	**104**	**125**	**138.5**
Max Month Data w/ WC (gpc/d)	93	113	90	112	147	156	132	135	107	90	83	102	113.4
Max Month Data w/ WC and Losses (gpc/d)	**106**	**128**	**101**	**127**	**166**	**177**	**149**	**153**	**122**	**102**	**94**	**116**	**128.5**

Water Losses = 11.7%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		5,355							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	32.5	32.3	37.7	41.8	57.2	58.0	51.9	52.7	42.6	37.5	34.7	35.6	514.4
Max Month Data w/ Losses	58.6	63.3	56.4	67.4	90.3	92.3	81.6	83.6	65.3	57.4	51.0	63.6	830.7
Max Month Data w/ WC and Losses	53.9	59.0	51.7	62.8	84.8	87.1	76.1	78.1	60.0	51.9	46.5	58.9	770.9

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		5,300							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	32.2	31.9	37.3	41.4	56.6	57.4	51.3	52.2	42.1	37.1	34.3	35.3	509.1
Max Month Data w/ Losses	58.0	62.6	55.8	66.7	89.3	91.4	80.8	82.7	64.6	56.8	50.5	62.9	822.2
Max Month Data w/ WC and Losses	53.3	58.4	51.2	62.2	83.9	86.2	75.4	77.3	59.4	51.4	46.0	58.3	763.0

Barnes Rural Water District Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	9.48	9.17	10.81	13.16	13.13	14.01	15.59	13.49	14.27	11.92	9.85	8.00	142.88	2,615	40.8%	4.9	150
1989	9.10	9.88	9.29	10.81	14.00	16.15	12.41	11.99	10.10	10.33	9.77	11.74	135.55	2,615	39.9%	4.5	142
1990	11.98	10.13	10.61	11.14	14.20	11.22	13.10	12.33	10.08	12.55	9.26	12.49	139.08	2,645	39.0%	4.5	144
1991	11.35	9.04	9.99	13.54	11.45	12.04	11.99	12.20	10.78	13.42	10.40	13.53	139.71	2,660	38.6%	4.5	144
1992	11.12	9.01	12.89	12.81	12.71	16.35	10.65	11.62	12.90	10.93	9.98	13.32	144.27	2,693	39.0%	4.7	147
1993	10.82	9.94	13.10	12.51	17.13	11.69	11.11	13.71	11.02	10.25	12.37	10.33	143.97	2,710	40.8%	4.9	146
1994	12.95	10.34	11.70	14.82	12.70	13.59	13.09	10.94	12.59	9.64	12.56	11.30	146.22	2,743	39.2%	4.8	146
1995	11.23	10.50	11.94	11.88	17.27	18.08	11.22	16.67	12.34	14.57	12.19	15.49	163.39	2,778	44.8%	6.1	161
1996	12.18	11.14	13.78	11.68	11.85	16.16	13.31	13.92	10.89	11.30	9.97	12.86	149.03	2,808	32.9%	4.1	145
1997	13.03	11.70	11.50	11.73	15.10	15.31	13.39	11.78	10.93	11.12	11.17	10.72	147.48	2,823	30.5%	3.8	143
1998	11.15	10.27	13.92	11.67	14.86	13.40	15.34	14.20	12.11	12.59	11.36	13.41	154.28	2,868	28.0%	3.6	147
1999	15.07	10.29	12.22	13.53	15.20	16.17	15.40	15.05	12.16	13.29	13.09	12.61	164.09	3,663	34.3%	4.7	123
2000	13.44	11.93	11.37	14.83	16.96	14.58	15.09	16.22	14.01	11.27	13.68	14.81	168.17	3,742	35.7%	5.0	123
2001	13.29	14.06	13.05	16.38	17.30	15.97	16.85	15.88	14.35	12.79	13.96	14.08	177.95	3,796	40.1%	5.9	128
2002	12.48	11.46	12.74	11.06	15.14	19.10	14.40	13.26	13.57	12.14	10.66	13.05	159.06	3,874	37.4%	5.0	112
Average	11.91	10.59	11.93	12.77	14.60	14.92	13.53	13.55	12.14	11.87	11.35	12.52	151.67		37.39%		140.1

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	4.62	4.32	5.95	8.31	8.28	9.15	10.74	8.64	9.42	7.06	5.00	3.15	84.65	2,615	89	10.74	137
1989	4.59	5.37	4.78	6.30	9.49	11.64	7.90	7.48	5.59	5.82	5.26	7.23	81.44	2,615	85	11.64	148
1990	7.46	5.61	6.09	6.62	9.68	6.70	8.58	7.81	5.56	8.03	4.73	7.96	84.82	2,645	88	9.68	122
1991	6.85	4.54	5.49	9.04	6.95	7.54	7.49	7.70	6.28	8.92	5.90	9.03	85.73	2,660	88	9.04	113
1992	6.43	4.32	8.20	8.13	8.02	11.67	5.97	6.94	8.22	6.24	5.30	8.63	88.06	2,693	90	11.67	144
1993	5.93	5.05	8.20	7.62	12.24	6.80	6.22	8.82	6.13	5.36	7.48	5.44	85.28	2,710	86	12.24	151
1994	8.18	5.56	6.93	10.04	7.93	8.82	8.32	6.17	7.82	4.87	7.78	6.53	88.95	2,743	89	10.04	122
1995	5.14	4.41	5.85	5.78	11.18	11.99	5.13	10.57	6.24	8.47	6.10	9.39	90.23	2,778	89	11.99	144
1996	8.09	7.05	9.69	7.59	7.76	12.07	9.22	9.83	6.80	7.21	5.88	8.77	99.97	2,808	98	12.07	143
1997	9.28	7.94	7.74	7.97	11.35	11.56	9.64	8.03	7.17	7.37	7.42	6.97	102.45	2,823	99	11.56	136
1998	7.55	6.67	10.32	8.07	11.26	9.80	11.74	10.60	8.51	8.99	7.76	9.81	111.07	2,868	106	11.74	136
1999	10.38	5.61	7.53	8.85	10.52	11.49	10.72	10.37	7.47	8.60	8.41	7.93	107.88	3,663	81	11.49	105
2000	8.44	6.93	6.37	9.83	11.96	9.59	10.09	11.22	9.01	6.28	8.68	9.81	108.21	3,742	79	11.96	107
2001	7.35	8.11	7.11	10.44	11.35	10.03	10.91	9.94	8.40	6.85	8.01	8.14	106.64	3,796	77	11.35	100
2002	7.52	6.51	7.79	6.11	10.18	14.14	9.45	8.31	8.61	7.18	5.70	8.10	99.59	3,874	70	14.14	122
Average	6.88	5.58	6.81	7.49	9.32	9.59	8.09	8.25	6.79	6.68	6.29	7.58	89.35		87.6	10.71	119.5
% Distrib.	7.7%	6.2%	7.6%	8.4%	10.4%	10.7%	9.1%	9.2%	7.6%	7.5%	7.0%	8.5%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	N/A				
1989	N/A				
1990	N/A				
1991	N/A				
1992	499,700	153,994	345,706	128	1.47
1993	512,000	160,815	351,185	130	1.48
1994	493,000	156,911	336,089	123	1.40
1995	618,000	200,433	417,567	150	1.72
1996	664,000	134,425	529,575	189	2.15
1997	690,000	123,370	566,630	201	2.29
1998	565,000	118,377	446,623	156	1.78
1999	678,000	153,980	524,020	143	1.63
2000	720,000	164,282	555,718	149	1.70
2001	630,000	195,366	434,634	114	1.31
2002	N/A				
Average	606,970	156,195	450,775	148	1.69

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	200.7
W. Conservation Reduction =	9.5
Subtotal =	191.3
Peak Daily Demand with WC and	
Water Losses =	305.5
Peak Daily Demand Factor with WC and	
Water Losses =	2.43

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	57	59	73	106	102	117	132	107	120	87	64	39	2,615	88.7
1989	57	73	59	80	117	148	97	92	71	72	67	89	2,615	85.3
1990	91	76	74	83	118	84	105	95	70	98	60	97	2,645	87.9
1991	83	61	67	113	84	94	91	93	79	108	74	110	2,660	88.3
1992	77	57	98	101	96	144	71	83	102	75	66	103	2,693	89.6
1993	71	67	98	94	146	84	74	105	75	64	92	65	2,710	86.2
1994	96	72	81	122	93	107	98	73	95	57	95	77	2,743	88.8
1995	60	57	68	69	130	144	60	123	75	98	73	109	2,778	89.0
1996	93	90	111	90	89	143	106	113	81	83	70	101	2,808	97.5
1997	106	101	88	94	130	136	110	92	85	84	88	80	2,823	99.4
1998	85	83	116	94	127	114	132	119	99	101	90	110	2,868	106.1
1999	91	55	66	81	93	105	94	91	68	76	77	70	3,663	80.7
2000	73	66	55	88	103	85	87	97	80	54	77	85	3,742	79.2
2001	62	76	60	92	96	88	93	84	74	58	70	69	3,796	77.0
2002	63	60	65	53	85	122	79	69	74	60	49	67	3,874	70.4
Average	78	70	79	91	107	114	95	96	83	78	74	85		87.6

Barnes Rural Water District Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) **Winter =** **Summer =**

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	57	59	73	106	102	117	132	107	120	87	64	39	2,615	66	111
1989	57	73	59	80	117	148	97	92	71	72	67	89	2,615	71	100
1990	91	76	74	83	118	84	105	95	70	98	60	97	2,645	80	95
1991	83	61	67	113	84	94	91	93	79	108	74	110	2,660	85	92
1992	77	57	98	101	96	144	71	83	102	75	66	103	2,693	84	95
1993	71	67	98	94	146	84	74	105	75	64	92	65	2,710	81	91
1994	96	72	81	122	93	107	98	73	95	57	95	77	2,743	91	87
1995	60	57	68	69	130	144	60	123	75	98	73	109	2,778	73	105
1996	93	90	111	90	89	143	106	113	81	83	70	101	2,808	92	102
1997	106	101	88	94	130	136	110	92	85	84	88	80	2,823	93	106
1998	85	83	116	94	127	114	132	119	99	101	90	110	2,868	96	115
1999	91	55	66	81	93	105	94	91	68	76	77	70	3,663	73	88
2000	73	66	55	88	103	85	87	97	80	54	77	85	3,742	74	84
2001	62	76	60	92	96	88	93	84	74	58	70	69	3,796	72	82
2002	63	60	65	53	85	122	79	69	74	60	49	67	3,874	59	81
Average	78	70	79	91	107	114	95	96	83	78	74	85		79.3	96

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	96
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	148
Estimated Water Losses (%) =	37%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	78	70	79	91	107	114	95	96	83	78	74	85	87.6
Average Monthly Demand w/ WC (gpc/d)	69	62	71	82	98	105	86	86	74	69	66	77	78.8
Average Monthly Demand w/ WC and Losses (gpc/d)	**111**	**99**	**113**	**132**	**156**	**168**	**137**	**138**	**118**	**110**	**105**	**122**	**125.9**
Max Month Data w/o Losses (gpc/d)	106	101	116	122	146	148	132	123	120	108	95	110	119.1
Max Month Data w/ Losses (gpc/d)	**169**	**161**	**185**	**195**	**233**	**237**	**212**	**196**	**192**	**173**	**151**	**176**	**190.1**
Max Month Data w/ WC (gpc/d)	98	92	108	114	136	139	123	113	111	99	86	102	110.2
Max Month Data w/ WC and Losses (gpc/d)	**156**	**148**	**172**	**182**	**218**	**222**	**196**	**181**	**177**	**158**	**138**	**163**	**176.1**

Water Losses = 37.4%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		2,266							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	23.9	19.3	24.3	27.5	33.7	35.0	29.6	29.7	24.6	23.7	22.0	26.4	319.5
Max Month Data w/ Losses	36.5	31.3	40.0	40.7	50.2	49.4	45.6	42.3	40.0	37.2	31.5	38.0	482.7
Max Month Data w/ WC and Losses	33.7	28.7	37.2	38.0	46.9	46.3	42.4	39.0	36.9	34.0	28.8	35.2	447.0

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		4,897							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	51.7	41.7	52.5	59.4	72.8	75.6	63.9	64.2	53.1	51.3	47.4	57.0	690.5
Max Month Data w/ Losses	78.9	67.6	86.4	87.9	108.4	106.8	98.6	91.3	86.5	80.5	68.1	82.1	1,043.1
Max Month Data w/ WC and Losses	72.9	62.1	80.3	82.0	101.4	100.0	91.5	84.3	79.7	73.5	62.3	76.0	965.9

Breckenridge Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1987	11.5	10.6	11.6	11.8	13.2	14.8	15.6	16.6	13.6	12.6	11.4	11.5	155	4,014	20.7%	2.7	106
1988	13.0	12.0	13.1	13.4	15.0	16.7	17.7	18.8	15.4	14.2	12.9	13.0	175	4,014	30.1%	4.4	120
1989	12.7	11.7	12.9	13.1	14.7	16.4	17.3	18.4	15.1	13.9	12.7	12.8	172	4,014	31.3%	4.5	117
1990	12.5	11.5	12.7	12.9	14.4	16.1	17.0	18.0	14.8	13.7	12.4	12.6	169	3,708	30.1%	4.2	125
1991	12.0	11.1	12.1	12.3	13.8	15.4	16.3	17.3	14.2	13.1	11.9	12.0	162	3,708	28.6%	3.9	119
1992	11.7	10.8	11.8	12.0	13.4	15.0	15.9	16.8	13.8	12.8	11.6	11.7	157	3,709	29.5%	3.9	116
1993	10.9	10.0	11.0	11.2	12.5	14.0	14.8	15.7	12.9	11.9	10.8	10.9	147	3,709	26.0%	3.2	108
1994	11.3	10.4	11.4	11.6	13.0	14.5	15.4	16.3	13.4	12.4	11.3	11.4	153	3,709	26.5%	3.4	113
1995	11.3	10.4	11.4	11.6	13.0	14.5	15.4	16.3	13.4	12.4	11.2	11.3	152	3,710	26.6%	3.4	113
1996	10.6	9.8	10.7	10.9	12.2	13.7	14.5	15.3	12.6	11.6	10.6	10.7	143	3,710	20.7%	2.5	106
1997	9.2	8.5	9.3	9.5	10.6	11.9	12.6	13.3	10.9	10.1	9.2	9.3	124	3,714	20.0%	2.1	92
1998	9.3	8.5	9.4	9.5	10.7	11.9	12.6	13.4	11.0	10.1	9.2	9.3	125	3,714	17.7%	1.8	92
1999	8.4	7.7	8.5	8.6	9.7	10.8	11.4	12.1	9.9	9.2	8.3	8.4	113	3,693	10.7%	1.0	84
2000	8.1	7.5	8.2	8.4	9.4	10.5	11.1	11.7	9.6	8.9	8.1	8.2	110	3,559	8.1%	0.7	84
2001	7.9	7.3	8.0	8.1	9.1	10.2	10.8	11.4	9.3	8.7	7.9	7.9	107	3,558	7.9%	0.7	82
Average	9.9	9.2	10.0	10.2	11.4	12.8	13.5	14.3	11.7	10.9	9.9	10.0	134		22.3%		98.0

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1987	8.8	7.9	8.9	9.1	10.6	12.1	13.0	13.9	10.9	9.9	8.8	8.9	123	4,014	84	13.9	115
1988	8.6	7.6	8.8	9.0	10.6	12.3	13.3	14.4	11.0	9.8	8.5	8.6	122	4,014	84	14.4	119
1989	8.3	7.3	8.4	8.6	10.2	11.9	12.9	13.9	10.6	9.5	8.2	8.3	118	4,014	81	13.9	115
1990	8.3	7.3	8.4	8.6	10.2	11.9	12.8	13.8	10.6	9.5	8.2	8.3	118	3,708	87	13.8	124
1991	8.2	7.2	8.3	8.5	10.0	11.6	12.5	13.5	10.3	9.3	8.1	8.2	115	3,708	85	13.5	121
1992	7.8	6.9	7.9	8.1	9.6	11.1	12.0	13.0	9.9	8.9	7.7	7.8	111	3,709	82	13.0	116
1993	7.7	6.9	7.8	8.0	9.4	10.8	11.6	12.5	9.7	8.7	7.6	7.7	108	3,709	80	12.5	112
1994	8.0	7.1	8.1	8.3	9.7	11.2	12.0	13.0	10.0	9.0	7.9	8.0	112	3,709	83	13.0	116
1995	7.9	7.0	8.1	8.2	9.6	11.1	12.0	12.9	10.0	9.0	7.9	8.0	112	3,710	83	12.9	116
1996	8.2	7.3	8.3	8.4	9.8	11.2	12.0	12.9	10.1	9.2	8.1	8.2	114	3,710	84	12.9	116
1997	7.2	6.4	7.3	7.4	8.6	9.8	10.5	11.2	8.8	8.0	7.1	7.2	99	3,714	73	11.2	101
1998	7.4	6.7	7.5	7.7	8.8	10.1	10.8	11.5	9.1	8.3	7.4	7.5	103	3,714	76	11.5	103
1999	7.4	6.7	7.5	7.6	8.7	9.8	10.4	11.1	8.9	8.2	7.3	7.4	101	3,693	75	11.1	100
2000	7.4	6.8	7.5	7.6	8.6	9.7	10.3	11.0	8.9	8.2	7.4	7.4	101	3,559	78	11.0	103
2001	7.2	6.6	7.3	7.4	8.4	9.5	10.1	10.7	8.6	8.0	7.2	7.2	98	3,558	76	10.7	100
Average	7.3	6.5	7.4	7.6	8.8	10.1	10.9	11.7	9.1	8.2	7.2	7.3	102		75.0	11.7	104.3
% Distrib.	7.1%	6.4%	7.2%	7.4%	8.6%	9.9%	10.6%	11.4%	8.9%	8.1%	7.1%	7.2%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1987	948,000	87,997	860,003	214	2.86
1988	975,000	144,545	830,455	207	2.76
1989	1,044,000	146,929	897,071	223	2.98
1990	782,000	138,948	643,052	173	2.31
1991	724,000	126,704	597,296	161	2.15
1992	824,000	127,118	696,882	188	2.51
1993	528,000	104,370	423,630	114	1.52
1994	712,000	110,625	601,375	162	2.16
1995	543,000	111,132	431,868	116	1.55
1996	709,000	81,271	627,729	169	2.26
1997	601,400	68,326	533,074	144	1.91
1998	524,590	60,436	464,154	125	1.67
1999	617,666	33,110	584,556	158	2.11
2000	446,700	24,397	422,303	119	1.58
2001	N/A				
Average	712,811	97,565	615,246	162	2.17

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	223.5
W. Conservation Reduction =	9.6
Subtotal =	213.9
Peak Daily Demand with WC and Water Losses =	237.7
Peak Daily Demand Factor with WC and Water Losses =	2.99

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1987	69	68	70	74	85	102	107	115	91	79	71	70	4,014	83.8
1988	69	68	70	74	85	102	107	115	91	79	71	70	4,014	83.6
1989	66	65	68	72	82	99	103	112	88	76	68	67	4,014	80.5
1990	72	70	73	78	89	107	111	120	95	82	74	72	3,708	87.1
1991	71	69	72	76	87	104	109	117	93	81	73	71	3,708	85.3
1992	68	66	69	73	83	100	104	113	89	77	70	68	3,709	81.8
1993	67	66	68	72	81	97	101	109	87	76	69	67	3,709	80.1
1994	69	68	70	74	84	100	105	113	90	79	71	70	3,709	82.9
1995	69	68	70	74	84	100	104	112	90	78	71	69	3,710	82.6
1996	71	71	72	76	85	100	104	112	91	80	73	71	3,710	83.9
1997	62	62	63	66	74	88	91	98	79	70	64	62	3,714	73.4
1998	65	64	65	69	77	90	94	100	82	72	66	65	3,714	75.8
1999	64	65	65	69	76	88	91	97	80	71	66	65	3,693	74.9
2000	67	68	68	71	78	91	94	100	83	74	69	67	3,559	77.5
2001	65	66	66	70	76	89	91	97	81	72	67	66	3,558	75.6
Average	68	67	69	73	82	97	101	109	87	76	69	68		75.0

Maximum historic water use month = 120 gpc/d

Breckenridge Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = [green] Summer = [blue]

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use	Summer Per Capita Use
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		(gpc/d)	(gpc/d)
1987	69	68	70	74	85	102	107	115	91	79	71	70	4,014	70	97
1988	69	68	70	74	85	102	107	115	91	79	71	70	4,014	70	97
1989	66	65	68	72	82	99	103	112	88	76	68	67	4,014	68	93
1990	72	70	73	78	89	107	111	120	95	82	74	72	3,708	73	101
1991	71	69	72	76	87	104	109	117	93	81	73	71	3,708	72	98
1992	68	66	69	73	83	100	104	113	89	77	70	68	3,709	69	94
1993	67	66	68	72	81	97	101	109	87	76	69	67	3,709	68	92
1994	69	68	70	74	84	100	105	113	90	79	71	70	3,709	70	95
1995	69	68	70	74	84	100	104	112	90	78	71	69	3,710	70	95
1996	71	71	72	76	85	100	104	112	91	80	73	71	3,710	72	95
1997	62	62	63	66	74	88	91	98	79	70	64	62	3,714	63	83
1998	65	64	65	69	77	90	94	100	82	72	66	65	3,714	66	86
1999	64	65	65	69	76	88	91	97	80	71	66	65	3,693	66	84
2000	67	68	68	71	78	91	94	100	83	74	69	67	3,559	68	87
2001	65	66	66	70	76	89	91	97	81	72	67	66	3,558	67	84
Average	68	67	69	73	82	97	101	109	87	76	69	68		68.9	92

Per Capita Water Use Analysis (Max Year Method)

Winter Demand without Losses (gpc/d) =	73
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	120
Estimated Water Losses (%) =	10%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	68	67	69	73	82	97	101	109	87	76	69	68	80.6
Average Monthly Demand w/ WC (gpc/d)	59	58	60	64	72	88	91	99	78	67	61	60	71.5
Average Monthly Demand w/ WC and Losses (gpc/d)	**66**	**65**	**67**	**71**	**80**	**97**	**102**	**110**	**86**	**74**	**68**	**66**	**79.5**
Max Month Data w/o Losses (gpc/d)	72	71	73	78	89	107	111	120	95	82	74	72	87.1
Max Month Data w/ Losses (gpc/d)	**80**	**78**	**81**	**86**	**99**	**118**	**124**	**134**	**106**	**92**	**82**	**81**	**96.8**
Max Month Data w/ WC (gpc/d)	64	62	65	69	79	97	102	111	85	73	65	64	78.1
Max Month Data w/ WC and Losses (gpc/d)	**71**	**69**	**72**	**77**	**88**	**108**	**113**	**123**	**95**	**81**	**73**	**71**	**86.8**

Water Losses = 10.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		2,540							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	15.9	14.2	16.2	16.6	19.4	22.8	24.6	26.6	20.2	18.0	15.8	16.0	226.2
Max Month Data w/ Losses (gpc/d)	19.4	17.1	19.7	20.2	23.8	27.7	29.9	32.3	24.7	22.1	19.2	19.5	275.4
Max Month Data w/ WC and Losses (gpc/d)	17.1	15.0	17.4	18.0	21.2	25.2	27.3	29.7	22.2	19.5	17.0	17.2	246.9

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		3,601							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	22.5	20.1	22.9	23.6	27.5	32.3	34.8	37.7	28.7	25.4	22.5	22.7	320.7
Max Month Data w/ Losses (gpc/d)	27.5	24.2	27.9	28.6	33.7	39.3	42.4	45.8	35.0	31.4	27.2	27.6	390.5
Max Month Data w/ WC and Losses (gpc/d)	24.2	21.3	24.7	25.5	30.1	35.7	38.7	42.1	31.5	27.7	24.1	24.4	350.0

Cass Rural Water Users Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	19.0	20.9	19.0	22.3	35.1	32.5	23.7	35.4	26.0	25.8	20.3	19.6	300	9,903	17.6%	4.4	83
1989	25.1	19.6	20.9	23.6	31.6	30.0	42.2	30.3	23.2	30.4	21.3	22.5	320	10,028	16.6%	4.4	88
1990	26.7	21.9	23.7	27.5	33.8	28.2	34.9	32.1	28.6	28.9	23.2	26.1	335	10,142	15.2%	4.3	91
1991	23.8	24.1	25.8	30.1	30.8	26.7	34.7	33.2	32.4	28.6	24.0	30.0	344	10,270	27.7%	7.9	92
1992	25.5	23.4	29.0	26.4	37.0	38.3	33.3	37.9	28.6	28.0	31.4	31.9	371	10,422	29.4%	9.1	97
1993	29.5	26.4	29.8	32.3	37.8	37.7	34.3	37.9	35.0	32.1	32.0	31.0	396	10,554	34.3%	11.3	103
1994	30.1	30.2	30.1	35.8	40.7	38.2	36.8	34.8	33.1	33.7	31.7	31.4	406	10,692	26.9%	9.1	104
1995	31.8	27.2	29.6	34.5	34.6	39.1	33.6	35.4	27.6	32.4	28.3	27.3	381	10,848	18.7%	5.9	96
1996	27.9	27.6	26.2	30.3	32.4	37.4	41.8	37.7	30.4	31.2	25.0	30.3	378	11,109	5.7%	1.8	93
1997	30.6	27.6	29.3	30.4	38.3	43.3	36.0	34.7	39.5	33.8	29.4	35.5	408	11,173	25.2%	8.6	100
1998	27.9	30.2	35.1	38.1	36.8	41.1	39.6	40.8	35.1	30.6	32.7	31.6	420	11,270	25.8%	9.0	102
1999	29.4	28.0	33.4	31.3	35.1	45.5	36.9	44.8	35.3	34.2	30.9	36.9	422	11,412	23.4%	8.2	101
2000	33.4	34.5	33.5	36.9	45.4	43.8	41.5	52.6	35.8	36.6	37.6	33.0	465	11,587	30.2%	11.7	110
2001	33.9	34.5	31.9	33.1	44.6	41.9	43.5	44.7	37.3	35.6	31.5	35.1	448	11,688	26.1%	9.7	105
Average	28.2	26.9	28.4	30.9	36.7	37.4	36.6	38.0	32.0	31.6	28.5	30.2	385		23.1%		97.5

1 Water loss data was not available from 1988 - 1995 so the average from 1996 - 2001 was used (10%)

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	14.6	16.5	14.6	18.0	30.7	28.1	19.3	31.1	21.6	21.5	15.9	15.3	247	9,903	68	31.1	105
1989	20.7	15.1	16.5	19.1	27.1	25.5	37.8	25.8	18.7	25.9	16.8	18.0	267	10,028	73	37.8	126
1990	22.4	17.6	19.4	23.3	29.5	24.0	30.7	27.9	24.3	24.6	19.0	21.8	284	10,142	77	30.7	101
1991	15.9	16.2	17.9	22.2	22.9	18.8	26.7	25.2	24.4	20.6	16.0	22.1	249	10,270	66	26.7	87
1992	16.4	14.3	19.9	17.4	28.0	29.3	24.2	28.8	19.5	18.9	22.3	22.8	262	10,422	69	29.3	94
1993	18.1	15.0	18.5	21.0	26.5	26.3	23.0	26.6	23.7	20.7	20.6	19.7	260	10,554	67	26.6	84
1994	21.0	21.1	20.9	26.7	31.5	29.1	27.6	25.7	24.0	24.6	22.6	22.2	297	10,692	76	31.5	98
1995	25.8	21.3	23.6	28.6	28.7	33.2	27.7	29.5	21.7	26.5	22.3	21.3	310	10,848	78	33.2	102
1996	26.1	25.8	24.4	28.5	30.6	35.6	40.0	35.9	28.6	29.4	23.2	28.5	357	11,109	88	40.0	120
1997	22.0	19.0	20.7	21.8	29.8	34.8	27.5	26.1	30.9	25.2	20.8	27.0	305	11,173	75	34.8	104
1998	18.8	21.2	26.1	29.0	27.8	32.1	30.6	31.8	26.1	21.6	23.7	22.5	311	11,270	76	32.1	95
1999	21.2	19.8	25.2	23.0	26.9	37.3	28.6	36.5	27.1	26.0	22.6	28.7	323	11,412	78	37.3	109
2000	21.7	22.8	21.8	25.2	33.7	32.1	29.8	40.9	24.1	24.9	25.9	21.4	324	11,587	77	40.9	118
2001	24.1	24.8	22.2	23.3	34.8	32.2	33.8	35.0	27.6	25.9	21.8	25.3	331	11,688	78	35.0	100
Average	20.6	19.3	20.8	23.4	29.2	29.9	29.1	30.5	24.5	24.0	21.0	22.6	295		74.7	33.3	102.9
% Distrib.	7.0%	6.6%	7.1%	7.9%	9.9%	10.1%	9.9%	10.3%	8.3%	8.1%	7.1%	7.7%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001	1,842,105	319,918	1,522,187	130	1.74
Average	1,842,105	319,918	1,522,187	130	1.74

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	130.2
W. Conservation Reduction =	9.5
Subtotal =	120.8
Peak Daily Demand with WC and Water Losses =	157.0
Peak Daily Demand Factor with WC and Water Losses =	1.83

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	48	59	47	60	100	95	63	101	73	70	53	50	9,903	68.3
1989	66	54	53	64	87	85	122	83	62	83	56	58	10,028	73.0
1990	71	62	62	77	94	79	98	89	80	78	62	69	10,142	76.9
1991	50	56	56	72	72	61	84	79	79	65	52	69	10,270	66.4
1992	51	49	62	56	87	94	75	89	62	59	71	71	10,422	68.8
1993	55	51	57	66	81	83	70	81	75	63	65	60	10,554	67.4
1994	63	70	63	83	95	91	83	77	75	74	70	67	10,692	76.1
1995	77	70	70	88	85	102	82	88	67	79	69	63	10,848	78.3
1996	76	83	71	85	89	107	116	104	86	85	70	83	11,109	88.0
1997	64	61	60	65	86	104	79	75	92	73	62	78	11,173	74.9
1998	54	67	75	86	80	95	88	91	77	62	70	64	11,270	75.7
1999	60	62	71	67	76	109	81	103	79	74	66	81	11,412	77.5
2000	60	70	61	73	94	92	83	114	69	69	75	59	11,587	76.7
2001	67	76	61	67	96	92	93	97	79	71	62	70	11,688	77.6
Average	62	64	62	72	87	92	87	91	75	72	65	67		74.7

Cass Rural Water Users Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	48	59	47	60	100	95	63	101	73	70	53	50	9,903	53	84
1989	66	54	53	64	87	85	122	83	62	83	56	58	10,028	58	87
1990	71	62	62	77	94	79	98	89	80	78	62	69	10,142	67	86
1991	50	56	56	72	72	61	84	79	79	65	52	69	10,270	59	73
1992	51	49	62	56	87	94	75	89	62	59	71	71	10,422	60	78
1993	55	51	57	66	81	83	70	81	75	63	65	60	10,554	59	76
1994	63	70	63	83	95	91	83	77	75	74	70	67	10,692	70	83
1995	77	70	70	88	85	102	82	88	67	79	69	63	10,848	73	84
1996	76	83	71	85	89	107	116	104	86	85	70	83	11,109	78	98
1997	64	61	60	65	86	104	79	75	92	73	62	78	11,173	65	85
1998	54	67	75	86	80	95	88	91	77	62	70	64	11,270	69	82
1999	60	62	71	67	76	109	81	103	79	74	66	81	11,412	68	87
2000	60	70	61	73	94	92	83	114	69	69	75	59	11,587	66	87
2001	67	76	61	67	96	92	93	97	79	71	62	70	11,688	67	88
Average	62	64	62	72	87	92	87	91	75	72	65	67		65.2	84

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	78
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	122
Estimated Water Losses (%) =	23%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	62	64	62	72	87	92	87	91	75	72	65	67	74.7
Average Monthly Demand w/ WC (gpc/d)	53	55	54	64	78	82	78	81	66	62	56	59	65.9
Average Monthly Demand w/ WC and Losses (gpc/d)	**69**	**72**	**70**	**83**	**101**	**107**	**101**	**106**	**86**	**81**	**73**	**77**	**85.6**
Max Month Data w/o Losses (gpc/d)	77	83	75	88	100	109	122	114	92	85	75	83	91.9
Max Month Data w/ Losses (gpc/d)	**100**	**108**	**97**	**114**	**130**	**142**	**158**	**148**	**120**	**111**	**97**	**108**	**119.4**
Max Month Data w/ WC (gpc/d)	69	75	66	80	91	100	112	104	83	76	66	75	83.1
Max Month Data w/ WC and Losses (gpc/d)	**89**	**97**	**86**	**103**	**118**	**129**	**146**	**136**	**108**	**99**	**86**	**97**	**108.0**

Water Losses = 23.1%
WC = Water Conservation

Annual Water Demand (acre-feet) =				Reclamation 2050 Pop =		16,244							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	107.3	100.7	108.2	124.1	156.3	160.3	155.7	163.5	128.2	125.3	109.7	119.0	1,558.2
Max Month Data w/ Losses (gpc/d)	154.3	150.4	149.8	170.6	200.8	211.9	244.2	228.8	179.2	171.5	145.0	166.2	2,172.6
Max Month Data w/ WC and Losses (gpc/d)	137.9	135.6	133.5	154.8	181.8	193.5	225.2	209.8	160.9	152.5	129.1	149.8	1,964.4

Water demands corrected for per capita water demand of cities included in RWS service area

Average Monthly Demand w/ WC and Losses (gpc/d)	102.5	96.2	103.4	118.6	149.3	153.2	148.8	156.3	122.5	119.7	104.8	113.7	1,489.0
Max Month Data w/ WC and Losses (gpc/d)	130.0	127.8	125.8	145.9	171.4	182.4	212.3	197.7	151.6	143.7	121.7	141.2	1,851.6

Annual Water Demand (acre-feet) =				Water Users 2050 Pop =		21,048							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	139	130	140	161	203	208	202	212	166	162	142	154	2,019
Max Month Data w/ Losses (gpc/d)	200	195	194	221	260	275	316	296	232	222	188	215	2,815
Max Month Data w/ WC and Losses (gpc/d)	179	176	173	201	236	251	292	272	208	198	167	194	2,545

Water demands corrected for per capita water demand of cities included in RWS service area

Average Monthly Demand w/ WC and Losses (gpc/d)	132.8	124.6	134.0	153.7	193.5	198.5	192.8	202.5	158.7	155.1	135.8	147.3	1,929.3
Max Month Data w/ WC and Losses (gpc/d)	168.4	165.6	163.0	189.0	222.1	236.4	275.1	256.2	196.5	186.3	157.7	183.0	2,399.2

Annual Water Demand Shortages (acre-feet) =					Annual Permitted Allocation =			1,150 Ac-ft					Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	11.4	4.8	12.4	28.3	60.5	64.5	59.8	67.7	32.3	29.4	13.8	23.1	408.2
Max Month Data w/ Losses (gpc/d)	58.5	54.5	54.0	74.8	105.0	116.1	148.4	132.9	83.4	75.6	49.1	70.4	1,022.6
Max Month Data w/ WC and Losses (gpc/d)	42.1	39.8	37.6	58.9	86.0	97.7	129.4	113.9	65.0	56.7	33.3	54.0	814.4

Shortages corrected for per capita water demand of cities included in RWS service area

Average Monthly Demand w/ WC and Losses (gpc/d)	6.7	0.4	7.6	22.8	53.5	57.4	52.9	60.4	26.6	23.9	9.0	17.9	339.0
Max Month Data w/ WC and Losses (gpc/d)	34.2	32.0	30.0	50.0	75.6	86.6	116.5	101.9	55.8	47.9	25.9	45.4	701.6

Annual Water Demand Shortages (acre-feet) =					Annual Permitted Allocation =			1,150.0 Ac-ft					Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	43.2	34.6	44.4	65.0	106.7	111.9	105.9	116.0	70.2	66.5	46.3	58.3	869.0
Max Month Data w/ Losses (gpc/d)	104.1	99.0	98.3	125.2	164.4	178.7	220.6	200.6	136.4	126.4	92.0	119.5	1,665.1
Max Month Data w/ WC and Losses (gpc/d)	82.9	79.9	77.1	104.7	139.8	154.9	196.0	176.0	112.6	101.8	71.5	98.3	1,395.3

Shortages corrected for per capita water demand of cities included in RWS service area

Average Monthly Demand w/ WC and Losses (gpc/d)	37.0	28.8	38.2	57.8	97.7	102.7	96.9	106.6	62.9	59.3	40.0	51.5	779.3
Max Month Data w/ WC and Losses (gpc/d)	72.6	69.8	67.2	93.2	126.3	140.5	179.2	160.4	100.6	90.4	61.9	87.2	1,249.2

Cooperstown Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpcd)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	65.26	1,286	0.0%	0.0	139.1
1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	67.77	1,266	0.0%	0.0	146.6
1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58.94	1,247	0.0%	0.0	129.5
1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58.68	1,228	0.0%	0.0	131.0
1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	56.47	1,208	0.0%	0.0	128.0
1993	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	45.16	1,189	0.0%	0.0	104.1
1994	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	48.61	1,169	0.0%	0.0	113.9
1995	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	50.99	1,150	0.0%	0.0	121.5
1996	3.66	2.97	3.32	3.12	5.27	6.83	6.05	5.22	3.96	3.50	3.82	3.27	51.01	1,131	0.0%	0.0	123.6
1997	2.99	3.03	2.91	3.24	5.16	6.23	4.19	6.18	5.18	3.75	3.43	4.01	50.32	1,111	0.0%	0.0	124.1
1998	3.32	3.35	4.47	5.13	4.05	6.49	5.50	8.63	4.65	3.31	3.73	3.11	55.72	1,092	0.0%	0.0	139.8
1999	2.97	3.22	4.21	3.02	3.89	3.75	3.00	4.58	3.44	2.61	3.15	2.30	40.14	1,072	0.0%	0.0	102.6
2000	3.10	2.30	2.34	2.40	5.12	4.41	6.09	7.54	4.19	3.84	2.46	4.20	47.99	1,053	0.0%	0.0	124.9
2001	2.88	3.62	3.16	3.23	3.36	3.92	5.71	3.44	5.10	4.35	2.39	3.10	44.26	1,034	0.0%	0.0	117.3
2002	2.54	2.75	2.89	3.74	4.20	5.64	7.25	4.89	5.57	3.01	3.16	3.71	49.35	1,014	0.0%	0.0	133.3
Average	3.07	3.03	3.33	3.41	4.43	5.32	5.40	5.78	4.58	3.48	3.16	3.39	52.71				125.3

[1] Unaccounted for losses data was not available so assumed 0

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpcd)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpcd)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	65.26	1,286	139	N/A	N/A
1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	67.77	1,266	147	N/A	N/A
1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58.94	1,247	129	N/A	N/A
1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58.68	1,228	131	N/A	N/A
1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	56.47	1,208	128	N/A	N/A
1993	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	45.16	1,189	104	N/A	N/A
1994	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	48.61	1,169	114	N/A	N/A
1995	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	50.99	1,150	121	N/A	N/A
1996	3.66	2.97	3.32	3.12	5.27	6.83	6.05	5.22	3.96	3.50	3.82	3.27	51.01	1,131	124	6.83	201
1997	2.99	3.03	2.91	3.24	5.16	6.23	4.19	6.18	5.18	3.75	3.43	4.01	50.32	1,111	124	6.23	187
1998	3.32	3.35	4.47	5.13	4.05	6.49	5.50	8.63	4.65	3.31	3.73	3.11	55.72	1,092	140	8.63	263
1999	2.97	3.22	4.21	3.02	3.89	3.75	3.00	4.58	3.44	2.61	3.15	2.30	40.14	1,072	103	4.58	142
2000	3.10	2.30	2.34	2.40	5.12	4.41	6.09	7.54	4.19	3.84	2.46	4.20	47.99	1,053	125	7.54	239
2001	2.88	3.62	3.16	3.23	3.36	3.92	5.71	3.44	5.10	4.35	2.39	3.10	44.26	1,034	117	5.71	184
2002	2.54	2.75	2.89	3.74	4.20	5.64	7.25	4.89	5.57	3.01	3.16	3.71	49.35	1,014	133	7.25	238
Average	3.07	3.03	3.33	3.41	4.43	5.32	5.40	5.78	4.58	3.48	3.16	3.39	48.36		125.3	6.68	207.8
% Distrib.	6.3%	6.3%	6.9%	7.0%	9.2%	11.0%	11.2%	12.0%	9.5%	7.2%	6.5%	7.0%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpcd)	Daily Peaking Factor
1988	N/A	0			
1989	N/A	0			
1990	N/A	0			
1991	N/A	0			
1992	N/A	0			
1993	192,607	0	192,607	162	1.29
1994	183,093	0	183,093	157	1.25
1995	224,385	0	224,385	195	1.56
1996	196,174	0	196,174	174	1.39
1997	204,767	0	204,767	184	1.47
1998	N/A	0			
1999	N/A	0			
2000	N/A	0			
2001	N/A	0			
2002	N/A	0			
Average	200,205	0	200,205	174	1.39

Peak Daily Demand Estimate (with WC and Losses) =	(gpcd)
Max Daily Water Use (w/o water losses) =	195.1
W. Conservation Reduction =	9.5
Subtotal =	185.7
Peak Daily Demand with WC and Water Losses =	185.7
Peak Daily Demand Factor with WC and Water Losses =	1.62

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpcd)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,286	139.1
1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,266	146.6
1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,247	129.5
1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,228	131.0
1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,208	128.0
1993	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,189	104.1
1994	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,169	113.9
1995	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,150	121.5
1996	105	94	95	92	150	201	173	149	117	100	113	93	1,131	123.6
1997	87	97	85	97	150	187	122	179	155	109	103	117	1,111	124.1
1998	98	109	132	157	120	198	162	255	142	98	114	92	1,092	139.8
1999	89	107	127	94	117	116	90	138	107	79	98	69	1,072	102.6
2000	95	78	72	76	157	140	187	231	133	118	78	129	1,053	124.9
2001	90	125	99	104	105	126	178	107	164	136	77	97	1,034	117.3
2002	81	97	92	123	134	185	231	156	183	96	104	118	1,014	133.3
Average	92	101	100	106	133	165	163	174	143	105	98	102		125.3

Cooperstown Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,286	N/A	N/A
1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,266	N/A	N/A
1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,247	N/A	N/A
1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,228	N/A	N/A
1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,208	N/A	N/A
1993	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,189	N/A	N/A
1994	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,169	N/A	N/A
1995	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,150	N/A	N/A
1996	105	94	95	92	150	201	173	149	117	100	113	93	1,131	99	148
1997	87	97	85	97	150	187	122	179	155	109	103	117	1,111	98	150
1998	98	109	132	157	120	198	162	255	142	98	114	92	1,092	117	162
1999	89	107	127	94	117	116	90	138	107	79	98	69	1,072	97	108
2000	95	78	72	76	157	140	187	231	133	118	78	129	1,053	88	161
2001	90	125	99	104	105	126	178	107	164	136	77	97	1,034	99	136
2002	81	97	92	123	134	185	231	156	183	96	104	118	1,014	102	164
Average	92	101	100	106	133	165	163	174	143	105	98	102		99.9	147

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	117
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	255
Estimated Water Losses (%) =	0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	92	101	100	106	133	165	163	174	143	105	98	102	123.6
Average Monthly Demand w/ WC (gpc/d)	84	93	92	98	124	155	154	164	134	95	90	94	114.8
Average Monthly Demand w/ WC and Losses (gpc/d)	**84**	**93**	**92**	**98**	**124**	**155**	**154**	**164**	**134**	**95**	**90**	**94**	**114.8**
Max Month Data w/o Losses (gpc/d)	105	125	132	157	157	201	231	255	183	136	114	129	160.5
Max Month Data w/ Losses (gpc/d)	**105**	**125**	**132**	**157**	**157**	**201**	**231**	**255**	**183**	**136**	**114**	**129**	**160.5**
Max Month Data w/ WC (gpc/d)	96	117	124	148	147	192	221	245	174	126	106	121	151.7
Max Month Data w/ WC and Losses (gpc/d)	**96**	**117**	**124**	**148**	**147**	**192**	**221**	**245**	**174**	**126**	**106**	**121**	**151.7**

Water Losses = 0.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		840							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	6.7	6.7	7.3	7.6	9.9	12.0	12.3	13.1	10.3	7.6	7.0	7.5	108
Max Month Data w/ Losses	8.4	9.0	10.5	12.1	12.5	15.6	18.4	20.4	14.2	10.9	8.8	10.3	151
Max Month Data w/ WC and Losses	7.7	8.4	9.9	11.5	11.8	14.8	17.7	19.6	13.4	10.1	8.2	9.6	143

Dakota Water Users Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	5.7	7.1	5.4	5.8	6.1	8.1	7.8	7.8	7.3	6.1	5.3	5.5	78	1,975	15.0%	1.0	108
1989	5.5	5.5	5.3	5.8	6.5	7.2	8.0	9.7	8.0	5.5	5.6	6.1	79	1,975	15.0%	1.0	109
1990	5.9	5.7	5.2	5.7	5.9	7.6	8.0	8.5	7.7	5.5	5.6	5.5	77	1,975	15.0%	1.0	107
1991	5.8	5.8	5.6	5.9	6.3	6.6	6.9	6.8	7.3	5.4	5.6	5.4	74	1,975	15.0%	0.9	102
1992	5.3	8.2	5.3	5.7	6.0	7.0	7.0	6.3	6.8	5.3	5.6	5.2	73	1,975	15.0%	0.9	102
1993	6.0	5.5	5.7	5.9	5.6	7.5	7.2	6.3	6.0	5.8	5.5	5.5	72	1,975	15.0%	0.9	101
1994	5.9	5.6	6.4	5.5	5.9	6.9	7.6	6.4	7.5	5.2	5.6	5.5	74	1,975	15.0%	0.9	103
1995	5.9	5.6	5.5	5.7	6.1	5.6	7.8	7.3	6.5	5.7	5.2	5.7	73	1,975	15.0%	0.9	101
1996	5.6	6.0	6.8	5.8	6.2	6.7	8.3	6.9	7.5	5.9	5.9	6.0	78	2,100	15.0%	1.0	101
1997	5.8	6.6	6.1	6.3	6.1	7.3	8.8	8.0	6.8	5.7	6.2	6.0	80	2,100	15.0%	1.0	104
1998	8.2	7.0	6.0	6.7	6.9	8.4	8.4	8.8	9.4	7.2	6.5	6.9	90	2,350	15.0%	1.1	105
1999	7.4	7.1	6.5	7.2	8.1	9.4	9.6	8.4	7.7	7.5	6.6	7.2	93	2,350	15.0%	1.2	108
2000	7.9	7.5	7.2	7.3	7.7	8.9	10.3	9.1	9.2	6.3	7.0	7.2	96	2,450	15.0%	1.2	107
2001	7.5	7.5	8.3	7.0	7.9	7.7	10.5	9.1	9.0	6.7	7.2	6.2	95	2,600	15.0%	1.2	100
Average	6.3	6.5	6.1	6.2	6.5	7.5	8.3	7.8	7.6	6.0	5.9	6.0	81		15.0%		104.1

[1] Water loss data was not available so used 0%

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	4.8	6.1	4.4	4.8	5.1	7.1	6.8	6.8	6.4	5.1	4.3	4.5	66	1,975	92	7.1	120
1989	4.5	4.5	4.3	4.8	5.5	6.2	7.0	8.8	7.0	4.6	4.6	5.1	67	1,975	93	8.8	148
1990	5.0	4.8	4.2	4.7	4.9	6.7	7.1	7.6	6.7	4.5	4.7	4.5	65	1,975	91	7.6	128
1991	4.9	4.9	4.7	5.0	5.4	5.7	5.9	5.8	6.4	4.5	4.7	4.5	63	1,975	87	6.4	109
1992	4.4	7.2	4.4	4.7	5.1	6.1	6.1	5.4	5.8	4.4	4.6	4.2	62	1,975	87	7.2	122
1993	5.1	4.6	4.8	5.0	4.7	6.6	6.3	5.4	5.1	4.9	4.5	4.6	62	1,975	85	6.6	112
1994	5.0	4.7	5.5	4.6	5.0	6.0	6.7	5.5	6.6	4.3	4.7	4.6	63	1,975	87	6.7	113
1995	5.0	4.7	4.6	4.8	5.2	4.7	6.9	6.4	5.6	4.8	4.3	4.8	62	1,975	85	6.9	117
1996	4.6	5.1	5.8	4.8	5.2	5.8	7.3	5.9	6.6	5.0	4.9	5.0	66	2,100	86	7.3	117
1997	4.8	5.6	5.1	5.3	5.1	6.3	7.8	7.0	5.8	4.7	5.2	5.0	68	2,100	89	7.8	125
1998	7.1	5.9	4.9	5.6	5.8	7.3	7.3	7.6	8.3	6.1	5.3	5.8	77	2,350	90	8.3	118
1999	6.2	6.0	5.3	6.1	6.9	8.2	8.5	7.3	6.6	6.3	5.4	6.0	79	2,350	92	8.5	120
2000	6.7	6.3	6.0	6.1	6.5	7.7	9.1	7.9	8.0	5.1	5.8	6.0	81	2,450	91	9.1	123
2001	6.4	6.3	7.1	5.8	6.8	6.5	9.3	7.9	7.8	5.5	6.0	5.0	80	2,600	85	9.3	119
Average	5.3	5.5	5.1	5.2	5.5	6.5	7.3	6.8	6.6	5.0	4.9	5.0	69		88.5	7.7	120.6
% Distrib.	7.8%	8.0%	7.4%	7.5%	8.0%	9.5%	10.6%	9.9%	9.6%	7.3%	7.2%	7.2%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001	648,000	38,863	609,137	234	2.65
Average	46,286	38,863	609,137	234	2.65

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	234.3
W. Conservation Reduction =	9.5
Subtotal =	224.8
Peak Daily Demand with WC and Water Losses =	264.5
Peak Daily Demand Factor with WC and Water Losses =	2.82

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	78	110	72	81	83	120	111	112	107	84	73	73	1,975	91.8
1989	74	81	70	82	90	104	114	143	118	75	78	83	1,975	92.8
1990	81	86	69	79	80	112	115	124	114	74	79	74	1,975	90.6
1991	81	88	77	85	89	96	97	95	109	74	79	73	1,975	86.8
1992	71	131	72	80	83	103	100	87	99	72	78	69	1,975	86.6
1993	83	83	78	84	76	112	102	88	87	80	77	76	1,975	85.4
1994	82	84	90	77	82	101	109	89	111	70	79	74	1,975	87.4
1995	82	84	75	81	85	79	113	104	95	78	72	78	1,975	85.5
1996	71	86	89	77	81	92	113	91	104	76	78	77	2,100	86.2
1997	74	96	78	85	79	100	121	108	93	73	82	76	2,100	88.7
1998	97	89	67	79	80	103	100	105	118	83	75	79	2,350	89.7
1999	85	91	73	86	95	117	116	100	93	87	77	82	2,350	91.8
2000	89	92	79	83	86	105	119	104	108	67	79	79	2,450	90.8
2001	79	87	88	74	84	84	115	98	100	68	77	63	2,600	84.7
Average	81	92	77	81	84	102	110	103	104	76	77	75		88.5

Dakota Water Users Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = [green] Summer = [blue]

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	78	110	72	81	83	120	111	112	107	84	73	73	1,975	81	103
1989	74	81	70	82	90	104	114	143	118	75	78	83	1,975	78	107
1990	81	86	69	79	80	112	115	124	114	74	79	74	1,975	78	103
1991	81	88	77	85	89	96	97	95	109	74	79	73	1,975	80	93
1992	71	131	72	80	83	103	100	87	99	72	78	69	1,975	84	91
1993	83	83	78	84	76	112	102	88	87	80	77	76	1,975	80	91
1994	82	84	90	77	82	101	109	89	111	70	79	74	1,975	81	94
1995	82	84	75	81	85	79	113	104	95	78	72	78	1,975	79	92
1996	71	86	89	77	81	92	113	91	104	76	78	77	2,100	80	93
1997	74	96	78	85	79	100	121	108	93	73	82	76	2,100	82	95
1998	97	89	67	79	80	103	100	105	118	83	75	79	2,350	81	98
1999	85	91	73	86	95	117	116	100	93	87	77	82	2,350	82	101
2000	89	92	79	83	86	105	119	104	108	67	79	79	2,450	83	98
2001	79	87	88	74	84	84	115	98	100	68	77	63	2,600	78	92
Average	81	92	77	81	84	102	110	103	104	76	77	75		80.6	97

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	78
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	143
Estimated Water Losses (%) =	15%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	81	92	77	81	84	102	110	103	104	76	77	75	88.5
Average Monthly Demand w WC (gpc/d)	72	84	69	73	74	93	101	94	94	66	69	67	79.7
Average Monthly Demand w/ WC and Losses (gpc/d)	**85**	**99**	**81**	**86**	**87**	**109**	**119**	**111**	**111**	**78**	**81**	**79**	**93.7**
Max Month Data w/o Losses (gpc/d)	97	131	90	86	95	120	121	143	118	87	82	83	104.2
Max Month Data w/ Losses (gpc/d)	**115**	**154**	**106**	**101**	**112**	**141**	**142**	**168**	**139**	**102**	**97**	**97**	**122.6**
Max Month Data w/ WC (gpc/d)	89	123	82	78	86	110	111	134	109	77	74	75	95.4
Max Month Data w/ WC and Losses (gpc/d)	**105**	**144**	**96**	**92**	**101**	**130**	**131**	**157**	**128**	**91**	**87**	**88**	**112.2**

Water Losses = 15.0%
WC = Water Conservation

Annual Water Needs (acre-feet) prorated to include service to Cooperstown=			Reclamation 2050 Pop =		3,421							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses	29.3	30.7	27.8	28.4	30.0	36.2	40.8	38.0	36.9	26.8	27.1	27.2	379.2
Max Month Data w/ Losses	40.5	49.2	37.3	34.6	39.6	48.3	50.1	59.5	47.6	36.1	33.2	34.5	510.4
Max Month Data w/ WC and Losses	37.1	46.1	33.9	31.3	35.6	44.5	46.2	55.5	43.8	32.2	29.9	31.1	467.3

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		2,600							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses	22.2	23.3	21.2	21.6	22.8	27.5	31.0	28.9	28.1	20.3	20.6	20.7	288.2
Max Month Data w/ Losses	30.8	37.4	28.4	26.3	30.1	36.7	38.1	45.2	36.2	27.5	25.2	26.2	387.9
Max Month Data w/ WC and Losses	28.2	35.1	25.8	23.8	27.1	33.8	35.1	42.2	33.3	24.5	22.7	23.6	355.2

Drayton Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	12.8	10.0	10.0	8.2	11.0	12.0	13.2	10.2	14.2	13.5	19.2	20.2	154	971	11.0%	1.4	436
1989	18.0	18.7	16.1	7.8	9.6	10.4	17.1	11.7	13.6	22.2	17.4	22.4	185	966	11.0%	1.7	525
1990	21.3	18.9	22.5	7.0	7.0	9.0	14.9	13.6	14.0	22.2	18.3	19.9	189	961	11.0%	1.7	538
1991	9.3	8.4	9.2	10.2	4.8	3.8	3.9	4.6	6.1	8.4	7.3	7.4	83	956	11.0%	0.8	239
1992	7.2	6.3	6.8	6.2	3.3	4.6	3.8	4.3	8.2	8.4	7.4	7.9	74	951	11.0%	0.7	214
1993	6.7	6.4	8.0	8.0	3.5	3.6	2.9	3.4	6.7	6.7	5.9	5.9	68	947	11.0%	0.6	196
1994	6.3	6.1	6.1	4.3	2.8	3.4	3.5	3.5	6.5	6.5	5.5	6.0	60	942	11.0%	0.6	176
1995	6.5	5.4	9.1	7.9	7.9	4.9	3.5	5.7	8.3	6.3	5.6	4.1	75	937	11.0%	0.7	220
1996	5.0	6.0	6.2	7.0	4.9	4.1	3.9	3.8	7.1	8.0	5.2	4.0	65	932	11.0%	0.6	192
1997	5.6	6.5	6.2	5.2	7.3	5.5	3.5	4.1	5.2	5.4	5.5	6.0	66	927	11.0%	0.6	195
1998	6.5	7.6	7.4	6.8	6.8	3.5	3.5	3.8	8.8	8.9	8.5	8.0	80	923	11.0%	0.7	238
1999	8.8	8.2	8.6	7.3	8.7	6.5	2.7	4.3	6.4	6.7	6.6	8.0	83	918	11.0%	0.8	247
2000	8.2	6.8	7.6	7.0	6.8	4.2	4.3	5.0	8.3	8.1	6.6	11.9	85	913	11.0%	0.8	254
2001	10.8	10.1	11.3	11.0	8.6	3.4	3.5	3.3	7.5	8.3	8.6	8.8	95	908	11.0%	0.9	287
Average	9.5	9.0	9.6	7.4	6.6	5.6	6.0	5.8	8.6	10.0	9.1	10.0	97		11.0%		282.7

[1] Actual unaccounted for losses data was not available but Drayton estimates 11% annual losses

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	11.4	8.6	8.6	6.8	9.6	10.6	11.8	8.8	12.8	12.1	17.8	18.8	137	971	388	18.8	645
1989	16.3	17.0	14.4	6.1	7.9	8.7	15.4	10.0	11.9	20.5	15.7	20.7	165	966	467	20.7	715
1990	19.6	17.2	20.8	5.3	5.3	7.3	13.1	11.9	12.2	20.5	16.6	18.1	168	961	479	18.1	629
1991	8.5	7.6	8.4	9.5	4.1	3.0	3.1	3.9	5.4	7.7	6.5	6.6	74	956	213	8.4	294
1992	6.5	5.6	6.1	5.5	2.6	3.9	3.1	3.6	7.5	7.8	6.7	7.2	66	951	191	7.8	272
1993	6.1	5.7	7.4	7.4	2.9	3.0	2.3	2.7	6.0	6.1	5.3	5.3	60	947	174	7.4	260
1994	5.8	5.6	5.5	3.7	2.2	2.8	2.9	2.9	5.9	6.0	4.9	5.4	54	942	156	6.0	212
1995	5.9	4.7	8.5	7.2	7.2	4.3	2.8	5.0	7.6	5.6	4.9	3.4	67	937	196	8.5	301
1996	4.4	5.4	5.6	6.4	4.3	3.5	3.3	3.2	6.5	7.4	4.6	3.4	58	932	170	5.9	212
1997	5.0	5.9	5.6	4.6	6.7	4.8	2.9	3.5	4.6	4.8	4.9	5.4	59	927	174	5.9	213
1998	5.7	6.9	6.7	6.1	6.1	2.7	2.8	3.1	8.0	8.2	7.7	7.2	71	923	212	7.7	280
1999	8.1	7.4	7.8	6.6	7.9	5.7	1.9	3.6	5.6	6.0	5.9	7.3	74	918	220	7.9	288
2000	7.5	6.0	6.9	6.2	6.0	3.4	3.5	4.2	7.5	7.3	5.8	11.2	75	913	226	11.2	407
2001	10.0	9.3	10.4	10.1	7.7	2.6	2.6	2.4	6.6	7.4	7.8	7.9	85	908	255	10.4	381
Average	8.6	8.1	8.8	6.5	5.7	4.7	5.1	4.9	7.7	9.1	8.2	9.1	87		251.6	10.3	364.9
% Distrib.	9.9%	9.3%	10.1%	7.5%	6.6%	5.5%	5.9%	5.7%	8.9%	10.5%	9.5%	10.5%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	N/A				
1989	N/A				
1990	N/A				
1991	N/A				
1992	N/A				
1993	N/A				
1994	N/A				
1995	N/A				
1996	N/A				
1997	N/A				
1998	N/A				
1999	N/A				
2000	N/A				
2001	420,000	28,676	391,324	431	1.71
Average	420,000	28,676	394,000	431	1.71

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	430.9
W. Conservation Reduction =	9.5
Subtotal =	421.4
Peak Daily Demand with WC and Water Losses =	473.5
Peak Daily Demand Factor with WC and Water Losses =	1.74

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	378	316	285	233	319	364	392	292	439	402	610	624	971	388.1
1989	543	630	480	211	264	300	515	335	411	683	541	692	966	467.0
1990	658	639	698	183	177	253	441	400	424	687	575	609	961	478.7
1991	287	285	284	330	137	105	106	131	187	259	228	223	956	212.9
1992	220	211	207	194	88	138	106	124	263	263	235	244	951	190.7
1993	207	217	251	260	97	106	78	94	212	209	186	181	947	174.2
1994	197	211	189	133	76	101	101	101	210	205	174	185	942	156.3
1995	202	178	291	257	249	151	96	173	272	194	174	117	937	196.0
1996	152	209	193	229	149	124	114	111	234	256	165	117	932	170.5
1997	175	228	194	165	232	174	102	122	166	167	177	188	927	173.9
1998	201	267	234	220	212	99	98	108	290	287	280	253	923	211.8
1999	284	289	275	238	279	208	68	126	205	210	213	255	918	220.2
2000	263	234	243	226	213	123	123	149	274	257	213	394	913	226.2
2001	354	364	369	370	273	94	93	84	243	264	285	281	908	255.5
Average	294	305	299	232	197	167	174	168	274	310	290	312		251.6

Maximum historic water use month = 698 gpc/d

Drayton Water Demand Calculations
Maximum Month Method

With Industry | Without Industry

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	378	316	285	233	319	364	392	292	439	402	610	624	971	411	228
1989	543	630	480	211	264	300	515	335	411	683	541	692	966	524	236
1990	658	639	698	183	177	253	441	400	424	687	575	609	961	559	212
1991	287	285	284	330	137	105	106	131	187	259	228	223	956	260	80
1992	220	211	207	194	88	138	106	124	263	263	235	244	951	230	76
1993	207	217	251	260	97	106	78	94	212	209	186	181	947	215	62
1994	197	211	189	133	76	101	101	101	210	205	174	185	942	188	63
1995	202	178	291	257	249	151	96	173	272	194	174	117	937	210	112
1996	152	209	193	229	149	124	114	111	234	256	165	117	932	194	83
1997	175	228	194	165	232	174	102	122	166	167	177	188	927	183	105
1998	201	267	234	220	212	99	98	108	290	287	280	253	923	254	86
1999	284	289	275	238	279	208	68	126	205	210	213	255	918	246	113
2000	263	234	243	226	213	123	123	149	274	257	213	394	913	263	101
2001	354	364	369	370	273	94	93	84	243	264	285	281	908	316	91
Average	294	305	299	232	197	167	174	168	274	310	290	312		290	118

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	559
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	698
Estimated Water Losses (%) =	11%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/ Losses (gpc/d)	294	305	299	232	197	167	174	168	274	310	290	312	251.6
Average Monthly Demand w/ WC (gpc/d)	286	297	291	224	188	158	164	158	264	301	282	303	242.8
Average Monthly Demand w/ WC and Losses (gpc/d)	**322**	**334**	**327**	**252**	**211**	**177**	**185**	**178**	**297**	**338**	**316**	**341**	**272.8**
Max Month Data w/o Losses (gpc/d)	658	639	698	370	319	364	515	400	439	687	610	692	532.6
Max Month Data w/ Losses (gpc/d)	**740**	**717**	**784**	**416**	**358**	**408**	**579**	**449**	**493**	**772**	**685**	**778**	**598.4**
Max Month Data w/ WC (gpc/d)	650	630	690	362	309	354	506	391	430	677	601	684	523.8
Max Month Data w/ WC and Losses (gpc/d)	**731**	**708**	**775**	**407**	**347**	**398**	**568**	**439**	**483**	**761**	**676**	**769**	**588.5**

Water Losses = 11.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =	920									**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	28.1	26.4	28.6	21.3	18.5	15.0	16.2	15.6	25.1	29.6	26.8	29.8	281
Max Month Data w/ Losses	64.8	56.7	68.6	35.3	31.3	34.6	50.7	39.3	41.8	67.5	58.0	68.1	617
Max Month Data w/ WC and Losses	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	607

East Grand Forks Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988*	36.8	33.8	38.2	45.3	53.1	61.6	55.9	51.8	51.4	50.8	39.9	39.5	558.2	8,507	18.1%	8.4	180
1989	38.6	36.9	38.4	35.8	46.9	40.1	67.8	55.6	43.5	50.4	39.7	42.2	535.8	8,583	18.1%	8.1	171
1990	40.9	35.9	44.0	40.5	48.7	34.2	43.2	44.8	40.1	38.2	33.8	36.6	480.9	8,658	18.1%	7.2	152
1991	35.2	34.4	50.3	35.7	39.9	38.8	35.7	41.2	43.2	38.0	33.6	35.6	461.6	8,733	18.1%	7.0	145
1992	36.6	34.7	37.0	36.9	41.3	38.2	36.9	40.1	43.0	39.3	35.8	38.1	457.8	8,809	18.1%	6.9	142
1993	35.9	33.9	39.0	38.4	43.7	36.5	33.4	43.7	43.2	45.0	40.5	44.8	478.0	8,884	18.1%	7.2	147
1994	45.5	41.4	51.8	44.3	45.0	44.2	43.9	57.3	51.9	46.6	38.3	39.5	550	8,947	18.1%	8.3	168
1995	37.3	32.9	42.9	44.6	65.8	51.4	40.8	42.2	50.9	49.9	45.2	54.4	558	8,983	18.1%	8.4	170
1996	56.2	49.4	40.2	43.0	62.0	47.6	43.3	50.8	55.5	44.7	40.0	36.3	569	9,003	18.1%	8.6	173
1997	39.7	33.5	37.5	33.6	37.8	50.1	44.6	39.5	43.4	47.4	46.8	43.8	498	7,000	21.9%	9.1	195
1998	32.0	30.6	33.5	37.8	46.5	42.5	41.5	48.3	52.1	46.1	33.2	30.2	474	7,300	15.7%	6.2	178
1999	29.9	28.5	31.7	37.4	43.4	42.4	47.3	42.0	32.2	36.0	33.6	29.8	434	7,400	21.3%	7.7	161
2000	27.9	26.2	28.1	28.4	40.3	44.1	44.7	60.6	53.0	45.2	35.0	29.2	463	7,500	16.7%	6.4	169
2001	30.4	28.3	30.9	29.6	35.8	42.2	40.5	40.2	34.3	33.3	28.2	31.4	405	7,501	14.7%	5.0	148
2002	29.4	26.1	28.8	30.0	34.3	34.7	32.1	33.8	29.3	35.6	29.2	33.1	376	7,501	18.1%	5.7	137
Average	36.8	33.8	38.2	37.4	45.6	43.2	43.4	46.1	44.5	43.1	36.8	37.6	487		18.1%		162.5

1 Used data between 1997 and 2001 for unaccounted-for-water loss for pther years.
* No data was available for Jan-Mar of 1988. The average of 1989 - 2002 was used in the document.

Per Capita Water Use Analysis (Monthly water diversion*without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	28.4	25.3	29.7	36.9	44.7	53.2	47.5	43.4	43.0	42.4	31.5	31.1	457	8,507	147	53.2	209
1989	30.6	28.8	30.3	27.7	38.8	32.1	59.7	47.6	35.4	42.4	31.6	34.1	439	8,583	140	59.7	232
1990	33.6	28.7	36.7	33.3	41.5	27.0	36.0	37.6	32.9	31.0	26.6	29.3	394	8,658	125	41.5	160
1991	28.2	27.5	43.4	28.8	32.9	31.8	28.8	34.2	36.3	31.1	26.6	28.7	378	8,733	119	43.4	165
1992	29.7	27.8	30.1	30.0	34.4	31.3	30.0	33.2	36.1	32.4	28.9	31.2	375	8,809	117	36.1	137
1993	28.7	26.7	31.8	31.2	36.5	29.3	26.2	36.5	36.0	37.8	33.3	37.6	392	8,884	121	37.8	142
1994	37.2	33.1	43.5	36.0	36.8	35.9	35.6	49.0	43.7	38.3	30.0	31.2	450	8,947	138	49.0	183
1995	28.9	24.5	34.5	36.2	57.4	43.0	32.3	33.8	42.5	41.5	36.8	46.0	457	8,983	139	57.4	213
1996	47.7	40.8	31.6	34.5	53.5	39.0	34.7	42.2	47.0	36.2	31.4	27.8	466	9,003	142	53.5	198
1997	30.6	24.4	28.4	24.5	28.7	41.0	35.5	30.4	34.3	38.3	37.7	34.7	389	7,000	152	41.0	195
1998	25.8	24.3	27.3	31.6	40.3	36.3	35.3	42.1	45.9	39.9	26.9	24.0	400	7,300	150	45.9	210
1999	22.2	20.8	24.0	29.7	35.7	34.7	39.6	34.4	24.5	28.3	25.9	22.1	342	7,400	127	39.6	178
2000	21.4	19.7	21.7	21.9	33.9	37.7	38.3	54.1	46.5	38.8	28.5	22.8	385	7,500	141	54.1	241
2001	25.5	23.3	25.9	24.6	30.8	37.3	35.5	35.2	29.3	28.3	23.2	26.4	345	7,501	126	37.3	166
2002	23.7	20.4	23.2	24.4	28.6	29.0	26.5	28.1	23.6	30.0	23.5	27.4	308	7,501	113	30.0	133
Average	29.5	26.4	30.8	30.1	38.3	35.9	36.1	38.8	37.1	35.8	29.5	30.3	394		136.4	45.3	190.7
% Distrib.	7.5%	6.7%	7.8%	7.6%	9.7%	9.1%	9.2%	9.9%	9.4%	9.1%	7.5%	7.7%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	4,000,000	276,413	3,723,587	438	3.21
1989	4,000,000	265,310	3,734,690	435	3.19
1990					
1991					
1992					
1993					
1994	3,348,000	272,218	3,075,782	344	2.52
1995	3,400,000	276,413	3,123,587	348	2.55
1996	3,308,000	281,861	3,026,139	336	2.46
1997	2,407,000	299,125	2,107,875	301	2.21
1998	2,397,000	204,310	2,192,690	300	2.20
1999	2,247,000	252,949	1,994,051	269	1.98
2000	2,867,000	211,857	2,655,143	354	2.60
2001	2,326,000	163,432	2,162,568	288	2.11
2002	2,066,000	186,346	1,879,654	251	1.84
Average	2,942,364	244,567	2,697,797	333	2.44

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	437.7
W. Conservation Reduction =	9.6
Subtotal =	428.1
Peak Daily Demand with WC and	
Water Losses =	522.6
Peak Daily Demand Factor with WC	
and Water Losses =	3.45

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	108	106	113	145	170	209	180	165	168	161	123	118	8,507	147.3
1989	115	120	114	108	146	124	224	179	138	159	123	128	8,583	140.1
1990	125	118	137	128	155	104	134	140	127	115	102	109	8,658	124.7
1991	104	112	160	110	122	122	106	126	138	115	102	106	8,733	118.6
1992	109	113	110	114	126	118	110	121	137	119	109	114	8,809	116.6
1993	104	107	116	117	132	110	95	132	135	137	125	137	8,884	120.8
1994	134	132	157	134	133	134	129	177	163	138	112	113	8,947	137.9
1995	104	97	124	134	206	159	116	121	158	149	136	165	8,983	139.5
1996	171	162	113	128	192	145	124	151	174	130	116	99	9,003	141.9
1997	141	125	131	116	132	195	164	140	163	177	180	160	7,000	152.1
1998	114	119	121	144	178	166	156	186	210	176	123	106	7,300	150.1
1999	97	100	105	134	156	156	173	150	110	123	117	96	7,400	126.6
2000	92	94	93	97	146	167	165	233	207	167	127	98	7,500	140.8
2001	109	111	111	109	132	166	153	151	130	122	103	113	7,501	126.1
2002	102	97	100	108	123	129	114	121	105	129	105	118	7,501	112.6
Average	115	114	120	122	150	147	143	153	151	141	120	119		133.0

Maximum historic water use month = 233 gpc/d

East Grand Forks Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = **Summer =**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	108	106	113	145	170	209	180	165	168	161	123	118	8,507	119	175
1989	115	120	114	108	146	124	224	179	138	159	123	128	8,583	118	162
1990	125	118	137	128	155	104	134	140	127	115	102	109	8,658	120	129
1991	104	112	160	110	122	122	106	126	138	115	102	106	8,733	116	121
1992	109	113	110	114	126	118	110	121	137	119	109	114	8,809	111	122
1993	104	107	116	117	132	110	95	132	135	137	125	137	8,884	118	124
1994	134	132	157	134	133	134	129	177	163	138	112	113	8,947	130	145
1995	104	97	124	134	206	159	116	121	158	149	136	165	8,983	127	152
1996	171	162	113	128	192	145	124	151	174	130	116	99	9,003	132	153
1997	141	125	131	116	132	195	164	140	163	177	180	160	7,000	142	162
1998	114	119	121	144	178	166	156	186	210	176	123	106	7,300	121	179
1999	97	100	105	134	156	156	173	150	110	123	117	96	7,400	108	145
2000	92	94	93	97	146	167	165	233	207	167	127	98	7,500	100	181
2001	109	111	111	109	132	166	153	151	130	122	103	113	7,501	110	142
2002	102	97	100	108	123	129	114	121	105	129	105	118	7,501	105	120
Average	115	114	120	122	150	147	143	153	151	141	120	119		118	147

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	142
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	233
Estimated Water Losses (%) =	18.1%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	115	114	120	122	150	147	143	153	151	141	120	119	133.0
Average Monthly Demand w/ WC (gpc/d)	107	106	112	113	140	137	133	143	141	132	112	110	124.0
Average Monthly Demand w/ WC and Losses (gpc/d)	**130**	**129**	**136**	**138**	**171**	**168**	**163**	**175**	**172**	**161**	**136**	**135**	**151.4**
Max Month Data w/o Losses (gpc/d)	171	162	160	145	206	209	224	233	210	177	180	165	186.9
Max Month Data w/ Losses (gpc/d)	**208**	**198**	**195**	**177**	**252**	**255**	**274**	**284**	**256**	**215**	**219**	**202**	**228.2**
Max Month Data w/ WC (gpc/d)	162	154	152	136	197	199	215	223	200	167	171	157	177.9
Max Month Data w/ WC and Losses (gpc/d)	**198**	**187**	**185**	**166**	**240**	**243**	**262**	**273**	**244**	**204**	**209**	**191**	**217.1**

Water Losses = 18.1%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		9,800							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	122	109	127	125	160	151	152	163	156	150	123	126	1,662
Max Month Data w/ Losses	194	167	182	159	235	230	255	265	231	201	198	188	2,505
Max Month Data w/ WC and Losses	185	158	173	150	224	219	244	254	220	190	189	178	2,384

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		13,619							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	168.9	151.2	176.8	173.4	221.8	210.2	210.7	226.8	216.2	208.0	171.0	174.5	2,309.4
Max Month Data w/ Losses (gpc/d)	270.1	231.5	253.3	221.5	325.9	319.2	354.8	368.2	320.9	279.2	275.0	261.4	3,481.0
Max Month Data w/ WC and Losses (gpc/d)	256.7	219.4	239.9	208.5	310.8	304.5	339.6	353.1	306.2	264.0	262.0	248.0	3,312.9

Enderlin Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
1988														1,007	18.9%	0.0	0.0
1989														1,002	18.9%	0.0	0.0
1990														997	18.9%	0.0	0.0
1991														992	18.9%	0.0	0.0
1992	14.2	14.6	14.4	14.2	18.2	17.6	10.5	12.0	13.6	12.7	9.9	14.9	167	987	13.8%	1.9	462.9
1993	15.3	11.2	13.8	15.5	15.7	11.7	12.7	6.1	12.4	13.8	14.3	13.5	156	982	15.4%	2.0	435.6
1994	10.6	13.1	14.7	12.9	14.8	10.6	10.1	15.6	13.4	13.2	13.6	13.0	155	977	14.9%	1.9	436.0
1995	12.9	11.7	13.0	13.7	14.2	13.1	14.4	9.0	7.0	12.5	12.5	13.4	147	972	10.1%	1.2	415.3
1996	12.8	10.6	11.6	6.0	5.0	6.4	6.7	8.6	10.9	11.8	11.4	11.8	113	967	25.3%	2.4	321.3
1997	11.4	9.8	11.1	10.3	12.4	12.0	12.0	11.9	14.0	17.7	17.9	18.7	159	962	16.2%	2.1	453.1
1998	18.0	13.9	18.4	17.7	19.1	18.2	17.6	19.8	20.7	20.6	21.1	19.5	225	957	10.1%	1.9	642.8
1999	18.2	16.4	16.6	16.6	19.9	20.6	22.5	18.7	19.4	22.5	21.7	20.8	234	952	11.5%	2.2	673.5
2000	16.8	18.2	19.4	19.8	2.2	26.5	22.1	28.5	28.9	26.5	24.5	26.7	260	947	4.1%	0.9	752.7
2001	25.4	21.8	23.0	19.4	19.4	23.7	20.1	27.5	24.9	24.8	25.4	23.1	279	942	17.7%	4.1	810.2
Average	15.6	14.1	15.6	14.6	14.1	16.0	14.9	15.8	16.5	17.6	17.2	17.5	190		18.9%		540.3

[1] The unaccounted for water percentage was increased by 5% to reflect treatment process residuals production.

Per Capita Water Use Analysis (Monthly water diversion*without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
1988														1,007	0	0.0	0
1989														1,002	0	0.0	0
1990														997	0	0.0	0
1991														992	0	0.0	0
1992	10.8	13.7	12.9	11.9	12.6	17.4	13.5	6.8	12.3	10.9	11.4	9.7	144	987	399	17.4	588
1993	15.1	10.4	7.1	13.9	13.6	11.0	10.1	8.2	7.7	11.3	12.5	11.0	132	982	368	15.1	513
1994	10.9	8.6	12.0	13.3	11.0	13.2	4.2	11.6	14.4	8.9	11.4	13.1	132	977	371	14.4	490
1995	13.0	11.8	10.9	13.7	11.7	15.2	8.7	10.1	6.4	8.9	10.4	11.5	132	972	373	15.2	522
1996	11.0	10.3	9.9	7.7	2.8	3.7	3.7	4.2	8.6	6.2	7.9	8.7	85	967	240	11.0	379
1997	8.4	8.6	9.2	8.6	10.0	10.9	8.6	11.9	12.7	12.0	17.8	14.6	133	962	380	17.8	618
1998	17.4	14.7	15.4	16.1	18.0	15.4	15.4	16.4	17.5	19.6	18.1	18.0	202	957	578	19.6	683
1999	16.6	17.0	13.6	15.5	15.5	17.5	19.5	19.7	14.6	19.4	15.5	22.5	207	952	596	22.5	789
2000	18.3	15.8	15.9	19.0	17.8	23.8	19.4	22.9	28.7	21.7	23.4	22.6	249	947	722	28.7	1012
2001	23.6	21.0	19.2	18.1	19.0	17.7	14.8	15.9	24.1	12.5	23.5	19.8	229	942	667	24.1	853
Average	14.5	13.2	12.6	13.8	13.2	14.6	11.8	12.8	14.7	13.1	15.2	15.2	165		469.4	18.6	644.6
% Distrib.	8.8%	8.0%	7.7%	8.4%	8.0%	8.9%	7.2%	7.8%	8.9%	8.0%	9.2%	9.2%	100.0%				

[1] Major Differences between the Historic Monthly Filtered Water Production and Total Historic Monthly Metered Water Billed are attributable to an offset in the billing (meter reading) cycle and the water volume reporting system.

Year	Sheldon: Historic Monthly Metered Water Usage (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	-	-	-	-	-	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-	-	-	-	-	-
1992	0.38	0.40	0.40	0.40	0.48	0.46	0.42	0.49	0.40	0.40	0.44	0.37	5.05
1993	0.43	0.39	0.34	0.40	0.52	0.48	0.42	0.51	0.49	0.44	0.42	0.39	5.23
1994	0.45	0.36	0.47	0.44	0.36	0.70	0.37	0.46	0.51	0.36	0.35	0.38	5.21
1995	0.35	0.35	0.36	0.37	0.30	0.50	0.34	0.39	0.42	0.45	0.68	0.47	4.96
1996	0.37	0.31	0.32	0.25	0.31	0.39	0.41	0.37	0.50	0.35	0.41	0.32	4.30
1997	0.41	0.31	0.29	0.28	0.34	0.53	0.44	0.38	0.38	0.35	0.29	0.24	4.22
1998	0.29	0.35	0.20	0.26	0.33	0.30	0.65	0.45	0.37	0.38	0.31	0.31	4.19
1999	0.34	0.35	0.29	0.36	0.37	0.51	0.52	0.41	0.40	0.43	0.42	0.37	4.78
2000	0.47	0.36	0.31	0.44	0.49	0.59	0.57	0.49	0.52	0.45	0.46	0.56	5.70
2001	0.70	0.65	0.60	0.35	0.45	0.43	0.51	0.32	0.65	0.48	0.38	0.38	5.89
Average	0.42	0.38	0.36	0.35	0.39	0.49	0.47	0.43	0.46	0.41	0.42	0.38	4.95

Year	Sunflower Plant: Historic Monthly Metered Water Usage (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	-	-	-	-	-	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-	-	-	-	-	-
1992	8.6	11.2	10.4	9.2	9.7	14.0	10.9	3.8	9.6	7.9	8.5	7.2	111
1993	10.8	7.8	4.9	9.6	10.4	7.1	7.1	3.9	4.1	8.5	9.6	8.4	92
1994	7.8	6.4	9.7	10.5	8.3	9.5	1.5	9.0	11.5	6.5	9.0	10.5	100
1995	10.4	9.4	8.6	10.9	9.3	11.5	6.3	7.0	3.2	6.3	7.8	9.3	100
1996	8.3	7.4	7.3	5.3	0.3	0.3	0.7	1.4	5.5	3.7	5.4	6.4	52
1997	6.0	6.0	7.0	6.4	7.2	8.0	6.2	9.2	10.1	9.5	15.3	12.5	103
1998	15.0	12.3	13.3	13.8	15.2	12.9	12.6	13.1	14.9	17.1	15.7	16.0	172
1999	14.3	14.8	11.7	13.1	13.1	14.8	16.9	17.1	12.1	16.7	13.1	20.2	178
2000	15.7	13.4	13.1	16.5	13.0	21.1	16.6	19.8	25.9	19.2	21.0	20.3	215
2001	20.8	18.5	16.8	15.9	16.4	15.0	11.6	12.8	21.2	10.1	21.1	17.6	198
Average	11.8	10.7	10.3	11.1	10.3	11.4	9.0	9.7	11.8	10.6	12.7	12.8	132

Year	Historic Monthly Metered Water Usage Less Sunflower Plant and Sheldon (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
1988														1,007	0	0.0	0
1989														1,002	0	0.0	0
1990														997	0	0.0	0
1991														992	0	0.0	0
1992	1.8	2.1	2.1	2.3	2.5	2.9	2.2	2.5	2.3	2.6	2.4	2.2	28	987	77	2.9	98
1993	3.8	2.2	1.8	3.9	2.7	3.5	2.6	3.9	3.1	2.4	2.4	2.2	34	982	96	3.9	133
1994	2.6	1.8	1.9	2.3	2.3	3.0	2.4	2.1	2.3	2.0	2.1	2.2	27	977	76	3.0	102
1995	2.2	2.0	2.0	2.4	2.1	3.2	2.1	2.7	2.8	2.2	2.0	1.8	27	972	77	3.2	111
1996	2.3	2.6	2.3	2.2	2.2	3.0	2.6	2.4	2.6	2.2	2.1	2.0	29	967	81	3.0	102
1997	2.0	2.3	1.8	2.0	2.5	2.3	2.0	2.4	2.2	2.2	2.2	1.9	26	962	73	2.5	85
1998	2.1	2.0	1.9	2.0	2.5	2.3	2.1	2.9	2.2	2.1	2.1	1.7	26	957	74	2.9	99
1999	2.0	1.9	1.6	2.0	1.9	2.3	2.1	2.2	2.1	2.2	2.1	1.9	24	952	70	2.3	79
2000	2.2	2.0	2.4	2.1	4.3	2.1	2.3	2.7	2.3	2.1	2.0	1.8	28	947	82	4.3	152
2001	2.1	1.8	1.7	1.9	2.2	2.3	2.7	2.8	2.3	1.9	2.0	1.8	26	942	74	2.8	100
Average	2.3	2.1	2.0	2.3	2.5	2.7	2.3	2.7	2.4	2.2	2.1	1.9	27		78.0	3.1	106.2
% Distrib.	1.4%	1.3%	1.2%	1.4%	1.5%	1.6%	1.4%	1.6%	1.5%	1.3%	1.3%	1.2%	16.7%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	N/A				
1989	N/A				
1990	N/A				
1991	N/A				
1992	N/A				
1993	N/A				
1994	N/A				

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	1243.7
W. Conservation Reduction =	9.5
Subtotal =	1234.2
Peak Daily Demand with WC and	
Water Losses =	1522.1
Peak Daily Demand Factor with WC	

Enderlin Water Demand Calculations
Maximum Month Method

1995	N/A				
1996	N/A				
1997	676,000	70,620	605,380	629	1.34
1998	789,000	62,132	726,868	760	1.62
1999	943,000	73,735	869,265	913	1.95
2000	1,207,000	29,224	1,177,776	1244	2.65
2001	1,159,000	135,087	1,023,913	1087	2.32
Average	954,800	74,160	880,640	927	1.97

and Water Losses =	1.93

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Average Per Capita Use (gpc/d)
1988													1,007	0.0
1989													1,002	0.0
1990													997	0.0
1991													992	0.0
1992	58	75	68	78	82	98	72	81	76	84	82	71	987	77.1
1993	126	80	61	133	90	118	85	127	106	77	82	71	982	96.2
1994	85	64	61	79	77	102	78	70	79	67	70	73	977	75.6
1995	74	75	65	81	68	111	70	88	97	72	67	59	972	77.3
1996	78	95	77	78	73	102	87	81	88	74	72	67	967	80.8
1997	66	84	62	68	82	81	66	80	77	73	77	64	962	73.2
1998	69	75	65	70	84	79	71	96	77	70	72	59	957	73.9
1999	69	70	54	69	66	79	72	75	75	75	72	65	952	70.1
2000	74	76	83	73	147	75	78	91	81	71	69	60	947	81.6
2001	71	69	60	68	75	81	94	97	81	65	70	63	942	74.3
Average	77	76	66	80	84	93	77	89	84	73	73	65		78.0

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter Summer

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988													1,007	0	0
1989													1,002	0	0
1990													997	0	0
1991													992	0	0
1992	58	75	68	78	82	98	72	81	76	84	82	71	987	72	82
1993	126	80	61	133	90	118	85	127	106	77	82	71	982	92	100
1994	85	64	61	79	77	102	78	70	79	67	70	73	977	72	79
1995	74	75	65	81	68	111	70	88	97	72	67	59	972	70	85
1996	78	95	77	78	73	102	87	81	88	74	72	67	967	78	84
1997	66	84	62	68	82	81	66	80	77	73	77	64	962	70	76
1998	69	75	65	70	84	79	71	96	77	70	72	59	957	68	79
1999	69	70	54	69	66	79	72	75	75	75	72	65	952	67	74
2000	74	76	83	73	147	75	78	91	81	71	69	60	947	72	91
2001	71	69	60	68	75	81	94	97	81	65	70	63	942	67	82
Average	77	76	66	80	84	93	77	89	84	73	73	65		73	83

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	92
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	147
Estimated Water Losses (%) =	19%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	77	76	66	80	84	93	77	89	84	73	73	65	78.0
Average Monthly Demand w/ WC (gpc/d)	69	68	58	71	75	83	68	79	74	63	65	57	69.2
Average Monthly Demand w/ WC and Losses (gpc/d)	**85**	**84**	**71**	**88**	**92**	**102**	**84**	**98**	**92**	**78**	**80**	**70**	**85.3**
Max Month Data w/o Losses (gpc/d)	126	95	83	133	147	118	94	127	106	84	82	73	105.7
Max Month Data w/ Losses (gpc/d)	**155**	**117**	**103**	**164**	**182**	**145**	**115**	**157**	**131**	**103**	**101**	**90**	**130.3**
Max Month Data w/ WC (gpc/d)	118	87	75	125	138	108	84	118	97	74	74	65	96.9
Max Month Data w/ WC and Losses (gpc/d)	**145**	**107**	**93**	**154**	**170**	**134**	**104**	**145**	**119**	**91**	**91**	**80**	**119.5**

Water Losses = 18.9%
WC = Water Conservation

Annual Water Needs (acre-feet) =				Reclamation 2050 Pop =		860							**Subtotal**	**Annual Sunflower Plant Demand**	**Annual Sheldon Demand**	**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)	(Ac-Ft)	(Ac-Ft)	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	6.9	6.2	5.8	7.0	7.6	8.1	6.8	8.0	7.2	6.4	6.4	5.7	82	659.9	18.4	760.5
Max Month Data w/ Losses	12.7	8.7	8.4	13.0	14.9	11.5	9.4	12.9	10.4	8.4	8.0	7.3	126	659.9	18.4	803.9
Max Month Data w/ WC and Losses	11.9	7.9	7.6	12.2	13.9	10.6	8.5	11.9	9.4	7.5	7.2	6.5	115	659.9	18.4	793.4
Max Month Data w/ WC and Losses (includes Sunflower Plant and Sheldon)	68.4	64.4	64.1	68.7	70.5	67.1	65.0	68.4	66.0	64.0	63.7	63.0	793.4			

Annual Water Needs (acre-feet) =				Water User 2050 Pop =		947							**Subtotal**	**Annual Sunflower Plant Demand**	**Annual Sheldon Demand**	**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)	(Ac-Ft)	(Ac-Ft)	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	7.7	6.9	6.4	7.7	8.3	8.9	7.5	8.8	8.0	7.1	7.0	6.3	91	659.9	18.4	768.8
Max Month Data w/ Losses	14.0	9.5	9.3	14.3	16.4	12.7	10.4	14.2	11.4	9.3	8.8	8.1	138	659.9	18.4	816.6
Max Month Data w/ WC and Losses	13.1	8.7	8.4	13.4	15.3	11.6	9.3	13.1	10.4	8.2	7.9	7.2	127	659.9	18.4	805.0
Max Month Data w/ WC and Losses (includes Sunflower Plant and Sheldon)	69.6	65.2	64.9	69.9	71.9	68.2	65.9	69.6	66.9	64.8	64.5	63.7	805.0			

Fargo Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	336	294	340	363	459	566	565	442	417	361	385	320	4,849	71,230	20.0%	81.0	187
1989	338	294	316	326	399	445	618	484	347	308	286	367	4,528	72,660	20.0%	75.6	171
1990	308	284	316	324	372	384	483	543	416	375	338	337	4,478	74,111	31.1%	116.1	166
1991	323	278	292	300	372	393	407	464	389	356	298	297	4,169	75,883	27.6%	95.9	151
1992	300	283	291	291	392	395	371	374	306	350	311	316	3,982	77,558	26.1%	86.6	141
1993	318	297	297	300	336	326	339	413	388	362	312	322	4,010	79,164	27.0%	90.2	139
1994	338	356	374	344	418	474	442	457	381	351	322	341	4,598	80,924	25.3%	96.9	156
1995	340	290	324	312	375	517	392	525	424	361	310	310	4,480	82,442	25.2%	94.1	149
1996	335	339	341	355	379	491	560	539	433	386	345	351	4,854	83,822	29.7%	120.1	159
1997	362	328	375	324	300	345	329	361	297	280	244	243	3,790	85,358	15.7%	49.6	122
1998	246	221	240	264	326	294	359	433	344	292	269	281	3,568	86,935	4.1%	12.2	112
1999	327	254	286	271	323	365	400	371	309	303	279	281	3,770	88,128	12.5%	39.3	117
2000	276	275	293	285	341	319	379	450	314	297	265	283	3,777	90,599	9.5%	29.9	114
2001	276	246	292	281	323	331	436	407	332	302	272	276	3,774	92,410	6.7%	21.1	112
Average	316	288	313	310	365	403	434	447	364	335	303	309	4,188		20.0%		142.4

[1] Unaccounted for losses data was not available for 1988 and 1989 so the 1990 % of 31.1% was used

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	255	213	259	282	378	485	484	361	336	280	304	239	3,877	71,230	149	485	227
1989	262	218	241	250	324	369	543	408	272	232	210	292	3,620	72,660	137	543	249
1990	192	168	200	208	256	268	366	427	299	259	222	221	3,085	74,111	114	427	192
1991	227	182	196	204	276	297	311	368	293	261	202	202	3,018	75,883	109	368	161
1992	213	196	205	205	306	309	284	287	220	264	225	229	2,943	77,558	104	309	133
1993	228	207	207	209	246	236	249	323	298	271	222	232	2,928	79,164	101	323	136
1994	241	259	277	247	321	377	345	360	284	254	225	245	3,434	80,924	116	377	155
1995	246	196	230	218	280	423	298	431	330	267	216	216	3,351	82,442	111	431	174
1996	215	219	221	235	258	371	440	419	312	265	225	231	3,412	83,822	112	440	175
1997	313	279	326	275	251	295	280	311	247	231	195	194	3,195	85,358	103	326	127
1998	233	209	227	252	314	282	347	421	332	280	257	268	3,422	86,935	108	421	161
1999	288	215	247	231	284	326	361	332	270	264	240	241	3,299	88,128	103	361	136
2000	246	245	263	255	311	289	349	420	284	267	235	253	3,418	90,599	103	420	155
2001	255	225	271	260	302	310	415	386	311	281	251	255	3,521	92,410	104	415	150
Average	244	216	241	238	293	331	362	375	292	263	231	237	3,323		112.4	403.1	166.5
% Distrib.	7.3%	6.5%	7.2%	7.2%	8.8%	10.0%	10.9%	11.3%	8.8%	7.9%	6.9%	7.1%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988 [1]	23,220,000	2,662,681	20,557,319	289	2.57
1989					
1990	No				
1991	Daily				
1992	Peaking				
1993	Data				
1994					
1995					
1996					
1997	19,300,000	1,630,043	17,669,957	207	1.84
1998	20,900,000	400,840	20,499,160	236	2.10
1999	19,900,000	1,291,207	18,608,793	211	1.88
2000	21,700,000	982,982	20,717,018	229	2.03
2001	21,400,000	692,815	20,707,185	224	1.99
Average	21,070,000	1,276,761	19,793,239	233	2.07

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	288.6
W. Conservation Reduction =	9.2
Subtotal =	279.4
Estimated Storage Depletion =	28.1
Estimated Peak Day Demand Attenuation	36.0
Subtotal =	343.5
Peak Daily Demand with WC and	
Water Losses =	381.7
Peak Daily Demand Factor with Water	
Conservation and Water Losses=	3.29

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	116	107	117	132	171	227	219	164	157	127	142	108	71,230	149.1
1989	116	107	107	115	144	169	241	181	125	103	96	129	72,660	136.5
1990	84	81	87	93	111	121	160	186	135	113	100	96	74,111	114.1
1991	96	86	83	90	117	130	132	156	129	111	89	86	75,883	109.0
1992	89	90	85	88	127	133	118	120	94	110	97	95	77,558	103.9
1993	93	93	84	88	100	99	101	132	125	111	93	95	79,164	101.3
1994	96	114	110	102	128	155	138	143	117	101	93	97	80,924	116.3
1995	96	85	90	88	110	171	117	169	133	104	87	85	82,442	111.4
1996	83	93	85	93	99	148	169	161	124	102	89	89	83,822	111.5
1997	118	117	123	107	95	115	106	118	96	87	76	73	85,358	102.5
1998	87	86	84	97	116	108	129	156	127	104	99	100	86,935	107.8
1999	105	87	90	88	104	123	132	121	102	97	91	88	88,128	102.6
2000	88	97	94	94	111	106	124	150	105	95	87	90	90,599	103.4
2001	89	87	95	94	105	112	145	135	112	98	91	89	92,410	104.4
Average	97	95	95	98	117	137	145	149	120	104	95	94		112.4

Maximum historic water use month = 241 gpc/d

Fargo Water Demand Calculations

Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = **Summer =**

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	116	107	117	132	171	227	219	164	157	127	142	108	71,230	120	178
1989	116	107	107	115	144	169	241	181	125	103	96	129	72,660	112	161
1990	84	81	87	93	111	121	160	186	135	113	100	96	74,111	90	137
1991	96	86	83	90	117	130	132	156	129	111	89	86	75,883	88	129
1992	89	90	85	88	127	133	118	120	94	110	97	95	77,558	91	117
1993	93	93	84	88	100	99	101	132	125	111	93	95	79,164	91	111
1994	96	114	110	102	128	155	138	143	117	101	93	97	80,924	102	130
1995	96	85	90	88	110	171	117	169	133	104	87	85	82,442	89	134
1996	83	93	85	93	99	148	169	161	124	102	89	89	83,822	89	134
1997	118	117	123	107	95	115	106	118	96	87	76	73	85,358	102	103
1998	87	86	84	97	116	108	129	156	127	104	99	100	86,935	92	123
1999	105	87	90	88	104	123	132	121	102	97	91	88	88,128	92	113
2000	88	97	94	94	111	106	124	150	105	95	87	90	90,599	91	115
2001	89	87	95	94	105	112	145	135	112	98	91	89	92,410	91	118
Average	97	95	95	98	117	137	145	149	120	104	95	94		95.7	128.9

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	120
Indoor W. Conservation Reduction (gpc/d) =	6.67
Outdoor W. Conservation Reduction (gpc/d) =	1.26
Peak Monthly Demand w/o System Losses (gpc/d) =	241
Estimated Water Losses (%) =	10%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	96.8	95.0	95.4	97.7	117.1	137.0	145.0	149.4	120.2	104.5	94.9	94.4	112.4
Average Monthly Demand w/ WC (gpc/d)	90.1	88.3	88.7	91.1	107.9	127.8	135.8	140.2	111.0	95.3	88.3	87.7	104.5
Average Monthly Demand w/ WC and Losses (gpc/d)	**100.1**	**98.1**	**98.6**	**101.2**	**119.9**	**142.0**	**150.9**	**155.7**	**123.3**	**105.8**	**98.1**	**97.4**	**116.1**
Max Month Data w/o Losses (gpc/d)	118.2	116.6	123.0	132.0	171.3	226.9	240.9	185.7	157.5	126.8	142.5	129.5	156.1
Max Month Data w/ Losses (gpc/d)	**131.3**	**129.6**	**136.7**	**146.6**	**190.4**	**252.1**	**267.7**	**206.3**	**175.0**	**140.9**	**158.3**	**143.8**	**173.5**
Max Month Data w/ WC (gpc/d)	111.5	109.9	116.4	125.3	162.1	217.7	231.7	176.5	148.3	117.6	135.8	122.8	148.2
Max Month Data w/ WC and Losses (gpc/d)	**123.9**	**122.1**	**129.3**	**139.2**	**180.2**	**241.8**	**257.5**	**196.1**	**164.7**	**130.7**	**150.9**	**136.4**	**164.65**

Water Losses = 10.0%

WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		204,300							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	1,946	1,723	1,916	1,903	2,331	2,671	2,934	3,027	2,320	2,057	1,845	1,894	26,567
Max Month Data w/ Losses	2,552	2,274	2,657	2,758	3,700	4,741	5,203	4,011	3,291	2,739	2,977	2,796	39,701
Max Month Data w/ WC and Losses	2,408	2,144	2,513	2,619	3,502	4,549	5,005	3,812	3,099	2,540	2,838	2,652	37,682

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		243,073							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	2,315.7	2,049.5	2,279.7	2,264.4	2,772.9	3,178.0	3,490.3	3,601.6	2,760.4	2,447.9	2,194.9	2,253.3	31,608.7
Max Month Data w/ Losses (gpc/d)	3,036.5	2,706.1	3,161.4	3,281.9	4,402.4	5,641.2	6,191.0	4,771.9	3,915.6	3,258.7	3,542.5	3,326.5	47,235.7
Max Month Data w/ WC and Losses (gpc/d)	2,865.1	2,551.3	2,990.0	3,116.0	4,166.3	5,412.6	5,954.9	4,535.7	3,687.1	3,022.6	3,376.7	3,155.1	44,833.3

Grafton Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
1988	18.8	19.5	18.3	20.9	23.3	30.1	28.6	29.3	25.9	21.9	19.2	20.1	276	4,905	19.6%	4.5	154
1989	20.4	20.2	18.8	16.9	20.3	25.4	25.4	28.9	23.7	21.7	21.9	21.0	265	4,872	19.6%	4.3	149
1990	21.4	21.2	19.7	21.7	23.4	24.6	27.2	28.9	24.9	21.7	21.2	19.2	275	4,840	19.6%	4.5	156
1991	18.7	18.7	18.2	21.4	19.6	23.8	24.6	24.8	23.7	19.3	19.7	18.9	251	4,808	19.6%	4.1	143
1992	19.9	20.0	19.3	20.2	19.9	22.6	22.4	25.9	22.3	20.4	19.1	19.6	252	4,775	19.6%	4.1	144
1993	19.2	18.8	18.2	22.0	22.7	24.5	25.1	25.5	23.8	22.0	21.9	21.1	265	4,743	19.6%	4.3	153
1994	22.2	21.8	21.5	26.3	24.5	26.6	25.9	28.7	27.4	24.9	25.3	24.4	299	4,710	19.6%	4.9	174
1995	24.7	25.8	22.6	25.9	23.4	30.7	28.6	29.7	26.4	23.2	22.6	21.5	305	4,678	13.1%	3.3	179
1996	22.0	22.5	21.6	25.3	23.8	30.2	28.9	30.6	30.2	26.5	22.2	21.0	305	4,646	18.0%	4.6	180
1997	21.5	22.9	20.0	20.5	20.2	23.4	18.0	20.6	19.5	17.4	16.5	17.7	238	4,613	22.3%	4.4	142
1998	19.7	20.3	19.2	22.9	26.4	25.9	25.9	28.8	26.2	22.7	23.4	21.4	283	4,581	17.4%	4.1	169
1999	21.2	22.1	19.8	24.5	23.5	26.1	26.1	29.8	24.2	23.0	22.1	20.2	283	4,548	19.3%	4.6	170
2000	26.9	27.4	21.2	25.6	33.9	37.4	35.3	36.0	30.4	27.1	26.2	24.5	352	4,516	27.8%	8.1	214
2001	21.3	22.4	19.7	21.7	23.5	25.2	37.1	27.3	24.9	21.0	21.4	20.7	286	4,484	19.4%	4.6	175
Average	21.3	21.7	19.9	22.6	23.5	26.9	27.1	28.2	25.2	22.4	21.6	20.8	281		19.6%		164.4

[1] Unaccounted for losses data was not available from 1988 - 1994 so the average from 2001 - 1995 (19.6%) was used

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
1988	14.3	15.0	13.8	16.4	18.8	25.5	24.1	24.7	21.4	17.4	14.7	15.5	222	4,905	124	25.5	174
1989	16.0	15.9	14.5	12.6	16.0	21.1	21.1	24.6	19.3	17.4	17.6	16.7	213	4,872	120	24.6	168
1990	16.9	16.7	15.2	17.2	18.9	20.1	22.7	24.3	20.4	17.2	16.7	14.7	221	4,840	125	24.3	168
1991	14.6	14.6	14.1	17.3	15.5	19.6	20.5	20.7	19.6	15.2	15.5	14.7	202	4,808	115	20.7	144
1992	15.8	15.9	15.1	16.1	15.8	18.5	18.3	21.8	18.1	16.3	15.0	15.5	202	4,775	116	21.8	152
1993	14.9	14.4	13.8	17.7	18.4	20.2	20.7	21.2	19.5	17.7	17.6	16.8	213	4,743	123	21.2	149
1994	17.3	16.9	16.6	21.4	19.6	21.7	21.0	23.8	22.5	20.0	20.3	19.5	241	4,710	140	23.8	168
1995	21.4	22.5	19.3	22.6	20.0	27.4	25.3	26.4	23.0	19.9	19.2	18.2	265	4,678	155	27.4	195
1996	17.4	17.9	17.0	20.7	19.3	25.6	24.3	26.0	25.6	21.9	17.6	16.4	250	4,646	147	26.0	187
1997	17.0	18.5	15.5	16.1	15.8	19.0	13.6	16.2	15.1	13.0	12.1	13.3	185	4,613	110	19.0	137
1998	15.6	16.2	15.1	18.8	22.3	21.8	21.8	24.7	22.1	18.7	19.3	17.3	234	4,581	140	24.7	180
1999	16.7	17.6	15.2	20.0	18.9	21.6	21.6	25.2	19.7	18.4	17.6	15.7	228	4,548	137	25.2	185
2000	18.8	19.3	13.0	17.4	25.8	29.2	27.2	27.8	22.2	19.0	18.0	16.4	254	4,516	154	29.2	216
2001	16.6	17.8	15.1	17.1	18.8	20.6	32.5	22.7	20.2	16.3	16.7	16.1	231	4,484	141	32.5	242
Average	16.7	17.1	15.2	18.0	18.8	22.3	22.5	23.6	20.6	17.7	17.0	16.2	226		132.0	24.7	176.0
% Distrib.	7.4%	7.6%	6.8%	8.0%	8.3%	9.9%	10.0%	10.5%	9.1%	7.9%	7.5%	7.2%	100.0%				

Historic Monthly Metered Water Usage Purchased by WRWD (Millions of Gallons)

Year	Historic Monthly Metered Water Usage Purchased by WRWD (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.13	0.06	0.07	0.65	4,516
2001	0.31	1.22	0.04	0.44	0.17	0.96	2.38	1.80	0.41	0.06	0.05	0.05	7.89	4,484
Average	0.2	0.6	0.0	0.2	0.1	0.5	1.3	1.0	0.3	0.1	0.1	0.1	4.3	

[3] Walsh Rural Water District bought 662,000 gallons in 2000, and 7,879,000 gallons in 2001. Volumes distributed per meter readings provided by System Manager.

Per Capita Water Use Analysis Less Water Sold to WRWD(Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
1988	14.3	15.0	13.8	16.4	18.8	25.5	24.1	24.7	21.4	17.4	14.7	15.5	222	4,905	124	25.5	174
1989	16.0	15.9	14.5	12.6	16.0	21.1	21.1	24.6	19.3	17.4	17.6	16.7	213	4,872	120	24.6	168
1990	16.9	16.7	15.2	17.2	18.9	20.1	22.7	24.3	20.4	17.2	16.7	14.7	221	4,840	125	24.3	168
1991	14.6	14.6	14.1	17.3	15.5	19.6	20.5	20.7	19.6	15.2	15.5	14.7	202	4,808	115	20.7	144
1992	15.8	15.9	15.1	16.1	15.8	18.5	18.3	21.8	18.1	16.3	15.0	15.5	202	4,775	116	21.8	152
1993	14.9	14.4	13.8	17.7	18.4	20.2	20.7	21.2	19.5	17.7	17.6	16.8	213	4,743	123	21.2	149
1994	17.3	16.9	16.6	21.4	19.6	21.7	21.0	23.8	22.5	20.0	20.3	19.5	241	4,710	140	23.8	168
1995	21.4	22.5	19.3	22.6	20.0	27.4	25.3	26.4	23.0	19.9	19.2	18.2	265	4,678	155	27.4	195
1996	17.4	17.9	17.0	20.7	19.3	25.6	24.3	26.0	25.6	21.9	17.6	16.4	250	4,646	147	26.0	187
1997	17.0	18.5	15.5	16.1	15.8	19.0	13.6	16.2	15.1	13.0	12.1	13.3	185	4,613	110	19.0	137
1998	15.6	16.2	15.1	18.8	22.3	21.8	21.8	24.7	22.1	18.7	19.3	17.3	234	4,581	140	24.7	180
1999	16.7	17.6	15.2	20.0	18.9	21.6	21.6	25.2	19.7	18.4	17.6	15.7	228	4,548	137	25.2	185
2000	18.8	19.3	13.0	17.4	25.8	29.2	27.1	27.7	22.1	18.9	18.0	16.3	254	4,516	154	29.2	216
2001	16.3	16.6	15.1	16.6	18.7	19.6	30.1	20.9	19.8	16.3	16.7	16.1	223	4,484	136	30.1	224
Average	16.6	17.0	15.2	17.9	18.8	22.2	22.3	23.5	20.6	17.7	17.0	16.2	225.1		131.6	24.6	174.8
% Distrib.	7.4%	7.5%	6.8%	8.0%	8.4%	9.9%	9.9%	10.4%	9.1%	7.9%	7.5%	7.2%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	1,331,800	148,459	1,183,341	241	1.83
1989	1,355,300	142,527	1,212,773	249	1.89
1990	1,191,600	148,064	1,043,536	216	1.64
1991	1,240,600	135,312	1,105,288	230	1.75
1992	1,200,400	135,431	1,064,969	223	1.69
1993	1,137,600	142,612	994,988	210	1.59
1994	1,088,000	161,191	926,809	197	1.50
1995	1,431,200	109,354	1,321,846	283	2.15
1996	1,249,400	150,198	1,099,202	237	1.80
1997	1,288,900	145,854	1,143,046	248	1.88
1998	1,115,600	134,541	981,059	214	1.63
1999	1,273,900	149,890	1,124,010	247	1.88
2000	1,340,000	267,809	1,072,191	237	1.80
2001	1,171,500	151,943	1,019,557	227	1.73
Average	1,243,986	151,656	1,092,330	233	1.77

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	282.6
W. Conservation Reduction =	9.6
Subtotal =	273.0
Peak Daily Demand with WC and Water Losses =	339.7
Peak Daily Demand Factor with WC and Water Losses =	2.23

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Average Per Capita Use (gpc/d)
1988	94	109	90	112	123	174	159	163	145	114	100	102	4,905	123.8
1989	106	116	96	86	106	144	140	163	132	115	120	110	4,872	119.6
1990	112	123	101	118	126	138	151	162	140	115	115	98	4,840	125.1
1991	98	109	94	120	104	136	137	139	136	102	108	99	4,808	115.1
1992	106	119	102	112	107	129	124	147	127	110	104	105	4,775	116.0
1993	101	109	94	124	125	142	141	144	137	120	123	114	4,743	123.0
1994	119	128	114	151	134	153	144	163	159	137	144	133	4,710	139.9
1995	148	172	133	161	138	195	175	182	164	137	137	126	4,678	155.4
1996	121	138	118	149	134	184	169	181	184	152	126	114	4,646	147.4
1997	119	143	109	116	110	137	95	113	109	91	87	93	4,613	109.9
1998	110	126	107	137	157	159	154	174	161	131	140	122	4,581	139.8
1999	118	138	108	146	134	158	153	179	144	131	129	111	4,548	137.4
2000	134	152	93	129	184	216	193	198	163	135	133	117	4,516	153.8
2001	117	132	108	124	134	146	217	150	147	117	124	116	4,484	136.1
Average	115	130	105	128	130	158	154	161	146	122	121	111		131.6

Maximum historic water use month = 217 gpc/d

Grafton Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	94	109	90	112	123	174	159	163	145	114	100	102	4,905	101	146
1989	106	116	96	86	106	144	140	163	132	115	120	110	4,872	106	133
1990	112	123	101	118	126	138	151	162	140	115	115	98	4,840	111	139
1991	98	109	94	120	104	136	137	139	136	102	108	99	4,808	105	126
1992	106	119	102	112	107	129	124	147	127	110	104	105	4,775	108	124
1993	101	109	94	124	125	142	141	144	137	120	123	114	4,743	111	135
1994	119	128	114	151	134	153	144	163	159	137	144	133	4,710	132	148
1995	148	172	133	161	138	195	175	182	164	137	137	126	4,678	146	165
1996	121	138	118	149	134	184	169	181	184	152	126	114	4,646	128	167
1997	119	143	109	116	110	137	95	113	109	91	87	93	4,613	111	109
1998	110	126	107	137	157	159	154	174	161	131	140	122	4,581	124	156
1999	118	138	108	146	134	158	153	179	144	131	129	111	4,548	125	150
2000	134	152	93	129	184	216	193	198	163	135	133	117	4,516	126	182
2001	117	132	108	124	134	146	217	150	147	117	124	116	4,484	120	152
Average	115	130	105	128	130	158	154	161	146	122	121	111		118	145

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	146
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	217
Estimated Water Losses (%) =	19.6%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	115	130	105	128	130	158	154	161	146	122	121	111	131.6
Average Monthly Demand w/ WC (gpc/d)	106	121	96	119	120	148	144	152	137	112	112	103	122.6
Average Monthly Demand w/ WC and Losses (gpc/d)	**132**	**151**	**120**	**148**	**150**	**185**	**179**	**189**	**170**	**140**	**140**	**128**	**152.5**
Max Month Data w/o Losses (gpc/d)	148	172	133	161	184	216	217	198	184	152	144	133	170.0
Max Month Data w/ Losses (gpc/d)	**184**	**214**	**165**	**200**	**229**	**268**	**270**	**246**	**229**	**189**	**179**	**166**	**211.6**
Max Month Data w/ WC (gpc/d)	139	163	124	153	175	206	207	188	174	142	136	125	161.0
Max Month Data w/ WC and Losses (gpc/d)	**173**	**203**	**155**	**190**	**217**	**257**	**258**	**234**	**217**	**177**	**169**	**155**	**200.3**

Water Losses = 19.6%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Population =		4,130							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	52	53	47	56	59	70	70	74	65	55	53	50	706
Max Month Data w/ Losses (gpc/d)	72	76	65	76	90	102	106	97	87	74	68	65	979
Max Month Data w/ WC and Losses (gpc/d)	68	72	61	72	85	98	101	92	83	70	64	61	927

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		6,244							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	78.4	80.8	71.2	85.2	88.9	106.1	106.5	112.2	97.9	83.1	80.4	76.1	1,066.7
Max Month Data w/ Losses (gpc/d)	109.2	114.7	98.2	115.2	136.1	154.3	160.2	146.2	131.6	112.4	103.0	98.6	1,479.8
Max Month Data w/ WC and Losses (gpc/d)	102.9	109.0	91.9	109.2	129.0	147.5	153.1	139.2	124.8	105.3	96.9	92.3	1,401.2

Grand Forks Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	195	179	176	193	247	312	280	228	207	191	182	200	2,590	46,595	8.3%	18.0	152
1989	197	194	213	218	267	263	384	301	211	218	195	181	2,840	48,010	8.3%	19.7	162
1990	181	173	181	178	226	213	256	268	221	206	183	191	2,478	49,425	8.3%	17.2	137
1991	199	170	185	198	217	237	216	235	204	204	179	183	2,427	49,870	8.3%	16.8	133
1992	181	189	198	187	218	227	212	240	205	219	194	195	2,464	50,315	9.8%	20.2	134
1993	206	190	215	207	248	227	217	203	211	213	192	191	2,521	50,759	12.7%	26.7	136
1994	184	181	187	186	216	223	202	249	219	216	193	200	2,456	51,204	7.8%	16.0	131
1995	215	199	231	217	233	309	260	255	241	238	224	213	2,836	51,649	10.5%	24.8	150
1996	228	217	250	235	238	271	244	286	262	240	226	209	2,906	51,192	6.5%	15.7	156
1997	231	219	238	126	192	291	262	275	254	242	211	206	2,747	50,736	8.3%	19.1	148
1998	222	206	237	243	268	261	279	308	287	236	214	211	2,972	50,279	10.2%	25.3	162
1999	219	202	226	214	239	197	263	261	222	231	222	219	2,715	49,823	3.1%	7.1	149
2000	219	198	207	224	270	289	235	274	254	252	223	225	2,871	49,366	8.8%	21.0	159
2001	221	207	221	218	235	251	291	227	259	262	222	219	2,835	49,958	5.4%	12.8	155
Average	207	195	212	203	237	255	257	258	233	226	204	203	2,690		8.3%	19	147.6

[1] Unaccounted for losses data was not available for 1988 - 1991 and 1997 data was skewed due to flood so the average of the other years (8.3%) was used

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	177	161	158	175	229	294	262	210	189	173	164	182	2,374	46,595	140	294	210
1989	177	174	193	198	247	243	364	281	191	199	175	161	2,604	48,010	149	364	253
1990	163	155	163	161	209	196	239	251	204	189	166	173	2,272	49,425	126	251	169
1991	182	153	169	181	200	220	199	218	187	187	163	166	2,225	49,870	122	220	147
1992	161	168	178	167	198	207	191	219	185	198	174	175	2,221	50,315	121	219	145
1993	179	163	189	180	222	200	191	177	184	186	165	164	2,200	50,759	119	222	146
1994	168	165	171	170	200	207	186	233	203	200	177	184	2,265	51,204	121	233	151
1995	190	175	206	192	208	284	235	231	217	213	199	188	2,538	51,649	135	284	184
1996	213	201	235	219	223	255	229	270	246	225	210	193	2,718	51,192	145	270	176
1997	212	200	219	107	173	272	243	256	235	223	192	187	2,518	50,736	136	272	179
1998	196	181	212	218	243	236	254	283	262	211	188	186	2,668	50,279	145	283	187
1999	212	195	219	207	232	190	256	254	215	224	215	212	2,630	49,823	145	256	171
2000	198	177	186	203	249	268	214	253	233	230	202	204	2,619	49,366	145	268	181
2001	209	194	208	205	222	239	278	214	247	250	209	206	2,681	49,958	147	278	186
Average	188	176	193	185	218	237	239	239	214	208	186	184	2,467		135.4	265.3	177.5
% Distrib.	7.6%	7.1%	7.8%	7.5%	8.8%	9.6%	9.7%	9.7%	8.7%	8.4%	7.5%	7.5%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	15,120,000	590,617	14,529,383	312	2.30
1989 [1]	17,520,000	647,690	16,872,310	351	2.60
1990	11,520,000	565,109	10,954,891	222	1.64
1991	12,970,000	553,465	12,416,535	249	1.84
1992	10,800,000	663,769	10,136,231	201	1.49
1993	10,800,000	879,418	9,920,582	195	1.44
1994	10,650,000	524,877	10,125,123	198	1.46
1995	14,690,000	816,857	13,873,143	269	1.98
1996	10,940,000	515,707	10,424,293	204	1.50
1997	11,520,000	626,424	10,893,576	215	1.59
1998	13,680,000	832,650	12,847,350	256	1.89
1999	13,260,000	232,357	13,027,643	261	1.93
2000	14,080,000	691,312	13,388,688	271	2.00
2001	12,600,000	421,017	12,178,983	244	1.80
Average	12,867,857	611,519	12,256,338	246	1.82

[1] Information provided by Grand Forks and does not includes 2.5 million gallons of water lost in storage and 1.8 million gallons attunuated through drought contingency measures.

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	351.4
Estimated Storage Depletion =	52.1
Estimated Peak Day Demand Attenuation =	38
Simplot Peak Day Water Demand[1] =	23.9
W. Conservation Reduction =	9.1
Subtotal =	456.3
Peak Daily Demand with WC and Water Losses =	526.3
Peak Daily Demand Factor with WC and Water Losses =	3.57

WC = Water Conservation

[1] Simplot was not in operation on the peak day in 1989

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (10^6-gals)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	122	123	109	125	158	210	181	146	136	120	117	126	46,595	139.6
1989	119	130	130	138	166	169	245	189	132	133	122	108	48,010	148.6
1990	107	112	107	109	137	132	156	164	138	124	112	113	49,425	125.9
1991	118	110	109	121	130	147	129	141	125	121	109	108	49,870	122.2
1992	103	120	114	110	127	137	123	141	123	127	115	112	50,315	121.0
1993	114	115	120	118	141	132	121	112	121	118	108	104	50,759	118.7
1994	106	115	108	111	126	135	117	147	132	126	115	116	51,204	121.2
1995	119	121	129	124	130	184	147	144	140	133	129	117	51,649	134.6
1996	134	140	148	143	140	166	144	170	160	142	137	122	51,192	145.5
1997	135	141	139	127	144	179	154	163	154	142	126	119	50,736	136.0
1998	126	128	136	144	156	156	163	181	173	135	125	119	50,279	145.4
1999	137	140	142	138	150	127	166	164	144	145	144	137	49,823	144.6
2000	130	128	121	137	163	181	140	166	158	151	136	133	49,366	145.3
2001	135	139	134	137	144	159	180	138	165	161	140	133	49,958	147.0
Average	122	126	125	127	144	158	155	155	143	134	124	119		135.4

Maximum historic water use month = 245 gpc/d

Grand Forks Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	122	123	109	125	158	210	181	146	136	120	117	126	46,595	121	158
1989	119	130	130	138	166	169	245	189	132	133	122	108	48,010	124	172
1990	107	112	107	109	137	132	156	164	138	124	112	113	49,425	110	142
1991	118	110	109	121	130	147	129	141	125	121	109	108	49,870	112	132
1992	103	120	114	110	127	137	123	141	123	127	115	112	50,315	112	130
1993	114	115	120	118	141	132	121	112	121	118	108	104	50,759	113	124
1994	106	115	108	111	126	135	117	147	132	126	115	116	51,204	112	130
1995	119	121	129	124	130	184	147	144	140	133	129	117	51,649	123	146
1996	134	140	148	143	140	166	144	170	160	142	137	122	51,192	137	154
1997	135	141	139	127	144	179	154	163	154	142	126	119	50,736	131	156
1998	126	128	136	144	156	156	163	181	173	135	125	119	50,279	130	161
1999	137	140	142	138	150	127	166	164	144	145	144	137	49,823	140	149
2000	130	128	121	137	163	181	140	166	158	151	136	133	49,366	131	160
2001	135	139	134	137	144	159	180	138	165	161	140	133	49,958	136	158
Average	122	126	125	127	144	158	155	155	143	134	124	119		124	148

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Simplot Water Use* (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	12	11	12	10	10	10	5	0	7	10	8	7	46,595	10	7
1989	10	14	16	8	14	14	0	0	5	15	15	14	48,010	13	8
1990	11	13	16	11	13	11	0	0	13	12	17	10	49,425	13	8
1991	17	13	14	12	13	11	9	3	12	14	9	11	49,870	13	10
1992	24	21	24	20	23	25	17	13	19	22	20	18	50,315	21	20
1993	19	16	15	17	15	14	17	14	9	18	17	15	50,759	17	15
1994	16	15	14	11	15	13	12	0	18	20	2	15	51,204	12	13
1995	35	29	23	34	28	30	28	34	26	28	35	25	51,649	30	29
1996	32	24	32	24	32	32	62	4	17	29	39	21	51,192	29	29
1997	23	25	31	20	23	77	27	33	28	29	24	17	50,736	23	36
1998	38	32	35	29	31	36	15	22	32	36	36	27	50,279	33	29
1999	31	38	29	30	39	3	7	27	7	11	33	18	49,823	30	16
2000	32	14	30	31	41	35	9	21	37	33	3	30	49,366	23	29
2001	31	26	43	26	30	43	36	8	41	33	31	33	49,958	32	32
Average	24	21	24	20	23	25	17	13	19	22	21	19		21	20

* No data was available from January to September 1992 so the average was used.

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	GRAFB* (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	21	24	23	22	28	27	31	54	29	26	29	22	46,595	24	33
1989	19	21	21	20	25	24	28	49	26	23	26	20	48,010	21	29
1990	12	14	14	13	16	16	19	32	17	15	17	13	49,425	14	19
1991	11	12	12	12	15	14	17	29	15	14	15	12	49,870	12	17
1992	11	12	12	11	14	14	16	28	15	13	15	11	50,315	12	17
1993	9	10	10	10	12	12	14	24	13	11	13	10	50,759	10	14
1994	10	11	11	10	13	12	14	25	13	12	13	10	51,204	11	15
1995	13	13	13	13	15	15	18	28	17	15	16	12	51,649	13	18
1996	13	9	15	15	11	16	25	14	19	13	10	11	51,192	12	16
1997	12	9	9	13	15	11	16	23	25	19	13	12	50,736	11	18
1998	10	9	11	16	17	19	17	17	19	19	18	17	50,279	14	18
1999	17	21	11	7	7	10	15	20	6	5	10	9	49,823	13	11
2000	10	8	11	10	15	12	8	20	9	9	9	6	49,366	9	12
2001	8	9	6	7	10	8	14	24	19	15	15	7	49,958	9	15
Average	13	13	13	13	15	15	18	28	17	15	16	12		13	18

* 1988-1994's Annual volume was distributed by the average monthly distribution from 1996-2001. Where no data was available the average was used.

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Grand Forks less Simplot and GRAFB Water Use (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	89	88	74	93	120	173	145	92	100	84	80	97	46,595	87	119
1989	90	95	93	110	127	131	217	140	101	95	81	74	48,010	90	135
1990	84	85	77	85	108	105	137	132	108	97	78	90	49,425	83	114
1991	90	85	83	97	102	122	103	109	98	93	85	85	49,870	87	104
1992	68	87	78	79	90	98	90	100	89	92	80	83	50,315	79	93
1993	86	89	95	91	114	106	90	74	99	89	78	79	50,759	86	95
1994	80	89	83	90	98	110	91	122	101	94	100	91	51,204	89	103
1995	71	79	93	77	87	139	101	82	97	90	78	80	51,649	80	99
1996	89	107	101	104	97	118	57	152	124	100	88	90	51,192	96	108
1997	100	107	99	94	106	91	111	107	101	94	89	90	50,736	96	102
1998	78	87	90	99	108	101	131	142	122	80	71	75	50,279	83	114
1999	89	81	102	101	104	114	144	117	131	129	101	110	49,823	97	123
2000	88	106	80	96	107	134	123	125	112	109	124	97	49,366	99	118
2001	96	104	85	104	104	108	130	106	105	113	94	93	49,958	96	111
Average	85	92	88	94	105	118	119	114	106	97	88	88		89	110

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Grand Forks and GRAFB less Simplot Water Use (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	110	112	97	115	148	200	176	146	129	110	109	119	46,595	111	151
1989	109	116	114	130	152	155	245	189	127	118	107	94	46,595	111	164
1990	96	99	91	98	124	121	156	164	125	112	95	103	48,010	97	133
1991	101	97	95	109	117	136	120	138	113	107	100	97	49,425	100	122
1992	79	99	90	90	104	112	106	128	104	105	95	94	49,870	91	110
1993	95	99	105	101	126	118	104	98	112	100	91	89	50,315	97	110
1994	90	100	94	100	111	122	105	147	114	106	113	101	50,759	100	117
1995	84	92	106	90	102	154	119	110	114	105	94	92	51,204	93	117
1996	102	116	116	119	108	134	82	166	143	113	98	101	51,649	109	124
1997	112	116	108	107	121	102	127	130	126	113	102	102	51,192	108	120
1998	88	96	101	115	125	120	148	159	141	99	89	92	50,736	97	132
1999	106	102	113	108	111	124	159	137	137	134	111	119	50,279	110	134
2000	98	114	91	106	122	146	131	145	121	118	133	103	49,823	108	130
2001	104	113	91	111	114	116	144	130	124	128	109	100	49,366	105	126
Average	98	105	101	107	120	133	137	142	124	112	103	101		102	128

Grand Forks Water Demand Calculations
Maximum Month Method

Per Capita Water Use Analysis (Max Month Method)

Grand Forks less Simplot and GFAFB Maximum Monthly Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	90
Indoor W. Conservation Reduction (gpc/d) =	7.38
Outdoor W. Conservation Reduction (gpc/d) =	0.87
Peak Monthly Demand w/o System Losses (gpc/d) =	217
Estimated Water Losses (%) =	13.3%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	85	92	88	94	105	118	119	114	106	97	88	88	99.6
Average Monthly Demand w/ WC (gpc/d)	78	85	81	87	96	109	110	105	97	88	80	81	91.4
Average Monthly Demand w/ WC and Losses (gpc/d)	**90**	**98**	**93**	**100**	**111**	**125**	**127**	**121**	**112**	**101**	**93**	**93**	**105.4**
Max Month Data w/o Losses (gpc/d)	100	107	102	110	127	173	217	152	131	129	124	110	132.0
Max Month Data w/ Losses (gpc/d)	**115**	**124**	**117**	**126**	**146**	**200**	**250**	**176**	**151**	**149**	**144**	**127**	**152.2**
Max Month Data w/ WC (gpc/d)	92	100	94	102	118	164	208	143	122	120	117	103	123.7
Max Month Data w/ WC and Losses (gpc/d)	**106**	**115**	**109**	**118**	**136**	**189**	**239**	**165**	**140**	**138**	**135**	**119**	**142.7**

Water Losses = 13.3%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		83,800							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	718	703	742	774	882	968	1,012	967	864	809	714	743	9,895
Max Month Data w/ Losses	916	891	935	976	1,167	1,541	1,992	1,400	1,165	1,184	1,108	1,014	14,287
Max Month Data w/ WC and Losses	848	830	867	910	1,083	1,460	1,908	1,316	1,083	1,100	1,042	946	13,393

Annual Water Needs (acre-feet) =			2050 Population =		89,631							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	768	752	793	828	944	1,035	1,082	1,034	924	865	764	795	10,584
Max Month Data w/ Losses	979	953	1,000	1,044	1,248	1,648	2,131	1,497	1,246	1,267	1,185	1,084	15,281
Max Month Data w/ WC and Losses	907	888	927	973	1,158	1,561	2,041	1,407	1,159	1,177	1,114	1,012	14,325

Simplot Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	32
Indoor W. Conservation Reduction (gpc/d) =	0
Outdoor W. Conservation Reduction (gpc/d) =	0
Peak Monthly Demand w/o System Losses (gpc/d) =	43
Estimated Water Losses (%) =	13.3%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	24	21	24	20	23	25	17	13	19	22	21	19	20.7
Average Monthly Demand w/ WC (gpc/d)	24	21	24	20	23	25	17	13	19	22	21	19	20.7
Average Monthly Demand w/ WC and Losses (gpc/d)	**27**	**24**	**28**	**23**	**27**	**29**	**20**	**15**	**22**	**26**	**24**	**22**	**23.9**
Max Month Data w/o Losses (gpc/d)	38	38	43	34	41	77	62	34	41	36	39	33	43.0
Max Month Data w/ Losses (gpc/d)	**44**	**44**	**50**	**39**	**47**	**89**	**72**	**39**	**47**	**42**	**45**	**38**	**49.6**
Max Month Data w/ WC (gpc/d)	38	38	43	34	41	77	62	34	41	36	39	33	43.0
Max Month Data w/ WC and Losses (gpc/d)	**44**	**44**	**50**	**39**	**47**	**89**	**72**	**39**	**47**	**42**	**45**	**38**	**49.6**

Water Losses = 13.3%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		83,800							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	217	173	219	180	215	225	161	117	173	204	184	171	2,239
Max Month Data w/ Losses	349	316	395	303	377	685	570	313	365	331	347	303	4,655
Max Month Data w/ WC and Losses	349	316	395	303	377	685	570	313	365	331	347	303	4,655

Annual Water Needs (acre-feet) =			2050 Population =		49,958							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	129	103	131	107	128	134	96	70	103	121	110	102	1,335
Max Month Data w/ Losses	208	188	236	180	225	409	340	186	218	197	207	181	2,775
Max Month Data w/ WC and Losses	208	188	236	180	225	409	340	186	218	197	207	181	2,775

Grand Forks Water Demand Calculations
Maximum Month Method

GFAFB Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	24
Indoor W. Conservation Reduction (gpc/d) =	0
Outdoor W. Conservation Reduction (gpc/d) =	0
Peak Monthly Demand w/o System Losses (gpc/d) =	54
Estimated Water Losses (%) =	13.3%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	13	13	13	13	15	15	18	28	17	15	16	12	15.6
Average Monthly Demand w/ WC (gpc/d)	13	13	13	13	15	15	18	28	17	15	16	12	15.6
Average Monthly Demand w/ WC and Losses (gpc/d)	**14**	**15**	**15**	**15**	**18**	**17**	**21**	**32**	**20**	**17**	**18**	**14**	**18.0**
Max Month Data w/o Losses (gpc/d)	21	24	23	22	28	27	31	54	29	26	29	22	28.0
Max Month Data w/ Losses (gpc/d)	**24**	**28**	**27**	**25**	**32**	**31**	**36**	**62**	**33**	**30**	**33**	**25**	**32.3**
Max Month Data w/ WC (gpc/d)	21	24	23	22	28	27	31	54	29	26	29	22	28.0
Max Month Data w/ WC and Losses (gpc/d)	**24**	**28**	**27**	**25**	**32**	**31**	**36**	**62**	**33**	**30**	**33**	**25**	**32.3**

Water Losses = 13.3%
WC = Water Conservation

Annual Water Needs (acre-feet) =	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Ac-Ft)
Average Monthly Demand w/ WC and Losses	115	108	117	113	140	133	166	254	154	137	139	113	1,691
Max Month Data w/ Losses	193	199	212	196	257	240	285	497	258	239	258	202	3,037
Max Month Data w/ WC and Losses	193	199	212	196	257	240	285	497	258	239	258	202	3,037

Annual Water Needs (acre-feet) =	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (Ac-Ft)
Average Monthly Demand w/ WC and Losses	123	115	126	121	150	143	177	272	165	147	149	121	1,808
Max Month Data w/ Losses	207	213	226	209	275	257	305	531	276	256	276	216	3,248
Max Month Data w/ WC and Losses	207	213	226	209	275	257	305	531	276	256	276	216	3,248

Grand Forks Annual Water Needs Including Simplot and GFAFB* (acre-ft) =

Annual Water Needs (acre-feet) =			2050 Population =		83,800								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	963	914	990	995	1,151	1,235	1,273	1,291	1,121	1,067	963	959	12,921
Max Month Data w/ Losses	1,317	1,279	1,382	1,352	1,649	2,189	2,617	2,083	1,640	1,621	1,573	1,397	20,099
Max Month Data w/ WC and Losses	1,249	1,217	1,314	1,286	1,565	2,108	2,533	1,999	1,559	1,537	1,507	1,329	19,205

* Simplot water use is not proportionate to the population of Grand Forks. The max year, 2001, water demand for Simplot was used in the analysis.

Grand Forks Annual Water Needs Including Simplot and GFAFB* (acre-ft) =

Annual Water Needs (acre-feet) =			2050 Population =		89,631								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	1,021	970	1,050	1,057	1,222	1,312	1,355	1,375	1,192	1,133	1,022	1,018	13,727
Max Month Data w/ Losses	1,394	1,355	1,462	1,433	1,748	2,313	2,776	2,215	1,739	1,720	1,668	1,482	21,304
Max Month Data w/ WC and Losses	1,322	1,289	1,389	1,363	1,658	2,227	2,686	2,125	1,652	1,630	1,597	1,409	20,348

* Simplot water use is not proportionate to the population of Grand Forks. The max year, 2001, water demand for Simplot was used in the analysis.

Grand Forks-Traill Water District Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
1988	15.3	22.3	23.0	18.0	30.8	30.2	26.5	27.5	21.9	23.0	21.1	18.8	278	7,248
1989	13.3	5.2	19.9	13.4	31.1	29.5	29.1	28.7	20.8	22.9	27.9	29.5	271	7,323
1990	25.3	24.0	28.9	30.0	35.4	31.8	34.2	30.7	25.8	25.1	25.6	24.0	341	7,373
1991	32.5	24.5	29.6	29.1	34.1	29.9	30.1	29.5	28.0	26.4	31.0	27.8	352	7,448
1992	25.1	24.4	25.8	27.9	33.9	29.3	31.2	24.4	24.9	27.6	19.1	26.1	320	7,523
1993	27.1	27.7	29.0	25.1	29.9	37.7	31.5	32.8	30.2	35.6	25.1	28.8	361	7,448
1994	28.2	34.7	25.6	39.7	21.0	33.5	27.2	41.7	29.6	30.9	19.6	27.8	360	7,575
1995	27.0	27.2	27.5	34.3	33.9	37.6	33.4	32.8	28.1	30.3	27.4	27.4	367	7,623
1996	35.6	30.0	31.3	27.8	31.7	41.5	33.7	37.0	26.2	35.3	21.8	26.9	379	7,733
1997	24.7	22.8	31.8	54.5	44.7	40.1	31.8	35.3	33.7	35.3	36.3	26.1	417	7,850
1998	18.0	19.6	33.8	24.1	39.1	30.3	34.3	29.7	25.9	30.4	26.0	27.3	338	8,840
1999	34.3	31.9	40.0	33.4	48.7	65.3	41.2	31.7	31.0	40.5	27.9	25.8	452	8,910
2000	29.2	23.1	25.1	26.3	35.5	36.1	27.6	34.0	25.9	26.3	26.5	25.9	342	8,940
2001	28.0	27.1	18.4	56.2	27.6	38.3	30.7	25.3	26.5	31.8	28.7	28.7	367	9,000
Average	26.0	24.6	27.8	31.4	34.1	36.5	31.6	31.5	27.0	30.1	26.0	26.5	353	

GF Traill - GF Air Force Base: Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	7.1	14
1990	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	85
1991	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	85
1992	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	85
1993	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	85
1994	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	85
1995	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	85
1996	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	85
1997	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	85
1998	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	85
1999	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	0.0	0.0	71
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Average	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	61

Per Capita Water Use Analysis (Monthly water diversion)

Year	GF Traill Less GF Air Force Base: Monthly Raw Water Diversions (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[2]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	15.3	22.3	23.0	18.0	30.8	30.2	26.5	27.5	21.9	23.0	21.1	18.8	278	7,248	13.5%	3.1	105
1989	13.3	5.2	19.9	13.4	31.1	29.5	29.1	28.7	20.8	22.9	20.9	22.4	257	7,323	13.5%	2.9	96
1990	18.2	16.9	21.8	22.9	28.3	24.7	27.1	23.6	18.7	18.0	18.5	16.9	256	7,373	13.5%	2.9	95
1991	25.4	17.5	22.6	22.0	27.0	22.8	23.0	22.4	20.9	19.3	23.9	20.7	267	7,448	13.5%	3.0	98
1992	18.0	17.3	18.7	20.8	26.8	22.3	24.1	17.3	17.8	20.5	12.0	19.0	235	7,523	13.5%	2.6	85
1993	20.0	20.7	21.9	18.0	22.8	30.6	24.4	25.7	23.1	28.5	18.1	21.7	276	7,448	13.5%	3.1	101
1994	21.1	27.6	18.5	32.6	14.0	26.4	20.1	34.6	22.5	23.8	12.6	20.7	275	7,575	13.5%	3.1	99
1995	19.9	20.1	20.4	27.2	26.8	30.6	26.3	25.7	21.1	23.2	20.3	20.3	282	7,623	13.5%	3.2	101
1996	28.5	22.9	24.2	20.7	24.6	34.4	26.6	29.9	19.1	28.2	14.7	19.8	294	7,733	13.5%	3.3	104
1997	17.7	15.7	24.7	47.4	37.6	33.1	24.8	28.2	26.7	28.2	29.2	19.0	332	7,850	13.5%	3.7	116
1998	10.9	12.5	26.7	17.0	32.0	23.2	27.2	22.6	18.8	23.3	18.9	20.3	253	8,840	33.5%	7.1	79
1999	27.3	24.8	33.0	26.3	41.7	58.2	34.1	24.6	23.9	33.4	27.9	25.8	381	8,910	33.5%	10.6	117
2000	29.2	23.1	25.1	26.3	35.5	36.1	27.6	34.0	25.9	26.3	26.5	25.9	342	8,940	33.5%	9.5	105
2001	28.0	27.1	18.4	56.2	27.6	38.3	30.7	25.3	26.5	31.8	28.7	28.7	367	9,000	33.5%	10.3	112
Average	20.9	19.6	22.8	26.3	29.1	31.5	26.6	26.4	22.0	25.0	20.9	21.4	292		19.2%		101.0

year was calculated using the following equation: Population($_{year\ x)}$ = 2.5*(# of Members($_{year\ x}$)

[2] Water loss data was estimated at 13.5% through the distribution system and 16.5% through treatment from 1998-2001 (membrane plant)

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	12.2	19.2	19.8	14.9	27.7	27.1	23.3	24.4	18.8	19.9	18.0	15.7	241	7,248	91	27.7	127
1989	10.4	2.3	17.0	10.5	28.2	26.6	26.2	25.8	17.9	20.0	18.0	19.5	222	7,323	83	28.2	128
1990	15.4	14.0	18.9	20.0	25.4	21.8	24.3	20.7	15.8	15.2	15.7	14.0	221	7,373	82	25.4	115
1991	22.4	14.4	19.5	19.0	24.0	19.8	20.0	19.4	17.9	16.3	20.9	17.7	231	7,448	85	24.0	108
1992	15.3	14.7	16.1	18.2	24.2	19.6	21.4	14.6	15.2	17.8	9.4	16.4	203	7,523	74	24.2	107
1993	16.9	17.6	18.8	14.9	19.7	27.5	21.3	22.6	20.0	25.4	15.0	18.6	238	7,448	88	27.5	123
1994	18.0	24.6	15.4	29.5	10.9	23.3	17.0	31.5	19.5	20.7	9.5	17.6	237	7,575	86	31.5	139
1995	16.7	16.9	17.2	24.0	23.7	27.4	23.2	22.6	17.9	20.0	17.1	17.2	244	7,623	88	27.4	120
1996	25.2	19.6	20.9	17.4	21.3	31.1	23.3	26.6	15.8	24.9	11.4	16.5	254	7,733	90	31.1	134
1997	13.9	12.0	21.0	43.7	33.9	29.3	21.0	24.5	22.9	24.5	25.5	15.2	287	7,850	100	43.7	186
1998	3.8	5.5	19.6	9.9	24.9	16.1	20.2	15.6	11.7	16.2	11.8	13.2	169	8,840	52	24.9	94
1999	16.6	14.2	22.3	15.7	31.0	47.6	23.5	13.9	13.3	22.8	17.3	15.1	253	8,910	78	47.6	178
2000	19.7	13.6	15.6	16.7	26.0	26.6	18.0	24.5	16.4	16.8	17.0	16.4	227	8,940	70	26.6	99
2001	17.7	16.9	8.2	45.9	17.4	28.0	20.5	15.0	16.3	21.5	18.5	18.4	244	9,000	74	45.9	170
Average	16.0	14.7	17.9	21.5	24.2	26.6	21.7	21.6	17.1	20.1	16.1	16.5	234		81.5	31.1	130.6
% Distrib.	6.9%	6.3%	7.6%	9.2%	10.3%	11.4%	9.3%	9.2%	7.3%	8.6%	6.9%	7.1%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998	1,563,000	232,584	1,330,416	150	1.85
1999	1,578,000	349,586	1,228,414	138	1.69
2000	1,327,000	313,476	1,013,524	113	1.39
2001	1,231,000	337,122	893,878	99	1.22
Average	1,424,750	308,192	1,116,558	125	1.54

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	150.5
W. Conservation Reduction =	9.5
Subtotal =	141.0
Peak Daily Demand with WC and	
Water Losses =	212.1
Peak Daily Demand Factor with WC	
and Water Losses =	1.94

WC = Water Conservation

Grand Forks-Traill Water District Water Demand Calculations
Maximum Month Method

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Average Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)													
1988	54	95	88	68	123	125	104	109	86	89	83	70	7,248	91.0
1989	46	11	75	48	124	121	115	114	82	88	82	86	7,323	83.2
1990	67	68	83	90	111	99	106	91	71	66	71	61	7,373	82.2
1991	97	69	85	85	104	89	87	84	80	71	94	77	7,448	85.1
1992	66	70	69	81	104	87	92	63	67	77	42	70	7,523	73.9
1993	73	84	81	67	86	123	92	98	90	110	67	81	7,448	87.7
1994	77	116	66	130	46	103	73	134	86	88	42	75	7,575	85.9
1995	71	79	73	105	100	120	98	95	78	85	75	73	7,623	87.7
1996	105	91	87	75	89	134	97	111	68	104	49	69	7,733	90.0
1997	57	54	86	186	139	125	86	101	97	101	108	63	7,850	100.3
1998	14	22	72	37	91	61	74	57	44	59	44	48	8,840	52.2
1999	60	57	81	59	112	178	85	50	50	82	65	55	8,910	77.9
2000	71	54	56	62	94	99	65	88	61	61	63	59	8,940	69.6
2001	64	67	29	170	62	104	73	54	60	77	68	66	9,000	74.4
Average	66	67	74	90	99	112	89	89	73	83	68	68		81.5

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	54	95	88	68	123	125	104	109	86	89	83	70	7,248	76	106
1989	46	11	75	48	124	121	115	114	82	88	82	86	7,323	58	107
1990	67	68	83	90	111	99	106	91	71	66	71	61	7,373	73	91
1991	97	69	85	85	104	89	87	84	80	71	94	77	7,448	84	86
1992	66	70	69	81	104	87	92	63	67	77	42	70	7,523	66	82
1993	73	84	81	67	86	123	92	98	90	110	67	81	7,448	76	100
1994	77	116	66	130	46	103	73	134	86	88	42	75	7,575	84	88
1995	71	79	73	105	100	120	98	95	78	85	75	73	7,623	79	96
1996	105	91	87	75	89	134	97	111	68	104	49	69	7,733	79	101
1997	57	54	86	186	139	125	86	101	97	101	108	63	7,850	92	108
1998	14	22	72	37	91	61	74	57	44	59	44	48	8,840	40	64
1999	60	57	81	59	112	178	85	50	50	82	65	55	8,910	63	93
2000	71	54	56	62	94	99	65	88	61	61	63	59	8,940	61	78
2001	64	67	29	170	62	104	73	54	60	77	68	66	9,000	77	72
Average	66	67	74	90	99	112	89	89	73	83	68	68		72.1	91

Per Capita Water Use Analysis (Max Month Method)

Winter Demand without Losses (gpc/d) =	92
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	186
Estimated Water Losses (%) =	34%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	66	67	74	90	99	112	89	89	73	83	68	68	81.5
Average Monthly Demand w/ WC (gpc/d)	58	59	65	82	90	102	80	80	63	73	60	60	72.7
Average Monthly Demand w/ WC and Losses (gpc/d)	**87**	**88**	**98**	**123**	**135**	**154**	**120**	**120**	**95**	**110**	**90**	**90**	**109.3**
Max Month Data w/o Losses (gpc/d)	105	116	88	186	139	178	115	134	97	110	108	86	121.8
Max Month Data w/ Losses (gpc/d)	**158**	**174**	**133**	**279**	**210**	**268**	**173**	**202**	**146**	**166**	**163**	**129**	**183.1**
Max Month Data w/ WC (gpc/d)	97	108	80	177	130	169	106	125	88	101	100	78	113.0
Max Month Data w/ WC and Losses (gpc/d)	**146**	**162**	**120**	**267**	**195**	**254**	**159**	**188**	**132**	**151**	**150**	**117**	**169.9**

Water Losses = 33.5%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		12,176							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	100.5	92.5	114.1	138.4	156.0	172.6	138.8	138.9	106.9	127.5	100.9	104.2	1,491.2
Max Month Data w/ Losses	183.2	182.1	153.7	312.9	242.7	300.2	200.9	233.7	164.1	191.7	182.4	149.9	2,497.6
Max Month Data w/ WC and Losses	169.0	169.3	139.5	299.1	226.2	284.3	184.4	217.3	148.2	175.3	168.7	135.7	2,317.0

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		15,000							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	123.8	114.0	140.5	170.5	192.1	212.6	171.0	171.1	131.7	157.1	124.3	128.4	1,837.1
Max Month Data w/ Losses	225.7	224.4	189.4	385.4	299.0	369.8	247.5	287.9	202.2	236.2	224.7	184.7	3,076.9
Max Month Data w/ WC and Losses	208.2	208.6	171.9	368.5	278.7	350.2	227.2	267.7	182.5	215.9	207.8	167.2	2,854.4

Annual Water Demand Shortages (acre-feet) =				Annual Permitted Allocation =			1,712 Ac-ft					**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Max Month Data w/ WC and Losses (gpc/d)	25.4	25.6	0.0	155.5	82.6	140.6	40.8	73.6	4.5	31.6	25.0	0.0	605.1

Annual Water Demand Shortages (acre-feet) =				Annual Permitted Allocation =			1,712 Ac-ft					**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Max Month Data w/ WC and Losses (gpc/d)	64.6	64.9	32.4	224.8	135.1	206.5	83.5	124.0	38.9	72.3	64.1	31.5	1,142.5

Gwinner Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses	Estimated Monthly Water Losses	Annual Per Capita Use
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total		(%)	(10^6-gals)	(gpc/d)
1991	4.8	4.3	5.0	6.1	6.3	8.8	9.1	7.0	6.2	8.1	5.5	4.8	76	598	28.9%	1.8	347.4
1992	5.9	4.7	4.9	5.5	5.9	6.3	6.6	7.5	5.9	5.5	4.7	5.2	68	611	30.0%	1.7	306.6
1993	4.8	5.4	5.2	5.5	6.1	6.0	5.7	6.5	6.5	6.1	4.8	5.0	68	625	30.3%	1.7	296.5
1994	5.1	5.0	6.1	6.4	7.5	7.7	6.7	7.1	6.2	5.9	5.1	4.7	73	638	32.1%	2.0	315.4
1995	4.9	4.6	5.6	4.8	7.5	8.0	7.4	8.6	7.2	7.3	6.4	6.0	78	651	28.9%	1.9	329.1
1996	6.2	6.5	6.9	6.8	7.9	9.6	9.4	8.9	7.5	6.5	6.0	5.2	87	664	22.9%	1.7	360.0
1997	6.1	5.5	6.0	5.4	6.6	7.9	7.1	6.8	7.9	6.1	5.2	5.1	76	677	23.2%	1.5	306.9
1998	4.7	5.4	5.6	6.1	6.9	6.6	7.6	7.7	6.5	5.4	4.2	4.9	71	691	23.8%	1.4	283.5
1999	4.6	4.5	5.6	5.4	6.2	7.1	7.1	7.8	5.3	5.4	5.1	5.1	69	704	25.6%	1.5	270.1
2000	5.1	5.4	6.2	5.0	7.3	7.0	7.5	9.3	7.0	6.3	5.5	4.8	76	717	29.7%	1.9	292.0
2001	5.4	4.8	5.2	5.2	7.0	7.1	7.3	7.6	5.4	5.0	4.6	4.1	68	730	27.6%	1.6	257.0
Average	5.2	5.1	5.7	5.6	6.8	7.5	7.4	7.7	6.5	6.1	5.2	5.0	74		27.5%		305.9

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use	High Monthly Water Use	Monthly High Per Capita Use
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total		(gpc/d)	(10^6-gals)	(gpc/d)
1991	2.9	2.4	3.2	4.3	4.5	6.9	7.3	5.2	4.4	6.2	3.6	3.0	54	598	247	7.3	406
1992	4.2	3.0	3.2	3.8	4.2	4.6	4.9	5.8	4.2	3.8	2.9	3.4	48	611	215	5.8	314
1993	3.1	3.7	3.5	3.8	4.4	4.3	4.0	4.8	4.8	4.4	3.1	3.3	47	625	207	4.8	258
1994	3.2	3.0	4.1	4.4	5.6	5.7	4.7	5.1	4.3	3.9	3.1	2.7	50	638	214	5.7	299
1995	3.0	2.7	3.7	2.9	5.6	6.1	5.6	6.7	5.3	5.4	4.6	4.1	56	651	234	6.7	343
1996	4.5	4.8	5.3	5.1	6.2	7.9	7.7	7.2	5.8	4.8	4.4	3.5	67	664	278	7.9	396
1997	4.6	4.1	4.6	3.9	5.2	6.4	5.7	5.3	6.5	4.6	3.8	3.7	58	677	236	6.5	318
1998	3.3	3.9	4.2	4.7	5.5	5.2	6.2	6.3	5.0	4.0	2.7	3.4	54	691	216	6.3	304
1999	3.1	3.1	4.2	3.9	4.8	5.7	5.6	6.3	3.8	3.9	3.6	3.6	52	704	201	6.3	299
2000	3.2	3.5	4.3	3.1	5.4	5.1	5.6	7.4	5.1	4.4	3.6	2.9	54	717	205	7.4	345
2001	3.8	3.2	3.6	3.6	5.4	5.5	5.7	6.0	3.9	3.4	3.0	2.5	50	730	186	6.0	273
Average	3.5	3.4	4.0	3.9	5.2	5.8	5.7	6.0	4.8	4.5	3.5	3.3	54		221.7	6.4	323.1
% Distrib.	6.6%	6.3%	7.4%	7.4%	9.6%	10.8%	10.7%	11.2%	9.0%	8.3%	6.5%	6.1%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
#REF!	N/A				
#REF!	N/A				
#REF!	N/A				
1991	N/A				
1992	N/A				
1993	N/A				
1994	N/A				
1995	N/A				
1996	N/A				
1997	N/A				
1998	N/A				
1999	N/A				
2000	N/A				
2001	300,000	51,709	248,291	340	1.53
Average	300,000	51,709	248,291	340	1.53

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses)	340.0
W. Conservation Reduction =	9.5
Subtotal =	330.6
Peak Daily Demand with WC and	
Water Losses =	456.2
Peak Daily Demand Factor with WC	
and Water Losses =	1.55

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		(gpc/d)
1991	158	145	173	237	241	387	393	278	245	336	202	162	598	247.1
1992	222	175	167	205	221	250	259	303	230	199	160	182	611	214.8
1993	158	209	181	202	226	230	207	249	256	229	164	171	625	206.8
1994	160	168	209	229	282	299	239	258	224	198	162	136	638	214.0
1995	150	146	184	148	276	314	276	332	270	269	233	202	651	233.9
1996	220	259	255	256	302	396	375	352	291	234	219	172	664	277.5
1997	219	214	218	193	247	317	270	255	318	220	185	175	677	235.8
1998	154	204	196	225	258	249	289	295	243	186	132	161	691	216.1
1999	143	155	191	184	218	268	259	290	181	180	172	164	704	200.9
2000	146	175	192	144	244	239	251	334	238	199	166	130	717	205.3
2001	168	158	158	165	238	251	252	264	176	151	137	111	730	186.1
Average	173	183	193	199	250	291	279	292	243	218	176	161		221.7

Maximum historic water use month = 396 gpc/d

Gwinner Water Demand Calculations
Maximum Month Method

With Industry | Without Industry

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1991	158	145	173	237	241	387	393	278	245	336	202	162	598	180	313
1992	222	175	167	205	221	250	259	303	230	199	160	182	611	185	244
1993	158	209	181	202	226	230	207	249	256	229	164	171	625	181	233
1994	160	168	209	229	282	299	239	258	224	198	162	136	638	178	250
1995	150	146	184	148	276	314	276	332	270	269	233	202	651	177	290
1996	220	259	255	256	302	396	375	352	291	234	219	172	664	230	325
1997	219	214	218	193	247	317	270	255	318	220	185	175	677	201	271
1998	154	204	196	225	258	249	289	295	243	186	132	161	691	179	253
1999	143	155	191	184	218	268	259	290	181	180	172	164	704	168	233
2000	146	175	192	144	244	239	251	334	238	199	166	130	717	159	251
2001	168	158	158	165	238	251	252	264	176	151	137	111	730	150	222
Average	173	183	193	199	250	291	279	292	243	218	176	161		181	262

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	230
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	396
Estimated Water Losses (%) =	28%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	173	183	193	199	250	291	279	292	243	218	176	161	221.7
Average Monthly Demand w/ WC (gpc/d)	164	174	185	191	241	281	270	282	233	209	168	152	212.9
Average Monthly Demand w/ WC and Losses (gpc/d)	**227**	**241**	**255**	**263**	**332**	**388**	**372**	**390**	**322**	**288**	**231**	**210**	**293.7**
Max Month Data w/o Losses (gpc/d)	222	259	255	256	302	396	393	352	318	336	233	202	293.8
Max Month Data w/ Losses (gpc/d)	**306**	**358**	**352**	**353**	**416**	**546**	**542**	**486**	**438**	**464**	**322**	**278**	**405.5**
Max Month Data w/ WC (gpc/d)	214	251	247	248	292	386	384	343	308	326	225	194	285.0
Max Month Data w/ WC and Losses (gpc/d)	**295**	**347**	**341**	**342**	**403**	**533**	**529**	**473**	**425**	**450**	**311**	**267**	**393.3**

Water Losses = 27.5%

[2] Water conservation and summer drought contingency water savings is included in the design demand w/o losses

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		1,170							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	25.3	24.2	28.4	28.4	37.0	41.8	41.4	43.4	34.7	32.1	24.9	23.4	385.0
Max Month Data w/ Losses (gpc/d)	34.1	36.0	39.2	38.0	46.4	58.9	60.4	54.1	47.2	51.6	34.7	31.0	531.5
Max Month Data w/ WC and Losses (gpc/d)	32.8	34.9	38.0	36.8	44.9	57.5	58.9	52.6	45.8	50.1	33.5	29.7	515.5

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		1,254							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	27.1	25.9	30.5	30.4	39.7	44.8	44.4	46.5	37.2	34.4	26.7	25.1	412.6
Max Month Data w/ Losses (gpc/d)	36.5	38.6	42.0	40.7	49.7	63.1	64.7	58.0	50.6	55.3	37.2	33.2	569.6
Max Month Data w/ WC and Losses (gpc/d)	35.2	37.4	40.7	39.4	48.1	61.6	63.2	56.4	49.1	53.7	35.9	31.9	552.5

Hankinson Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	3.9	3.6	3.9	4.0	4.5	5.0	5.3	5.6	4.6	4.2	3.9	3.9	52	1,034	0.0%	0.0	138.3
1989	3.4	3.1	3.5	3.5	3.9	4.4	4.6	4.9	4.0	3.7	3.4	3.4	46	1,036	0.0%	0.0	121.8
1990	3.7	3.4	3.8	3.8	4.3	4.8	5.1	5.4	4.4	4.1	3.7	3.7	50	1,038	0.0%	0.0	132.4
1991	3.0	2.8	3.1	3.1	3.5	3.9	4.1	4.4	3.6	3.3	3.0	3.0	41	1,040	0.0%	0.0	107.8
1992	3.2	2.9	3.2	3.2	3.6	4.1	4.3	4.6	3.7	3.5	3.1	3.2	43	1,042	0.0%	0.0	111.8
1993	2.8	2.6	2.9	2.9	3.3	3.6	3.8	4.1	3.3	3.1	2.8	2.8	38	1,044	0.0%	0.0	99.9
1994	3.8	3.5	3.9	3.9	4.4	4.9	5.2	5.5	4.5	4.2	3.8	3.8	51	1,046	0.0%	0.0	134.5
1995	4.1	3.7	4.1	4.2	4.7	5.2	5.5	5.8	4.8	4.4	4.0	4.1	55	1,048	0.0%	0.0	142.8
1996	4.6	4.2	4.6	4.7	5.3	5.9	6.2	6.6	5.4	5.0	4.5	4.6	62	1,050	0.0%	0.0	160.8
1997	3.4	3.2	3.5	3.5	4.0	4.4	4.7	4.9	4.1	3.8	3.4	3.4	46	1,052	0.0%	0.0	120.3
1998	3.7	3.4	3.7	3.8	4.3	4.8	5.0	5.3	4.4	4.0	3.7	3.7	50	1,054	0.0%	0.0	129.5
1999	3.4	3.2	3.5	3.5	3.9	4.4	4.7	4.9	4.0	3.7	3.4	3.4	46	1,056	0.0%	0.0	119.7
2000	4.0	3.7	4.0	4.1	4.6	5.1	5.4	5.7	4.7	4.4	4.0	4.0	54	1,058	0.0%	0.0	138.9
2001	3.5	3.2	3.5	3.6	4.0	4.5	4.7	5.0	4.1	3.8	3.5	3.5	47	1,060	0.0%	0.0	121.4
Average	3.6	3.3	3.6	3.7	4.2	4.6	4.9	5.2	4.3	3.9	3.6	3.6	49		0.0%		127.1

1 Water loss data was not available so zero% was assumed in analysis

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	3.9	3.6	3.9	4.0	4.5	5.0	5.3	5.6	4.6	4.2	3.9	3.9	52	1,034	138	5.6	180
1989	3.4	3.1	3.5	3.5	3.9	4.4	4.6	4.9	4.0	3.7	3.4	3.4	46	1,036	122	4.9	159
1990	3.7	3.4	3.8	3.8	4.3	4.8	5.1	5.4	4.4	4.1	3.7	3.7	50	1,038	132	5.4	172
1991	3.0	2.8	3.1	3.1	3.5	3.9	4.1	4.4	3.6	3.3	3.0	3.0	41	1,040	108	4.4	140
1992	3.2	2.9	3.2	3.2	3.6	4.1	4.3	4.6	3.7	3.5	3.1	3.2	43	1,042	112	4.6	146
1993	2.8	2.6	2.9	2.9	3.3	3.6	3.8	4.1	3.3	3.1	2.8	2.8	38	1,044	100	4.1	130
1994	3.8	3.5	3.9	3.9	4.4	4.9	5.2	5.5	4.5	4.2	3.8	3.8	51	1,046	134	5.5	175
1995	4.1	3.7	4.1	4.2	4.7	5.2	5.5	5.8	4.8	4.4	4.0	4.1	55	1,048	143	5.8	186
1996	4.6	4.2	4.6	4.7	5.3	5.9	6.2	6.6	5.4	5.0	4.5	4.6	62	1,050	161	6.6	209
1997	3.4	3.2	3.5	3.5	4.0	4.4	4.7	4.9	4.1	3.8	3.4	3.4	46	1,052	120	4.9	157
1998	3.7	3.4	3.7	3.8	4.3	4.8	5.0	5.3	4.4	4.0	3.7	3.7	50	1,054	129	5.3	169
1999	3.4	3.2	3.5	3.5	3.9	4.4	4.7	4.9	4.0	3.7	3.4	3.4	46	1,056	120	4.9	156
2000	4.0	3.7	4.0	4.1	4.6	5.1	5.4	5.7	4.7	4.4	4.0	4.0	54	1,058	139	5.7	181
2001	3.5	3.2	3.5	3.6	4.0	4.5	4.7	5.0	4.1	3.8	3.5	3.5	47	1,060	121	5.0	158
Average	3.6	3.3	3.6	3.7	4.2	4.6	4.9	5.2	4.3	3.9	3.6	3.6	49		127.1	5.2	165.5
% Distrib.	7.4%	6.8%	7.5%	7.6%	8.6%	9.5%	10.1%	10.7%	8.8%	8.1%	7.4%	7.4%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
Average	0	0	0	0	0.00

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	
W. Conservation Reduction =	
Subtotal =	
Peak Daily Demand with WC and Water Losses =	
Peak Daily Demand Factor with WC and Water Losses =	

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	121	123	122	128	139	160	164	174	148	132	124	121	1,034	138.3
1989	106	109	108	113	123	141	145	153	130	116	109	107	1,036	121.8
1990	116	118	117	123	133	154	157	167	141	127	119	116	1,038	132.4
1991	94	96	95	100	109	125	128	136	115	103	97	95	1,040	107.8
1992	98	100	99	104	113	130	133	141	119	107	100	98	1,042	111.8
1993	87	89	88	93	101	116	119	126	107	96	90	88	1,044	99.9
1994	118	120	119	125	135	156	160	169	144	129	121	118	1,046	134.5
1995	125	127	126	132	144	166	170	180	152	137	128	125	1,048	142.8
1996	141	143	142	149	162	187	191	203	172	154	144	141	1,050	160.8
1997	105	107	106	112	121	140	143	152	128	115	108	105	1,052	120.3
1998	113	115	114	120	130	150	154	163	138	124	116	114	1,054	129.5
1999	105	107	106	111	121	139	142	151	128	114	108	105	1,056	119.7
2000	121	124	123	129	140	161	165	175	148	133	125	122	1,058	138.9
2001	106	108	107	113	122	141	144	153	130	116	109	106	1,060	121.4
Average	111	113	112	118	128	147	151	160	136	122	114	111		127.1

Hankinson Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	121	123	122	128	139	160	164	174	148	132	124	121	1,034	123	153
1989	106	109	108	113	123	141	145	153	130	116	109	107	1,036	109	135
1990	116	118	117	123	133	154	157	167	141	127	119	116	1,038	118	147
1991	94	96	95	100	109	125	128	136	115	103	97	95	1,040	96	119
1992	98	100	99	104	113	130	133	141	119	107	100	98	1,042	100	124
1993	87	89	88	93	101	116	119	126	107	96	90	88	1,044	89	111
1994	118	120	119	125	135	156	160	169	144	129	121	118	1,046	120	149
1995	125	127	126	132	144	166	170	180	152	137	128	125	1,048	127	158
1996	141	143	142	149	162	187	191	203	172	154	144	141	1,050	143	178
1997	105	107	106	112	121	140	143	152	128	115	108	105	1,052	107	133
1998	113	115	114	120	130	150	154	163	138	124	116	114	1,054	116	143
1999	105	107	106	111	121	139	142	151	128	114	108	105	1,056	107	132
2000	121	124	123	129	140	161	165	175	148	133	125	122	1,058	124	154
2001	106	108	107	113	122	141	144	153	130	116	109	106	1,060	108	134
Average	111	113	112	118	128	147	151	160	136	122	114	111		113.4	141

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	143
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	203
Estimated Water Losses (%) =	0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	111	113	112	118	128	147	151	160	136	122	114	111	127.1
Average Monthly Demand w/ WC (gpc/d)	103	105	104	110	119	138	142	151	126	112	106	103	118.3
Average Monthly Demand w/ WC and Losses (gpc/d)	**103**	**105**	**104**	**110**	**119**	**138**	**142**	**151**	**126**	**112**	**106**	**103**	**118.3**
Max Month Data w/o Losses (gpc/d)	141	143	142	149	162	187	191	203	172	154	144	141	160.8
Max Month Data w/ Losses (gpc/d)	**141**	**143**	**142**	**149**	**162**	**187**	**191**	**203**	**172**	**154**	**144**	**141**	**160.8**
Max Month Data w/ WC (gpc/d)	132	135	134	141	152	177	182	193	162	144	136	133	152.0
Max Month Data w/ WC and Losses (gpc/d)	**132**	**135**	**134**	**141**	**152**	**177**	**182**	**193**	**162**	**144**	**136**	**133**	**152.0**

Water Losses = 0.0%

[2] Water conservation and summer drought contingency water savings is included in the design demand w/o losses

Annual Water Needs (acre-feet) =			2050 Population =		970								**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	9.5	8.8	9.6	9.8	10.9	12.3	13.1	13.9	11.3	10.3	9.5	9.5	129
Max Month Data w/ Losses	13.0	12.0	13.1	13.3	14.9	16.7	17.6	18.7	15.3	14.2	12.9	13.0	175
Max Month Data w/ WC and Losses	12.2	11.3	12.4	12.6	14.1	15.8	16.8	17.8	14.5	13.3	12.2	12.3	165

Harwood Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1995	0.8	1.0	1.1	1.1	1.2	1.7	1.3	1.3	1.5	1.2	1.2	1.0	14.5	597	0.0%	0.0	66.4
1996	1.4	1.2	1.4	1.2	1.3	1.8	1.5	1.5	1.0	1.3	1.3	1.2	15.9	599	0.0%	0.0	72.7
1997	1.1	0.8	1.1	1.1	1.4	1.8	1.1	1.2	1.0	0.9	1.0	1.1	13.6	601	0.0%	0.0	62.1
1998	1.0	1.0	1.0	1.1	1.0	1.1	1.6	1.5	1.4	1.4	1.2	1.0	14.3	603	0.0%	0.0	64.9
1999	0.9	1.2	1.2	1.0	1.2	1.3	1.4	1.5	1.1	1.3	1.1	1.1	14.4	605	0.0%	0.0	65.2
2000	1.1	1.0	1.1	1.2	1.3	1.6	1.4	1.4	1.0	1.1	1.0	1.1	14.2	607	0.0%	0.0	64.0
2001	1.1	1.0	1.1	1.0	1.4	1.7	1.5	1.2	1.3	1.1	1.1	1.0	14.5	609	0.0%	0.0	65.2
Average	1.1	1.0	1.1	1.1	1.2	1.6	1.4	1.4	1.2	1.2	1.1	1.1	14.5		0.0%		65.8

[1] Unaccounted for losses data was not available but Drayton estimates 11% annual losses

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1995	0.8	1.0	1.1	1.1	1.2	1.7	1.3	1.3	1.5	1.2	1.2	1.0	14.5	597	66	1.7	94
1996	1.4	1.2	1.4	1.2	1.3	1.8	1.5	1.5	1.0	1.3	1.3	1.2	15.9	599	73	1.8	101
1997	1.1	0.8	1.1	1.1	1.4	1.8	1.1	1.2	1.0	0.9	1.0	1.1	13.6	601	62	1.8	101
1998	1.0	1.0	1.0	1.1	1.0	1.1	1.6	1.5	1.4	1.4	1.2	1.0	14.3	603	65	1.6	86
1999	0.9	1.2	1.2	1.0	1.2	1.3	1.4	1.5	1.1	1.3	1.1	1.1	14.4	605	65	1.5	83
2000	1.1	1.0	1.1	1.2	1.3	1.6	1.4	1.4	1.0	1.1	1.0	1.1	14.2	607	64	1.6	86
2001	1.1	1.0	1.1	1.0	1.4	1.7	1.5	1.2	1.3	1.1	1.1	1.0	14.5	609	65	1.7	94
Average	1.1	1.0	1.1	1.1	1.2	1.6	1.4	1.4	1.2	1.2	1.1	1.1	14.5		65.8	1.7	92.1
% Distrib.	7.3%	7.2%	7.9%	7.6%	8.6%	10.9%	9.5%	9.5%	8.3%	8.2%	7.7%	7.4%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	N/A				
1989	N/A				
1990	N/A				
1991	N/A				
1992	N/A				
1993	N/A				
1994	N/A				
1995	N/A				
1996	N/A				
1997	N/A				
1998	N/A				
1999	N/A				
2000	N/A				
2001	N/A				
Average					

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	
W. Conservation Reduction =	
Subtotal =	
Peak Daily Demand with WC and Water Losses =	
Peak Daily Demand Factor with WC and Water Losses =	

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1995	45	60	62	59	65	94	70	71	86	65	65	55	597	66.4
1996	73	70	73	68	68	101	80	80	58	68	71	63	599	72.7
1997	59	49	57	59	75	101	59	64	57	49	55	61	601	62.1
1998	53	60	55	61	55	62	83	80	76	75	66	52	603	64.9
1999	48	74	66	55	63	70	75	81	61	70	60	60	605	65.2
2000	57	58	59	66	67	86	73	75	55	59	55	59	607	64.0
2001	59	60	59	55	72	94	77	65	71	57	63	52	609	65.2
Average	56	61	62	61	66	87	74	74	67	63	62	57		65.8

Harwood Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use	Summer Per Capita Use
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		(gpc/d)	(gpc/d)
1995	45	60	62	59	65	94	70	71	86	65	65	55	597	58	75
1996	73	70	73	68	68	101	80	80	58	68	71	63	599	70	76
1997	59	49	57	59	75	101	59	64	57	49	55	61	601	57	67
1998	53	60	55	61	55	62	83	80	76	75	66	52	603	58	72
1999	48	74	66	55	63	70	75	81	61	70	60	60	605	60	70
2000	57	58	59	66	67	86	73	75	55	59	55	59	607	59	69
2001	59	60	59	55	72	94	77	65	71	57	63	52	609	58	72
Average	56	61	62	61	66	87	74	74	67	63	62	57		60	72

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	70
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	101
Estimated Water Losses (%) =	0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	56	61	62	61	66	87	74	74	67	63	62	57	65.8
Average Monthly Demand w WC (gpc/d)	48	53	53	52	57	77	64	64	57	54	54	49	57.0
Average Monthly Demand w/ WC and Losses (gpc/d)	**48**	**53**	**53**	**52**	**57**	**77**	**64**	**64**	**57**	**54**	**54**	**49**	**57.0**
Max Month Data w/o Losses (gpc/d)	73	74	73	68	75	101	83	81	86	75	71	63	76.8
Max Month Data w/ Losses (gpc/d)	**73**	**74**	**73**	**68**	**75**	**101**	**83**	**81**	**86**	**75**	**71**	**63**	**76.8**
Max Month Data w/ WC (gpc/d)	65	65	65	60	65	92	74	71	77	66	62	54	68.0
Max Month Data w/ WC and Losses (gpc/d)	**65**	**65**	**65**	**60**	**65**	**92**	**74**	**71**	**77**	**66**	**62**	**54**	**68.0**

Water Losses = 0.0%

Annual Water Needs (acre-feet) =			2050 Population =	1,120									**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses (gpc/d)	5.1	5.1	5.7	5.4	6.1	8.0	6.9	6.8	5.9	5.7	5.5	5.2	71.5
Max Month Data w/ Losses (gpc/d)	7.8	7.1	7.8	7.0	8.0	10.4	8.9	8.6	8.9	8.0	7.3	6.7	96.4
Max Month Data w/ WC and Losses (gpc/d)	7.0	6.3	7.0	6.2	6.9	9.4	7.8	7.6	7.9	7.0	6.4	5.8	85.4

Hillsboro Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	5.4	5.0	5.4	5.9	7.7	10.0	10.0	8.0	7.5	6.9	5.7	5.9	83	1,488	7.5%	0.5	153
1989	6.0	5.2	5.3	5.0	5.9	7.4	9.3	7.8	4.8	5.3	4.4	5.0	72	1,485	7.5%	0.4	132
1990	4.9	4.1	4.7	5.2	6.1	5.9	8.0	7.9	5.7	6.4	4.9	5.0	69	1,482	7.5%	0.4	127
1991	4.9	4.4	5.5	5.9	7.4	7.8	9.2	10.1	8.9	7.5	2.0	5.4	79	1,479	7.5%	0.5	146
1992	5.1	4.8	5.0	5.1	7.1	6.8	6.3	7.1	6.1	5.7	5.2	5.2	70	1,476	7.5%	0.4	129
1993	5.3	5.0	5.1	5.6	6.2	6.4	6.2	6.3	6.3	6.1	5.5	5.1	69	1,473	7.5%	0.4	128
1994	5.2	5.5	5.5	5.9	6.1	7.5	5.9	5.0	5.0	4.6	4.1	4.3	64	1,470	7.5%	0.4	120
1995	4.3	3.9	4.4	4.7	4.6	5.8	5.4	6.1	5.0	4.7	4.0	4.1	57	1,467	7.5%	0.4	107
1996	4.5	4.4	4.9	4.8	5.1	6.2	6.2	6.2	6.1	5.8	4.8	5.0	64	1,462	14.4%	0.8	120
1997	6.5	5.4	6.0	6.1	6.5	7.6	6.1	6.2	5.6	5.7	4.8	4.9	71	1,487	7.8%	0.5	132
1998	4.6	4.5	5.0	5.8	6.2	6.1	6.8	6.9	5.6	4.8	4.5	4.7	65	1,512	6.3%	0.3	119
1999	4.7	4.3	5.0	5.3	5.4	6.8	5.9	6.2	5.9	5.3	4.7	5.1	65	1,537	3.6%	0.2	115
2000	5.7	5.0	5.7	6.3	6.6	6.7	7.0	7.2	6.4	6.1	5.6	5.7	74	1,563	9.3%	0.6	130
2001	4.9	4.2	4.9	4.8	5.6	6.3	6.2	6.0	5.0	5.7	4.8	4.9	63	1,588	3.8%	0.2	109
Average	5.1	4.7	5.2	5.5	6.2	6.9	7.0	6.9	6.0	5.8	4.6	5.0	69		7.5%		126.3

[1] Water loss data was not available from 1988 - 1995 so the average from 1996 - 2001 was used (7.5%)

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	4.8	4.4	4.9	5.3	7.1	9.5	9.5	7.5	7.0	6.4	5.2	5.4	77	1,488	142	9.5	213
1989	5.5	4.8	4.9	4.6	5.5	6.9	8.9	7.4	4.3	4.9	4.0	4.6	66	1,485	122	8.9	200
1990	4.5	3.7	4.3	4.8	5.6	5.5	7.6	7.5	5.2	6.0	4.4	4.6	64	1,482	118	7.6	171
1991	4.4	3.9	5.0	5.4	6.9	7.3	8.7	9.6	8.4	7.0	1.5	4.9	73	1,479	135	9.6	217
1992	4.7	4.4	4.5	4.7	6.7	6.4	5.9	6.7	5.7	5.3	4.8	4.8	65	1,476	120	6.7	152
1993	4.9	4.6	4.7	5.1	5.7	6.0	5.7	5.8	5.8	5.7	5.0	4.6	64	1,473	119	6.0	136
1994	4.8	5.1	5.1	5.5	5.6	7.1	5.5	4.6	4.6	4.2	3.7	3.9	60	1,470	111	7.1	160
1995	3.9	3.6	4.1	4.4	4.3	5.4	5.1	5.8	4.6	4.3	3.7	3.7	53	1,467	99	5.8	131
1996	3.7	3.7	4.1	4.1	4.3	5.4	5.4	5.4	5.3	5.1	4.1	4.3	55	1,462	103	5.4	124
1997	6.1	5.0	5.5	5.7	6.0	7.1	5.7	5.8	5.1	5.2	4.3	4.4	66	1,487	121	7.1	159
1998	4.3	4.1	4.7	5.4	5.9	5.7	6.4	6.6	5.2	4.5	4.1	4.4	61	1,512	111	6.6	146
1999	4.5	4.2	4.8	5.1	5.2	6.6	5.7	6.0	5.7	5.1	4.5	4.9	62	1,537	111	6.6	142
2000	5.1	4.4	5.1	5.8	6.1	6.1	6.4	6.6	5.8	5.6	5.0	5.1	67	1,563	118	6.6	140
2001	4.7	4.0	4.7	4.6	5.4	6.1	6.0	5.8	4.8	5.5	4.6	4.7	61	1,588	105	6.1	128
Average	4.7	4.3	4.7	5.0	5.7	6.5	6.6	6.5	5.5	5.3	4.2	4.6	64		116.7	7.1	158.4
% Distrib.	7.4%	6.7%	7.4%	7.9%	9.0%	10.2%	10.4%	10.2%	8.7%	8.3%	6.6%	7.2%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990	421,110	14,188	406,922	275	2.35
1991	477,100	16,258	460,842	312	2.67
1992	360,300	14,366	345,934	234	2.01
1993	322,100	14,214	307,886	209	1.79
1994	399,600	13,277	386,323	263	2.25
1995	315,800	11,760	304,040	207	1.78
1996	472,000	25,346	446,654	306	2.62
1997	335,300	15,216	320,084	215	1.84
1998	391,000	11,256	379,744	251	2.15
1999	300,000	6,342	293,658	191	1.64
2000	357,700	18,787	338,913	217	1.86
2001	347,700	6,508	341,192	215	1.84
Average	374,976	13,960	361,016	241	2.07

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	311.6
W. Conservation Reduction =	9.6
Subtotal =	302.0
Peak Daily Demand with WC and	
Water Losses =	335.6
Peak Daily Demand Factor with WC	
and Water Losses =	2.80

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	105	107	107	120	155	213	205	162	156	138	116	117	1,488	141.9
1989	120	115	106	102	119	156	193	160	97	106	89	100	1,485	122.1
1990	97	89	93	108	123	123	166	163	118	130	100	100	1,482	117.8
1991	96	94	108	121	151	164	189	210	189	152	35	108	1,479	135.2
1992	102	106	99	106	146	144	129	147	129	116	108	105	1,476	119.7
1993	107	111	103	116	125	136	126	128	132	124	114	102	1,473	118.7
1994	104	124	111	124	124	160	121	100	104	92	84	86	1,470	111.1
1995	86	87	90	99	94	123	112	127	105	95	83	81	1,467	98.6
1996	82	90	91	93	95	123	119	120	121	112	92	94	1,462	102.7
1997	132	120	120	127	130	159	123	125	114	113	97	96	1,487	121.3
1998	91	98	100	119	125	126	137	141	115	95	91	93	1,512	111.2
1999	95	97	100	110	110	142	120	125	124	107	98	103	1,537	111.0
2000	105	101	106	123	125	131	132	136	124	115	106	105	1,563	117.6
2001	95	91	95	97	109	128	122	117	101	111	97	95	1,588	104.9
Average	101	102	102	112	124	145	143	140	124	115	94	99		116.7

Hillsboro Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter =   **Summer =**

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	105	107	107	120	155	213	205	162	156	138	116	117	1,488	112	172
1989	120	115	106	102	119	156	193	160	97	106	89	100	1,485	105	138
1990	97	89	93	108	123	123	166	163	118	130	100	100	1,482	98	137
1991	96	94	108	121	151	164	189	210	189	152	35	108	1,479	94	176
1992	102	106	99	106	146	144	129	147	129	116	108	105	1,476	104	135
1993	107	111	103	116	125	136	126	128	132	124	114	102	1,473	109	129
1994	104	124	111	124	124	160	121	100	104	92	84	86	1,470	106	117
1995	86	87	90	99	94	123	112	127	105	95	83	81	1,467	88	109
1996	82	90	91	93	95	123	119	120	121	112	92	94	1,462	90	115
1997	132	120	120	127	130	159	123	125	114	113	97	96	1,487	115	128
1998	91	98	100	119	125	126	137	141	115	95	91	93	1,512	99	123
1999	95	97	100	110	110	142	120	125	124	107	98	103	1,537	101	121
2000	105	101	106	123	125	131	132	136	124	115	106	105	1,563	108	127
2001	95	91	95	97	109	128	122	117	101	111	97	95	1,588	95	115
Average	101	102	102	112	124	145	143	140	124	115	94	99		101.6	132

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	112
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	213
Estimated Water Losses (%) =	10%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/ Losses (gpc/d)	101	102	102	112	124	145	143	140	124	115	94	99	116.7
Average Monthly Demand w/ WC (gpc/d)	93	94	94	103	114	135	133	131	114	105	85	90	107.7
Average Monthly Demand w/ WC and Losses (gpc/d)	**103**	**104**	**104**	**115**	**127**	**150**	**148**	**145**	**127**	**117**	**95**	**101**	**119.6**
Max Month Data w/o Losses (gpc/d)	132	124	120	127	155	213	205	210	189	152	116	117	155.1
Max Month Data w/ Losses (gpc/d)	**146**	**138**	**133**	**141**	**172**	**236**	**228**	**233**	**210**	**169**	**129**	**130**	**172.3**
Max Month Data w/ WC (gpc/d)	123	116	111	119	145	203	196	200	179	143	107	109	146.1
Max Month Data w/ WC and Losses (gpc/d)	**137**	**129**	**123**	**132**	**161**	**226**	**218**	**222**	**199**	**159**	**119**	**121**	**162.3**

Water Losses = 10.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		1,930							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	19	17	19	20	23	27	27	27	22	21	17	18	259
Max Month Data w/ Losses	27	23	24	25	32	42	42	43	37	31	23	24	373
Max Month Data w/ WC and Losses	25	21	23	23	30	40	40	41	35	29	21	22	351

Horace Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	1.4	1.2	1.4	1.4	1.8	1.9	2.1	2.3	1.6	1.6	1.4	1.4	19	611	0.0%	0.0	87.2
1989	1.3	1.2	1.3	1.4	1.7	1.8	2.0	2.2	1.6	1.5	1.4	1.3	19	637	0.0%	0.0	80.9
1990	1.2	1.1	1.2	1.2	1.5	1.6	1.8	2.0	1.4	1.4	1.2	1.2	17	662	0.0%	0.0	69.6
1991	1.2	1.1	1.2	1.3	1.6	1.7	1.9	2.0	1.5	1.4	1.3	1.2	17	687	0.0%	0.0	69.6
1992	1.3	1.2	1.3	1.4	1.7	1.8	2.0	2.2	1.6	1.5	1.4	1.3	19	713	0.0%	0.0	72.4
1993	1.4	1.3	1.4	1.5	1.8	2.0	2.2	2.3	1.7	1.6	1.5	1.4	20	738	0.0%	0.0	74.2
1994	1.7	1.5	1.7	1.8	2.2	2.4	2.7	2.9	2.1	2.0	1.8	1.7	25	763	0.0%	0.0	88.0
1995	1.6	1.4	1.6	1.7	2.1	2.2	2.5	2.7	1.9	1.8	1.7	1.6	23	789	0.0%	0.0	79.4
1996	1.7	1.6	1.8	1.8	2.3	2.4	2.7	2.9	2.1	2.0	1.8	1.8	25	814	0.0%	0.0	83.7
1997	1.7	1.5	1.7	1.8	2.2	2.4	2.7	2.9	2.1	2.0	1.8	1.7	25	839	0.0%	0.0	80.2
1998	1.8	1.6	1.8	1.9	2.3	2.5	2.8	3.0	2.1	2.1	1.9	1.8	26	864	0.0%	0.0	80.9
1999	1.8	1.6	1.8	1.8	2.3	2.5	2.8	3.0	2.1	2.0	1.9	1.8	25	890	0.0%	0.0	78.3
2000	2.0	1.8	2.0	2.1	2.6	2.8	3.2	3.4	2.4	2.3	2.1	2.1	29	915	0.0%	0.0	87.0
2001	2.0	1.8	2.0	2.0	2.6	2.7	3.0	3.3	2.4	2.3	2.0	2.0	28	940	0.0%	0.0	81.5
Average	1.6	1.4	1.6	1.6	2.1	2.2	2.5	2.6	1.9	1.8	1.7	1.6	23		0.0%		79.5

1 Water loss data was not available so zero% was assumed in analysis

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	1.4	1.2	1.4	1.4	1.8	1.9	2.1	2.3	1.6	1.6	1.4	1.4	19	611	87	2.3	124
1989	1.3	1.2	1.3	1.4	1.7	1.8	2.0	2.2	1.6	1.5	1.4	1.3	19	637	81	2.2	115
1990	1.2	1.1	1.2	1.2	1.5	1.6	1.8	2.0	1.4	1.4	1.2	1.2	17	662	70	2.0	99
1991	1.2	1.1	1.2	1.3	1.6	1.7	1.9	2.0	1.5	1.4	1.3	1.2	17	687	70	2.0	99
1992	1.3	1.2	1.3	1.4	1.7	1.8	2.0	2.2	1.6	1.5	1.4	1.3	19	713	72	2.2	103
1993	1.4	1.3	1.4	1.5	1.8	2.0	2.2	2.3	1.7	1.6	1.5	1.4	20	738	74	2.3	106
1994	1.7	1.5	1.7	1.8	2.2	2.4	2.7	2.9	2.1	2.0	1.8	1.7	25	763	88	2.9	126
1995	1.6	1.4	1.6	1.7	2.1	2.2	2.5	2.7	1.9	1.8	1.7	1.6	23	789	79	2.7	113
1996	1.7	1.6	1.8	1.8	2.3	2.4	2.7	2.9	2.1	2.0	1.8	1.8	25	814	84	2.9	119
1997	1.7	1.5	1.7	1.8	2.2	2.4	2.7	2.9	2.1	2.0	1.8	1.7	25	839	80	2.9	114
1998	1.8	1.6	1.8	1.9	2.3	2.5	2.8	3.0	2.1	2.1	1.9	1.8	26	864	81	3.0	115
1999	1.8	1.6	1.8	1.8	2.3	2.5	2.8	3.0	2.1	2.0	1.9	1.8	25	890	78	3.0	112
2000	2.0	1.8	2.0	2.1	2.6	2.8	3.2	3.4	2.4	2.3	2.1	2.1	29	915	87	3.4	124
2001	2.0	1.8	2.0	2.0	2.6	2.7	3.0	3.3	2.4	2.3	2.0	2.0	28	940	82	3.3	116
Average	1.6	1.4	1.6	1.6	2.1	2.2	2.5	2.6	1.9	1.8	1.7	1.6	23		79.5	2.6	113.4
% Distrib.	7.0%	6.3%	7.1%	7.3%	9.1%	9.8%	10.9%	11.7%	8.4%	8.1%	7.3%	7.1%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
Average	0	0	0	0	0.00

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses)	
W. Conservation Reduction =	
Subtotal =	
Peak Daily Demand with WC and Water Losses =	
Peak Daily Demand Factor with WC and Water Losses =	

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	72	72	72	77	94	104	112	120	89	83	78	73	611	87.2
1989	67	66	67	71	87	96	104	112	83	77	72	67	637	80.9
1990	58	57	58	61	75	83	89	96	71	66	62	58	662	69.6
1991	58	57	58	61	75	83	89	96	71	66	62	58	687	69.6
1992	60	59	60	64	78	86	93	100	74	69	64	60	713	72.4
1993	61	61	62	66	80	88	95	102	76	70	66	62	738	74.2
1994	73	72	73	78	94	105	113	121	90	84	78	73	763	88.0
1995	66	65	66	70	85	94	102	110	81	75	71	66	789	79.4
1996	69	69	69	74	90	99	107	116	86	79	74	70	814	83.7
1997	66	66	67	71	86	95	103	111	82	76	71	67	839	80.2
1998	67	66	67	71	87	96	104	112	83	77	72	67	864	80.9
1999	65	64	65	69	84	93	100	108	80	74	70	65	890	78.3
2000	72	71	72	77	93	103	111	120	89	83	77	73	915	87.0
2001	68	67	68	72	87	97	104	113	84	77	73	68	940	81.5
Average	66	65	66	70	85	94	102	110	81	75	71	66		79.5

Horace Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) **Winter =** **Summer =**

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	72	72	72	77	94	104	112	120	89	83	78	73	611	74	100
1989	67	66	67	71	87	96	104	112	83	77	72	67	637	69	93
1990	58	57	58	61	75	83	89	96	71	66	62	58	662	59	80
1991	58	57	58	61	75	83	89	96	71	66	62	58	687	59	80
1992	60	59	60	64	78	86	93	100	74	69	64	60	713	61	83
1993	61	61	62	66	80	88	95	102	76	70	66	62	738	63	85
1994	73	72	73	78	94	105	113	121	90	84	78	73	763	75	101
1995	66	65	66	70	85	94	102	110	81	75	71	66	789	67	91
1996	69	69	69	74	90	99	107	116	86	79	74	70	814	71	96
1997	66	66	67	71	86	95	103	111	82	76	71	67	839	68	92
1998	67	66	67	71	87	96	104	112	83	77	72	67	864	69	93
1999	65	64	65	69	84	93	100	108	80	74	70	65	890	66	90
2000	72	71	72	77	93	103	111	120	89	83	77	73	915	74	100
2001	68	67	68	72	87	97	104	113	84	77	73	68	940	69	94
Average	66	65	66	70	85	94	102	110	81	75	71	66		67.4	91

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	75
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	121
Estimated Water Losses (%) =	0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	66	65	66	70	85	94	102	110	81	75	71	66	79.5
Average Monthly Demand w/ WC (gpc/d)	58	57	58	62	76	85	92	100	72	66	63	58	70.7
Average Monthly Demand w/ WC and Losses (gpc/d)	**58**	**57**	**58**	**62**	**76**	**85**	**92**	**100**	**72**	**66**	**63**	**58**	**70.7**
Max Month Data w/o Losses (gpc/d)	73	72	73	78	94	105	113	121	90	84	78	73	88.0
Max Month Data w/ Losses (gpc/d)	**73**	**72**	**73**	**78**	**94**	**105**	**113**	**121**	**90**	**84**	**78**	**73**	**88.0**
Max Month Data w/ WC (gpc/d)	65	64	65	70	85	95	103	112	81	74	70	65	79.2
Max Month Data w/ WC and Losses (gpc/d)	**65**	**64**	**65**	**70**	**85**	**95**	**103**	**112**	**81**	**74**	**70**	**65**	**79.2**

Water Losses = 0.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		1,950							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	10.7	9.6	10.7	11.1	14.1	15.3	17.1	18.6	12.9	12.3	11.2	10.8	154
Max Month Data w/ Losses	13.5	12.1	13.5	14.0	17.5	18.8	20.9	22.5	16.2	15.5	14.0	13.6	192
Max Month Data w/ WC and Losses	12.0	10.7	12.0	12.5	15.8	17.1	19.1	20.8	14.5	13.7	12.6	12.1	173

Langdon Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1986	7.6	7.9	7.6	5.7	5.8	5.9	6.1	6.3	6.1	4.8	4.3	4.8	73	2,269	25.9%	1.6	88
1987	8.4	8.6	8.3	6.2	6.4	6.5	6.7	6.9	6.7	5.3	4.7	5.3	80	2,269	25.9%	1.7	97
1988	10.2	10.6	10.1	7.6	7.8	8.0	8.2	8.5	8.2	6.5	5.8	6.5	98	2,269	25.9%	2.1	118
1989	11.7	12.0	11.5	8.7	8.9	9.1	9.3	9.6	9.3	7.4	6.6	7.4	112	2,255	25.9%	2.4	135
1990	9.4	9.7	9.3	7.0	7.2	7.3	7.5	7.8	7.5	6.0	5.3	5.9	90	2,241	25.9%	1.9	110
1991	8.7	9.0	8.6	6.5	6.6	6.8	6.9	7.2	7.0	5.5	4.9	5.5	83	2,227	25.9%	1.8	102
1992	9.8	10.2	9.7	7.3	7.5	7.7	7.8	8.1	7.9	6.2	5.5	6.2	94	2,213	25.9%	2.0	117
1993	8.3	8.5	8.2	6.2	6.3	6.4	6.6	6.8	6.6	5.2	4.7	5.2	79	2,213	25.9%	1.7	98
1994	9.8	10.1	9.7	7.3	7.5	7.6	7.8	8.1	7.8	6.2	5.5	6.2	93	2,185	25.3%	2.0	117
1995	9.3	9.6	9.2	6.9	7.1	7.2	7.4	7.7	7.4	5.9	5.2	5.9	89	2,171	21.0%	1.6	112
1996	18.2	18.8	18.0	13.5	13.9	14.2	14.5	15.0	14.6	11.5	10.3	11.5	174	2,157	13.7%	2.0	221
1997	10.7	11.0	10.6	8.0	8.2	8.3	8.5	8.8	8.6	6.8	6.0	6.8	102	2,143	26.6%	2.3	131
1998	12.2	12.6	12.1	9.1	9.3	9.5	9.7	10.1	9.8	7.8	6.9	7.7	117	2,129	32.3%	3.1	150
1999	12.1	12.5	12.0	9.0	9.2	9.4	9.6	10.0	9.7	7.7	6.8	7.7	116	2,115	25.9%	2.5	150
2000	11.4	11.8	11.3	8.5	8.7	8.9	9.1	9.4	9.1	7.2	6.4	7.2	109	2,101	30.0%	2.7	142
2001	11.8	12.2	11.7	8.8	9.0	9.2	9.4	9.8	9.5	7.5	6.7	7.5	113	2,087	32.3%	3.0	148
Average	10.6	10.9	10.5	7.9	8.1	8.3	8.4	8.8	8.5	6.7	6.0	6.7	101.4		25.9%		127.3

[1] Water loss data was not available from 1988 - 1993 and 1999 so average available data was used (25.9%)

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1986	6.1	6.3	6.0	4.1	4.3	4.4	4.5	4.7	4.5	3.3	2.7	3.3	54	2,269	65	6.3	93
1987	6.6	6.9	6.6	4.5	4.7	4.8	4.9	5.2	5.0	3.6	3.0	3.6	59	2,269	72	6.9	102
1988	8.1	8.5	8.0	5.5	5.7	5.9	6.0	6.3	6.1	4.4	3.7	4.4	73	2,269	88	8.5	124
1989	9.3	9.6	9.1	6.3	6.5	6.7	6.9	7.2	6.9	5.0	4.2	5.0	83	2,255	100	9.6	142
1990	7.5	7.8	7.4	5.1	5.2	5.4	5.5	5.8	5.6	4.0	3.4	4.0	67	2,241	81	7.8	115
1991	6.9	7.2	6.8	4.7	4.9	5.0	5.1	5.4	5.2	3.7	3.1	3.7	62	2,227	76	7.2	108
1992	7.8	8.1	7.7	5.3	5.5	5.6	5.8	6.1	5.9	4.2	3.5	4.2	70	2,213	86	8.1	122
1993	6.6	6.8	6.5	4.4	4.6	4.7	4.9	5.1	4.9	3.5	3.0	3.5	59	2,213	73	6.8	103
1994	7.8	8.1	7.7	5.3	5.5	5.6	5.8	6.1	5.9	4.2	3.5	4.2	70	2,185	87	8.1	124
1995	7.7	8.0	7.6	5.4	5.5	5.7	5.8	6.1	5.9	4.3	3.7	4.3	70	2,171	88	8.0	123
1996	16.2	16.8	16.0	11.6	11.9	12.2	12.5	13.0	12.6	9.6	8.3	9.5	150	2,157	191	16.8	260
1997	8.4	8.8	8.3	5.7	5.9	6.1	6.2	6.6	6.3	4.5	3.8	4.5	75	2,143	96	8.8	136
1998	9.1	9.5	9.0	6.0	6.2	6.4	6.6	7.0	6.7	4.6	3.7	4.6	79	2,129	102	9.5	148
1999	9.6	10.0	9.5	6.5	6.8	6.9	7.1	7.5	7.2	5.2	4.3	5.2	86	2,115	111	10.0	158
2000	8.7	9.0	8.6	5.8	6.0	6.2	6.4	6.7	6.4	4.5	3.7	4.5	76	2,101	100	9.0	144
2001	8.8	9.2	8.7	5.7	6.0	6.2	6.4	6.7	6.4	4.4	3.6	4.4	76	2,087	100	9.2	146
Average	8.4	8.8	8.3	5.7	5.9	6.1	6.3	6.6	6.3	4.6	3.8	4.5	75.5		94.8	8.8	134.2
% Distrib.	11.2%	11.6%	11.0%	7.6%	7.9%	8.1%	8.3%	8.7%	8.4%	6.0%	5.1%	6.0%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	757,000	69,490	687,510	303	3.20
1989	663,000	79,086	583,914	259	2.73
1990	644,000	63,752	580,248	259	2.73
1991	535,000	59,022	475,978	214	2.25
1992	572,000	66,745	505,255	228	2.41
1993	727,769	56,114	671,655	304	3.20
1994	678,000	64,845	613,155	281	2.96
1995	750,000	51,202	698,798	322	3.40
1996	731,000	65,134	665,866	309	3.26
1997	949,000	74,615	874,385	408	4.30
1998	667,000	103,358	563,642	265	2.79
1999	771,000	82,086	688,914	326	3.44
2000	863,000	89,467	773,533	368	3.88
2001	881,000	99,968	781,032	374	3.95
Average	727,769	73,206	654,563	301	3.18

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	408.0
W. Conservation Reduction =	9.6
Subtotal =	398.4
Peak Daily Demand with WC and	
Water Losses =	537.6
Peak Daily Demand Factor with WC	
and Water Losses =	4.65

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1986	86	99	85	60	61	64	64	67	67	46	40	46	2,269	65.3
1987	94	109	93	66	66	70	70	74	73	51	44	51	2,269	71.6
1988	116	133	114	81	81	86	86	90	90	62	54	62	2,269	87.7
1989	132	153	131	93	93	99	98	103	103	71	62	71	2,255	100.4
1990	107	124	106	75	75	80	80	84	83	58	50	58	2,241	81.4
1991	100	115	99	70	70	75	74	78	78	54	47	54	2,227	75.9
1992	114	131	112	80	80	85	85	89	88	61	53	61	2,213	86.3
1993	96	110	94	67	67	71	71	75	74	52	44	51	2,213	72.5
1994	115	133	114	81	81	86	86	90	89	62	54	62	2,185	87.5
1995	115	132	113	82	82	87	87	91	90	64	56	64	2,171	88.5
1996	242	278	240	179	178	188	187	195	195	143	128	142	2,157	190.8
1997	127	146	125	88	89	94	94	99	98	68	58	68	2,143	95.9
1998	138	159	136	93	94	100	100	105	104	70	59	69	2,129	101.9
1999	146	169	145	103	103	109	109	114	114	79	68	79	2,115	111.1
2000	133	154	131	91	92	98	98	103	102	69	59	69	2,101	99.6
2001	136	157	134	92	92	98	98	104	103	69	58	68	2,087	100.4
Average	125	144	123	88	88	93	93	98	97	68	58	67		94.8

Maximum historic water use month = 278 gpc/d

Langdon Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1986	86	99	85	60	61	64	64	67	67	46	40	46	2,269	69	62
1987	94	109	93	66	66	70	70	74	73	51	44	51	2,269	76	67
1988	116	133	114	81	81	86	86	90	90	62	54	62	2,269	93	83
1989	132	153	131	93	93	99	98	103	103	71	62	71	2,255	107	95
1990	107	124	106	75	75	80	80	84	83	58	50	58	2,241	87	77
1991	100	115	99	70	70	75	74	78	78	54	47	54	2,227	81	71
1992	114	131	112	80	80	85	85	89	88	61	53	61	2,213	92	81
1993	96	110	94	67	67	71	71	75	74	52	44	51	2,213	77	68
1994	115	133	114	81	81	86	86	90	89	62	54	62	2,185	93	82
1995	115	132	113	82	82	87	87	91	90	64	56	64	2,171	94	84
1996	242	278	240	179	178	188	187	195	195	143	128	142	2,157	202	181
1997	127	146	125	88	89	94	94	99	98	68	58	68	2,143	102	90
1998	138	159	136	93	94	100	100	105	104	70	59	69	2,129	109	96
1999	146	169	145	103	103	109	109	114	114	79	68	79	2,115	118	105
2000	133	154	131	91	92	98	98	103	102	69	59	69	2,101	106	93
2001	136	157	134	92	92	98	98	104	103	69	58	68	2,087	107	94
Average	125	144	123	88	88	93	93	98	97	68	58	67		100.8	89

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	202
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	278
Estimated Water Losses (%) =	26%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	125	144	123	88	88	93	93	98	97	68	58	67	94.8
Average Monthly Demand w/ WC (gpc/d)	116	135	115	79	78	84	83	88	87	58	50	59	85.8
Average Monthly Demand w/ WC and Losses (gpc/d)	**157**	**183**	**155**	**107**	**106**	**113**	**113**	**119**	**118**	**78**	**67**	**79**	**115.7**
Max Month Data w/o Losses (gpc/d)	242	278	240	179	178	188	187	195	195	143	128	142	190.8
Max Month Data w/ Losses (gpc/d)	**327**	**375**	**324**	**241**	**241**	**254**	**253**	**263**	**263**	**193**	**172**	**192**	**257.5**
Max Month Data w/ WC (gpc/d)	234	270	231	170	169	179	178	186	185	133	119	134	181.8
Max Month Data w/ WC and Losses (gpc/d)	**316**	**364**	**312**	**230**	**228**	**241**	**240**	**250**	**250**	**180**	**161**	**181**	**245.3**

Water Losses = 25.9%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =	2,100								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	31.4	33.0	31.0	20.6	21.1	21.8	22.5	23.7	22.8	15.6	13.0	15.8	272
Max Month Data w/ Losses (gpc/d)	65.4	67.7	64.6	46.6	48.1	49.1	50.5	52.6	50.8	38.5	33.4	38.4	606
Max Month Data w/ WC and Losses (gpc/d)	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577

Langdon Rural Water District Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)[2] Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
1989	0.8	0.8	0.8	1.1	1.2	1.6	1.5	1.1	0.9	0.8	0.9	1.3	13	910	15.9%	0.2	38
1990	2.6	1.6	1.0	2.4	1.9	3.0	2.6	2.3	2.0	1.8	1.9	1.9	25	910	9.2%	0.2	76
1991	2.0	1.7	1.9	2.0	2.7	2.8	1.9	2.4	2.3	2.4	2.7	3.2	28	1,435	6.9%	0.2	53
1992	2.4	2.2	2.7	2.6	2.9	4.4	2.6	3.0	2.8	3.1	2.5	2.8	34	1,435	3.1%	0.1	65
1993	2.7	2.5	2.9	3.0	3.7	4.2	3.3	3.0	3.0	3.1	2.7	2.9	37	1,435	4.9%	0.2	71
1994	3.1	2.7	3.3	3.6	3.8	5.0	3.3	3.1	3.0	3.0	3.6	4.0	41	1,435	0.0%	0.0	79
1995	4.1	3.5	3.8	4.4	4.9	6.4	4.6	4.5	4.2	4.3	4.4	4.9	54	2,100	11.9%	0.5	71
1996	4.2	3.6	3.9	4.5	5.1	6.5	4.7	4.6	4.3	4.4	4.5	5.0	55	2,100	9.9%	0.5	72
1997	4.1	3.5	3.8	4.4	4.9	6.4	4.6	4.5	4.2	4.3	4.3	4.9	54	2,100	10.2%	0.5	70
1998	3.9	3.3	3.6	4.1	4.6	6.0	4.3	4.2	3.9	4.0	4.1	4.6	51	2,100	7.9%	0.3	66
1999	3.7	3.1	3.4	4.0	4.5	5.8	4.1	4.1	3.8	3.9	3.9	4.4	49	2,100	7.8%	0.3	64
2000	3.9	3.3	3.6	4.2	4.7	6.1	4.4	4.3	4.0	4.1	4.1	4.6	51	2,100	6.6%	0.3	67
2001	3.8	3.2	3.5	4.1	4.6	5.9	4.2	4.2	3.9	4.0	4.0	4.5	50	2,100	11.9%	0.5	65
Average	3.2	2.7	2.9	3.4	3.8	4.9	3.5	3.5	3.3	3.3	3.4	3.8	42		8.2%		65.8

[1] 1994 data was negative so used 0%

[2] Data from 1995 - 2001 was developed from 1989 - 1994 monthly distribution

Per Capita Water Use Analysis (Monthly water diversion*without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
1989	0.7	0.7	0.7	0.9	1.1	1.4	1.3	0.9	0.7	0.7	0.7	1.1	11	910	32	1.4	52
1990	2.5	1.4	0.8	2.2	1.7	2.8	2.4	2.1	1.8	1.6	1.7	1.8	23	910	69	2.8	104
1991	1.8	1.5	1.7	1.8	2.5	2.7	1.8	2.2	2.1	2.2	2.5	3.0	26	1,435	50	3.0	70
1992	2.3	2.1	2.6	2.5	2.8	4.3	2.5	2.9	2.7	3.1	2.4	2.7	33	1,435	63	4.3	100
1993	2.5	2.3	2.8	2.9	3.6	4.0	3.1	2.9	2.8	2.9	2.6	2.7	35	1,435	67	4.0	93
1994	3.1	2.7	3.3	3.6	3.8	5.0	3.3	3.1	3.0	3.0	3.6	4.0	41	1,435	79	5.0	116
1995	3.6	2.9	3.3	3.9	4.4	5.9	4.1	4.0	3.7	3.8	3.8	4.3	48	2,100	62	5.9	93
1996	3.8	3.1	3.4	4.1	4.6	6.1	4.2	4.2	3.9	4.0	4.0	4.5	50	2,100	65	6.1	96
1997	3.6	3.0	3.3	4.0	4.5	5.9	4.1	4.1	3.8	3.8	3.9	4.4	48	2,100	63	5.9	94
1998	3.5	2.9	3.2	3.8	4.3	5.6	4.0	3.9	3.6	3.7	3.7	4.2	47	2,100	61	5.6	89
1999	3.4	2.8	3.1	3.7	4.1	5.4	3.8	3.8	3.5	3.6	3.6	4.1	45	2,100	59	5.4	86
2000	3.6	3.0	3.3	3.9	4.4	5.8	4.1	4.0	3.7	3.8	3.9	4.4	48	2,100	63	5.8	92
2001	3.3	2.7	3.0	3.6	4.1	5.4	3.7	3.7	3.4	3.5	3.5	4.0	44	2,100	57	5.4	86
Average	2.9	2.4	2.7	3.1	3.5	4.6	3.3	3.2	3.0	3.0	3.1	3.5	38		60.7	4.7	90.1
% Distrib.	10.3%	8.5%	9.5%	11.1%	12.5%	16.5%	11.6%	11.4%	10.6%	10.8%	10.9%	12.4%	136.2%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1989	96,000	5,545	90,455	99	1.64
1990	99,000	6,311	92,689	102	1.68
1991	125,000	5,269	119,731	83	1.38
1992	128,000	2,872	125,128	87	1.44
1993	139,100	4,986	134,114	93	1.54
1994	166,100	0	166,100	116	1.91
1995	222,800	17,582	205,218	98	1.61
1996	221,000	15,033	205,967	98	1.62
1997	214,500	15,045	199,455	95	1.57
1998	295,000	10,985	284,015	135	2.23
1999	316,000	10,458	305,542	145	2.40
2000	359,000	9,342	349,658	167	2.74
2001	426,000	16,222	409,778	195	3.22
Average	215,962	9,204	206,758	116	1.92

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	195.1
W. Conservation Reduction =	9.5
Subtotal =	185.7
Peak Daily Demand with WC and Water Losses =	206.3
Peak Daily Demand Factor with WC and Water Losses =	3.64

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Average Per Capita Use (gpc/d)
1989	24	26	23	33	37	52	46	32	25	23	26	39	910	32.2
1990	87	54	29	81	61	104	84	76	66	57	62	62	910	68.7
1991	41	38	38	42	57	62	40	49	50	50	59	68	1,435	49.6
1992	51	53	58	57	63	100	55	65	62	69	57	61	1,435	62.7
1993	56	58	63	67	81	93	70	65	65	65	59	61	1,435	67.0
1994	69	66	73	83	85	116	75	70	70	66	84	89	1,435	79.0
1995	55	45	50	60	68	90	62	61	57	58	59	67	2,100	62.2
1996	58	48	53	63	71	93	65	64	59	61	61	70	2,100	65.0
1997	56	46	51	61	69	91	63	62	58	59	60	68	2,100	63.1
1998	54	45	50	58	66	86	61	60	56	57	57	65	2,100	60.7
1999	52	43	48	56	64	84	59	58	54	55	55	63	2,100	58.6
2000	56	46	51	60	68	89	63	62	57	59	59	67	2,100	62.6
2001	51	42	47	55	63	83	58	57	52	54	54	62	2,100	57.4
Average	55	47	49	60	65	88	62	60	56	56	58	65		60.7

Langdon Rural Water District Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1989	24	26	23	33	37	52	46	32	25	23	26	39	910	28	36
1990	87	54	29	81	61	104	84	76	66	57	62	62	910	63	75
1991	41	38	38	42	57	62	40	49	50	50	59	68	1,435	48	51
1992	51	53	58	57	63	100	55	65	62	69	57	61	1,435	56	69
1993	56	58	63	67	81	93	70	65	65	65	59	61	1,435	61	73
1994	69	66	73	83	85	116	75	70	70	66	84	89	1,435	77	80
1995	55	45	50	60	68	90	62	61	57	58	59	67	2,100	56	66
1996	58	48	53	63	71	93	65	64	59	61	61	70	2,100	59	69
1997	56	46	51	61	69	91	63	62	58	59	60	68	2,100	57	67
1998	54	45	50	58	66	86	61	60	56	57	57	65	2,100	55	64
1999	52	43	48	56	64	84	59	58	54	55	55	63	2,100	53	62
2000	56	46	51	60	68	89	63	62	57	59	59	67	2,100	57	66
2001	51	42	47	55	63	83	58	57	52	54	54	62	2,100	52	61
Average	55	49	47	60	64	88	62	60	56	55	58	63		55.5	65

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	77
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	116
Estimated Water Losses (%) =	10%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	55	49	47	60	64	88	62	60	56	55	58	63	59.9
Average Monthly Demand w/ WC (gpc/d)	47	41	39	52	55	78	52	50	47	46	50	55	51.1
Average Monthly Demand w/ WC and Losses (gpc/d)	**52**	**46**	**44**	**58**	**61**	**87**	**58**	**56**	**52**	**51**	**55**	**61**	**56.7**
Max Month Data w/o Losses (gpc/d)	87	66	73	83	85	116	84	76	70	69	84	89	82.0
Max Month Data w/ Losses (gpc/d)	**97**	**73**	**81**	**92**	**95**	**129**	**94**	**85**	**78**	**76**	**94**	**99**	**91.1**
Max Month Data w/ WC (gpc/d)	79	58	65	75	76	106	75	67	61	59	76	81	73.2
Max Month Data w/ WC and Losses (gpc/d)	**88**	**64**	**72**	**83**	**84**	**118**	**83**	**74**	**67**	**66**	**85**	**90**	**81.3**

Water Losses = 10.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		1,568								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	7.7	6.1	6.5	8.4	9.1	12.6	8.7	8.3	7.5	7.6	8.0	9.2	99.6
Max Month Data w/ Losses	14.4	9.9	12.1	13.3	14.1	18.6	14.0	12.6	11.2	11.4	13.5	14.8	160.0
Max Month Data w/ WC and Losses	13.1	8.7	10.8	12.0	12.5	17.1	12.4	11.1	9.7	9.8	12.2	13.5	142.9

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		2,900								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	14.3	11.4	12.0	15.5	16.7	23.3	16.0	15.4	13.9	14.0	14.8	17.0	184.3
Max Month Data w/ Losses	26.7	18.3	22.4	24.7	26.1	34.3	25.9	23.3	20.8	21.1	25.0	27.4	296.0
Max Month Data w/ WC and Losses	24.2	16.0	19.9	22.2	23.2	31.5	23.0	20.4	18.0	18.2	22.6	24.9	264.2

Larimore Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	4.3	4.1	3.1	3.8	4.1	6.9	6.0	5.1	4.0	4.4	4.7	0.5	51	1,470	10.0%	0.4	95
1989	4.8	7.6	3.5	4.0	5.1	4.6	8.2	5.9	3.9	4.6	5.0	4.3	61	1,467	10.0%	0.5	115
1990	4.7	4.9	6.2	5.9	6.8	6.3	6.3	6.4	4.7	4.3	3.9	3.7	64	1,464	10.0%	0.5	120
1991	3.4	3.0	3.6	3.7	4.4	4.9	4.9	5.9	4.8	4.2	4.1	4.0	51	1,461	10.0%	0.4	95
1992	5.1	4.7	3.8	3.8	5.5	5.4	4.6	5.4	4.7	4.5	3.5	3.9	55	1,458	10.0%	0.5	103
1993	3.8	4.0	4.0	4.1	5.0	5.2	4.6	4.6	4.2	3.7	3.4	3.6	50	1,455	10.0%	0.4	94
1994	4.3	3.6	4.8	4.3	5.7	6.1	5.2	5.8	4.6	3.2	3.2	5.0	56	1,452	10.0%	0.5	105
1995	5.2	4.6	5.6	4.7	6.5	7.3	4.8	5.6	5.0	4.4	4.3	4.8	63	1,449	10.0%	0.5	119
1996	4.7	5.9	5.5	4.9	4.4	5.2	5.0	5.7	4.6	6.4	7.4	7.3	67	1,445	10.0%	0.6	127
1997	7.0	6.8	8.0	5.5	4.7	6.1	5.0	5.3	4.4	4.3	4.2	5.1	67	1,442	10.0%	0.6	126
1998	5.2	4.9	4.9	4.2	4.2	4.6	5.1	5.9	4.9	3.9	4.0	4.2	56	1,439	10.0%	0.5	106
1999	3.4	3.4	3.8	3.9	4.5	4.7	5.7	6.2	3.6	3.9	4.4	5.1	53	1,436	10.0%	0.4	101
2000	5.2	3.1	3.4	3.9	3.3	2.9	4.3	5.7	4.9	5.2	3.6	4.4	50	1,433	10.0%	0.4	95
2001	4.8	3.7	3.7	4.2	5.2	5.5	5.9	5.6	5.1	6.1	6.2	5.6	62	1,430	10.0%	0.5	118
Average	4.7	4.6	4.6	4.3	4.9	5.4	5.4	5.6	4.5	4.5	4.4	4.4	57		10.0%		108.6

[1] Water loss data was not available so zero% was assumed in analysis

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	3.9	3.7	2.6	3.4	3.7	6.4	5.6	4.7	3.6	4.0	4.3	0.1	46	1,470	86	6.4	146
1989	4.3	7.0	3.0	3.4	4.6	4.1	7.7	5.4	3.4	4.1	4.5	3.8	55	1,467	103	7.7	175
1990	4.2	4.4	5.6	5.4	6.3	5.8	5.7	5.9	4.2	3.8	3.4	3.2	58	1,464	108	6.3	144
1991	3.0	2.6	3.2	3.3	3.9	4.4	4.5	5.5	4.3	3.8	3.7	3.6	46	1,461	86	5.5	125
1992	4.6	4.2	3.4	3.3	5.0	4.9	4.2	4.9	4.2	4.1	3.1	3.5	49	1,458	93	5.0	115
1993	3.4	3.6	3.6	3.6	4.6	4.8	4.2	4.2	3.8	3.3	3.0	3.2	45	1,455	85	4.8	110
1994	3.9	3.2	4.3	3.8	5.2	5.7	4.8	5.3	4.2	2.7	2.7	4.5	50	1,452	95	5.7	130
1995	4.7	4.1	5.1	4.2	5.9	6.8	4.3	5.1	4.4	3.9	3.8	4.3	57	1,449	107	6.8	156
1996	4.1	5.4	4.9	4.3	3.8	4.7	4.5	5.1	4.0	5.8	6.8	6.7	60	1,445	114	6.8	157
1997	6.4	6.3	7.5	5.0	4.1	5.6	4.5	4.7	3.9	3.7	3.6	4.6	60	1,442	114	7.5	173
1998	4.7	4.4	4.4	3.8	3.7	4.1	4.6	5.4	4.4	3.5	3.5	3.7	50	1,439	96	5.4	125
1999	3.0	3.0	3.4	3.5	4.0	4.3	5.2	5.8	3.2	3.4	4.0	4.7	47	1,436	91	5.8	135
2000	4.8	2.6	3.0	3.4	2.8	2.5	3.9	5.2	4.4	4.8	3.2	4.0	45	1,433	86	5.2	122
2001	4.3	3.2	3.2	3.7	4.7	4.9	5.4	5.1	4.6	5.6	5.7	5.1	55	1,430	106	5.7	134
Average	4.2	4.1	4.1	3.9	4.5	4.9	4.9	5.2	4.0	4.0	3.9	3.9	52		97.7	6.0	138.9
% Distrib.	8.2%	8.0%	7.9%	7.5%	8.6%	9.5%	9.5%	10.0%	7.8%	7.8%	7.6%	7.6%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990	No data Available				
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
Average	0	0	0	0	0.00

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses)	
W. Conservation Reduction =	
Subtotal =	
Peak Daily Demand with WC and Water Losses =	
Peak Daily Demand Factor with WC and Water Losses =	

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	86	89	58	77	80	146	122	102	82	88	97	2	1,470	85.6
1989	95	172	67	78	100	93	169	118	77	90	102	84	1,467	103.3
1990	92	106	124	122	139	132	126	130	96	83	77	70	1,464	108.2
1991	67	63	70	75	87	101	98	121	99	83	84	79	1,461	85.8
1992	102	103	75	76	111	113	93	109	96	90	70	77	1,458	92.8
1993	74	88	79	84	102	110	92	94	87	72	68	71	1,455	85.0
1994	86	78	95	88	115	130	106	119	96	60	62	101	1,452	94.7
1995	105	102	114	96	132	156	95	113	102	86	88	96	1,449	107.1
1996	92	133	110	100	85	108	100	114	93	130	157	150	1,445	114.2
1997	144	155	167	115	93	129	100	106	89	83	84	102	1,442	113.7
1998	106	109	98	87	83	96	103	121	103	78	82	84	1,439	95.7
1999	68	75	77	80	90	100	117	130	73	77	93	105	1,436	90.5
2000	108	66	67	80	64	58	88	118	103	108	75	90	1,433	85.6
2001	97	81	71	87	106	115	121	114	106	125	134	115	1,430	106.2
Average	94	101	91	89	99	113	109	115	93	90	91	87		97.7

Maximum historic water use month = 172 gpc/d

Larimore Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	86	89	58	77	80	146	122	102	82	88	97	2	1,470	68	103
1989	95	172	67	78	100	93	169	118	77	90	102	84	1,467	100	108
1990	92	106	124	122	139	132	126	130	96	83	77	70	1,464	99	118
1991	67	63	70	75	87	101	98	121	99	83	84	79	1,461	73	98
1992	102	103	75	76	111	113	93	109	96	90	70	77	1,458	84	102
1993	74	88	79	84	102	110	92	94	87	72	68	71	1,455	77	93
1994	86	78	95	88	115	130	106	119	96	60	62	101	1,452	85	104
1995	105	102	114	96	132	156	95	113	102	86	88	96	1,449	100	114
1996	92	133	110	100	85	108	100	114	93	130	157	150	1,445	124	105
1997	144	155	167	115	93	129	100	106	89	83	84	102	1,442	128	100
1998	106	109	98	87	83	96	103	121	103	78	82	84	1,439	94	97
1999	68	75	77	80	90	100	117	130	73	77	93	105	1,436	83	98
2000	108	66	67	80	64	58	88	118	103	108	75	90	1,433	81	90
2001	97	81	71	87	106	115	121	114	106	125	134	115	1,430	97	115
Average	94	101	91	89	99	113	109	115	93	90	91	87		92.3	103

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	124
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	172
Estimated Water Losses (%) =	10%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	94	101	91	89	99	113	109	115	93	90	91	87	97.7
Average Monthly Demand w/ WC (gpc/d)	86	93	82	81	90	104	100	105	83	80	82	79	88.7
Average Monthly Demand w/ WC and Losses (gpc/d)	**95**	**103**	**92**	**89**	**100**	**115**	**111**	**117**	**93**	**89**	**92**	**88**	**98.6**
Max Month Data w/o Losses (gpc/d)	144	172	167	122	139	156	169	130	106	130	157	150	145.1
Max Month Data w/ Losses (gpc/d)	**160**	**191**	**186**	**136**	**154**	**174**	**188**	**145**	**118**	**145**	**175**	**166**	**161.2**
Max Month Data w/ WC (gpc/d)	135	163	159	114	129	147	160	121	97	121	149	141	136.1
Max Month Data w/ WC and Losses (gpc/d)	**150**	**181**	**176**	**126**	**144**	**163**	**177**	**134**	**107**	**134**	**165**	**157**	**151.2**

Water Losses = 10.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		1,190							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	10.8	10.6	10.4	9.8	11.3	12.6	12.6	13.3	10.2	10.1	10.0	9.9	131.4
Max Month Data w/ Losses (gpc/d)	18.1	19.5	21.0	14.9	17.5	19.0	21.3	16.4	12.9	16.4	19.1	18.8	214.9
Max Month Data w/ WC and Losses (gpc/d)	17.0	18.5	19.9	13.8	16.3	17.9	20.1	15.2	11.8	15.2	18.1	17.8	201.6

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		1,839							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	16.7	16.3	16.0	15.1	17.4	19.5	19.4	20.5	15.7	15.5	15.5	15.3	203.1
Max Month Data w/ Losses (gpc/d)	28.0	30.1	32.5	23.0	27.0	29.4	32.9	25.3	20.0	25.3	29.6	29.1	332.2
Max Month Data w/ WC and Losses (gpc/d)	26.3	28.6	30.8	21.4	25.2	27.6	31.0	23.5	18.2	23.5	28.0	27.4	311.5

Lidgerwood Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)[2] Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
1988	3.4	3.1	3.4	3.3	4.0	4.3	4.9	5.5	4.5	3.7	3.2	3.2	47	803	0.0%	0.0	158.8
1989	3.7	3.3	3.6	3.6	4.3	4.6	5.3	5.9	4.8	4.0	3.4	3.4	50	801	0.0%	0.0	170.6
1990	3.5	3.1	3.4	3.3	4.1	4.3	5.0	5.6	4.5	3.8	3.2	3.2	47	799	0.0%	0.0	160.8
1991	3.0	2.7	3.0	2.9	3.6	3.8	4.4	4.9	4.0	3.3	2.8	2.8	41	797	0.0%	0.0	141.4
1992	3.3	3.0	3.2	3.2	3.8	4.1	4.7	5.3	4.3	3.6	3.0	3.0	44	795	0.0%	0.0	153.2
1993	2.9	2.7	2.9	2.8	3.4	3.7	4.2	4.7	3.8	3.2	2.7	2.7	40	794	0.0%	0.0	137.3
1994	3.3	3.0	3.2	3.2	3.9	4.1	4.8	5.3	4.3	3.6	3.1	3.1	45	792	0.0%	0.0	155.2
1995	3.3	3.0	3.2	3.2	3.9	4.1	4.7	5.3	4.3	3.6	3.0	3.0	45	790	0.0%	0.0	154.5
1996	3.5	3.2	3.4	3.4	4.1	4.4	5.1	5.7	4.6	3.8	3.3	3.3	48	788	0.0%	0.0	165.8
1997	3.7	3.4	3.7	3.6	4.4	4.7	5.4	6.0	4.9	4.1	3.5	3.5	51	786	0.0%	0.0	176.6
1998	3.0	2.7	2.9	2.9	3.5	3.7	4.3	4.8	3.9	3.3	2.8	2.8	41	785	0.0%	0.0	141.9
1999	3.6	3.0	3.2	3.2	3.7	4.5	4.6	4.7	4.5	3.5	3.4	3.1	45	783	0.0%	0.0	156.8
2000	3.2	3.1	3.2	3.1	3.7	3.7	4.0	6.0	4.3	3.8	2.5	3.0	44	781	0.0%	0.0	152.8
2001	2.3	2.1	2.5	2.5	3.2	3.2	4.4	3.9	2.9	2.5	2.5	2.4	34	779	0.0%	0.0	120.4
Average	3.3	2.9	3.2	3.2	3.8	4.1	4.7	5.2	4.3	3.5	3.0	3.0	44		0.0%		153.3

[1] Unaccounted for losses data was not available so assumed 0% annual losses
[2] Monthly only available from 1999-2000, so rest on monthly data was calculated using 1999-2000 monthly distribu

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^o-gals)	Monthly High Per Capita Use (gpc/d)
1988	3.4	3.1	3.4	3.3	4.0	4.3	4.9	5.5	4.5	3.7	3.2	3.2	47	803	159	5.5	229
1989	3.7	3.3	3.6	3.6	4.3	4.6	5.3	5.9	4.8	4.0	3.4	3.4	50	801	171	5.9	246
1990	3.5	3.1	3.4	3.3	4.1	4.3	5.0	5.6	4.5	3.8	3.2	3.2	47	799	161	5.6	232
1991	3.0	2.7	3.0	2.9	3.6	3.8	4.4	4.9	4.0	3.3	2.8	2.8	41	797	141	4.9	204
1992	3.3	3.0	3.2	3.2	3.8	4.1	4.7	5.3	4.3	3.6	3.0	3.0	44	795	153	5.3	221
1993	2.9	2.7	2.9	2.8	3.4	3.7	4.2	4.7	3.8	3.2	2.7	2.7	40	794	137	4.7	198
1994	3.3	3.0	3.2	3.2	3.9	4.1	4.8	5.3	4.3	3.6	3.1	3.1	45	792	155	5.3	224
1995	3.3	3.0	3.2	3.2	3.9	4.1	4.7	5.3	4.3	3.6	3.0	3.0	45	790	154	5.3	223
1996	3.5	3.2	3.4	3.4	4.1	4.4	5.1	5.7	4.6	3.8	3.3	3.3	48	788	166	5.7	239
1997	3.7	3.4	3.7	3.6	4.4	4.7	5.4	6.0	4.9	4.1	3.5	3.5	51	786	177	6.0	255
1998	3.0	2.7	2.9	2.9	3.5	3.7	4.3	4.8	3.9	3.3	2.8	2.8	41	785	142	4.8	204
1999	3.6	3.0	3.2	3.2	3.7	4.5	4.6	4.7	4.5	3.5	3.4	3.1	45	783	157	4.7	199
2000	3.2	3.1	3.2	3.1	3.7	3.7	4.0	6.0	4.3	3.8	2.5	3.0	44	781	153	6.0	254
2001	2.3	2.1	2.5	2.5	3.2	3.2	4.4	3.9	2.9	2.5	2.5	2.4	34	779	120	4.4	189
Average	3.3	2.9	3.2	3.2	3.8	4.1	4.7	5.2	4.3	3.5	3.0	3.0	44		153.3	5.3	222.5
% Distrib.	7.4%	6.7%	7.2%	7.1%	8.6%	9.2%	10.6%	11.8%	9.6%	8.0%	6.8%	6.8%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	N/A				
1989	N/A				
1990	N/A				
1991	N/A				
1992	N/A				
1993	N/A				
1994	N/A				
1995	N/A				
1996	N/A				
1997	N/A				
1998	N/A				
1999	236,000	0	236,000	301	1.97
2000	259,500	0	259,500	332	2.17
2001	207,500	0	207,500	266	1.74
Average	234,333	0	234,333	300	1.96

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses)	332.3
W. Conservation Reduction =	9.5
Subtotal =	322.8
Peak Daily Demand with WC and Water Losses =	322.8
Peak Daily Demand Factor with WC and Water Losses =	2.23

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Average Per Capita Use (gpc/d)
1988	138	138	135	138	162	178	199	222	186	150	132	128	803	158.8
1989	148	148	145	148	174	191	214	238	199	161	142	137	801	170.6
1990	140	140	137	139	164	180	201	224	188	151	134	130	799	160.8
1991	123	123	120	123	144	158	177	197	165	133	117	114	797	141.4
1992	133	133	130	133	156	172	192	214	179	144	127	123	795	153.2
1993	119	119	117	119	140	154	172	192	161	129	114	111	794	137.3
1994	135	135	132	135	158	174	194	217	181	146	129	125	792	155.2
1995	134	134	131	134	157	173	193	215	181	145	128	124	790	154.5
1996	144	144	141	144	169	186	208	231	194	156	138	134	788	165.8
1997	153	153	150	153	180	198	221	246	206	166	147	142	786	176.6
1998	123	123	121	123	144	159	178	198	166	134	118	114	785	141.9
1999	147	135	131	137	152	190	189	193	193	144	145	126	783	156.8
2000	132	143	132	131	154	156	167	246	184	158	106	123	781	152.8
2001	94	95	103	105	132	135	183	161	125	104	107	98	779	120.4
Average	133	133	130	133	156	172	192	214	179	144	127	124		153.3

Lidgerwood Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

With Industry (green) / Without Industry (blue)

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	138	138	135	138	162	178	199	222	186	150	132	128	803	135	183
1989	148	148	145	148	174	191	214	238	199	161	142	137	801	145	196
1990	140	140	137	139	164	180	201	224	188	151	134	130	799	136	185
1991	123	123	120	123	144	158	177	197	165	133	117	114	797	120	163
1992	133	133	130	133	156	172	192	214	179	144	127	123	795	130	176
1993	119	119	117	119	140	154	172	192	161	129	114	111	794	117	158
1994	135	135	132	135	158	174	194	217	181	146	129	125	792	132	178
1995	134	134	131	134	157	173	193	215	181	145	128	124	790	131	178
1996	144	144	141	144	169	186	208	231	194	156	138	134	788	141	191
1997	153	153	150	153	180	198	221	246	206	166	147	142	786	150	203
1998	123	123	121	123	144	159	178	198	166	134	118	114	785	120	163
1999	147	135	131	137	152	190	189	193	193	144	145	126	783	137	176
2000	132	143	132	131	154	156	167	246	184	158	106	123	781	128	178
2001	94	95	103	105	132	135	183	161	125	104	107	98	779	100	140
Average	133	133	130	133	156	172	192	214	179	144	127	124		130	176

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	150
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	246
Estimated Water Losses (%) =	0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	133	133	130	133	156	172	192	214	179	144	127	124	153.3
Average Monthly Demand w/ WC (gpc/d)	125	125	122	125	147	162	182	204	170	135	119	115	144.5
Average Monthly Demand w/ WC and Losses (gpc/d)	**125**	**125**	**122**	**125**	**147**	**162**	**182**	**204**	**170**	**135**	**119**	**115**	**144.5**
Max Month Data w/o Losses (gpc/d)	153	153	150	153	180	198	221	246	206	166	147	142	176.6
Max Month Data w/ Losses (gpc/d)	**153**	**153**	**150**	**153**	**180**	**198**	**221**	**246**	**206**	**166**	**147**	**142**	**176.6**
Max Month Data w/ WC (gpc/d)	145	145	142	145	170	188	212	237	197	157	139	134	167.8
Max Month Data w/ WC and Losses (gpc/d)	**145**	**145**	**142**	**145**	**170**	**188**	**212**	**237**	**197**	**157**	**139**	**134**	**167.8**

Water Losses = 0.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		680							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	8.1	7.3	7.9	7.8	9.5	10.2	11.8	13.2	10.6	8.7	7.5	7.5	110
Max Month Data w/ Losses	9.9	9.0	9.7	9.6	11.6	12.4	14.3	15.9	12.9	10.8	9.2	9.2	135
Max Month Data w/ WC and Losses	9.4	8.5	9.2	9.1	11.0	11.8	13.7	15.3	12.3	10.2	8.7	8.7	128

Lisbon Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	7.6	7.0	8.0	8.3	10.0	11.0	10.9	10.4	8.3	7.6	7.1	7.4	104	2,154	11.8%	1.0	132
1989	7.3	6.8	7.9	7.4	8.6	10.4	10.5	9.7	8.1	8.5	7.8	8.2	101	2,166	9.3%	0.8	128
1990	8.5	7.6	7.6	8.4	9.6	9.6	9.8	10.0	9.5	8.3	7.9	8.2	105	2,177	1.8%	0.2	132
1991	8.6	8.8	8.3	9.5	9.8	10.0	8.9	10.4	9.3	8.4	9.3	9.5	111	2,189	16.6%	1.5	139
1992	7.7	7.7	8.3	8.2	9.5	8.8	9.1	9.3	8.1	8.3	7.8	7.8	101	2,200	17.8%	1.5	125
1993	8.3	7.5	8.4	8.4	9.7	9.1	8.8	9.2	8.5	8.0	7.1	7.2	100	2,212	17.5%	1.5	124
1994	7.5	6.9	8.0	8.1	9.3	10.4	9.1	9.9	8.5	8.8	8.3	9.7	104	2,223	17.4%	1.5	129
1995	10.1	9.8	7.2	7.4	7.5	8.4	8.4	8.8	8.7	7.6	7.9	7.5	99	2,235	7.4%	0.6	122
1996	7.7	7.8	7.7	8.4	8.1	9.9	9.6	9.7	10.0	8.5	8.3	8.1	104	2,246	7.6%	0.7	127
1997	8.4	8.3	7.6	8.4	8.3	11.0	9.5	9.8	9.7	8.8	9.0	8.6	107	2,258	11.6%	1.0	130
1998	9.2	9.1	8.3	9.4	10.0	11.0	10.5	11.4	11.0	9.9	9.4	9.0	118	2,269	14.6%	1.4	143
1999	9.3	9.2	8.5	9.5	10.0	11.3	10.6	11.2	9.9	7.9	7.9	7.5	113	2,281	19.6%	1.8	135
2000	8.2	7.8	7.4	8.2	8.6	9.9	9.6	11.6	10.4	8.6	8.5	8.4	107	2,292	22.7%	2.0	128
2001	8.6	9.5	7.6	8.8	10.1	10.7	11.3	11.9	12.4	11.5	10.8	10.6	124	2,304	25.5%	2.6	147
Average	8.4	8.1	7.9	8.5	9.2	10.1	9.8	10.2	9.5	8.6	8.4	8.4	107		14.4%		131.6

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	6.5	6.0	7.0	7.3	9.0	10.0	9.9	9.4	7.3	6.6	6.1	6.3	91	2,154	116	10.0	155
1989	6.5	6.1	7.1	6.7	7.8	9.6	9.7	8.9	7.3	7.7	7.1	7.4	92	2,166	116	9.7	149
1990	8.3	7.4	7.4	8.2	9.5	9.5	9.7	9.9	9.3	8.2	7.7	8.0	103	2,177	130	9.9	151
1991	7.1	7.3	6.8	8.0	8.2	8.5	7.4	8.9	7.7	6.9	7.7	7.9	93	2,189	116	8.9	135
1992	6.2	6.2	6.8	6.7	8.0	7.3	7.6	7.8	6.6	6.8	6.3	6.4	83	2,200	103	8.0	121
1993	6.8	6.0	7.0	6.9	8.2	7.6	7.4	7.7	7.1	6.5	5.7	5.8	83	2,212	102	8.2	124
1994	6.0	5.4	6.5	6.5	7.8	8.9	7.5	8.4	7.0	7.2	6.7	8.1	86	2,223	106	8.9	133
1995	9.5	9.1	6.6	6.8	6.9	7.8	7.8	8.2	8.1	7.0	7.3	6.9	92	2,235	113	9.5	142
1996	7.1	7.1	7.1	7.8	7.5	9.2	8.9	9.1	9.3	7.8	7.7	7.4	96	2,246	117	9.3	138
1997	7.4	7.3	6.6	7.3	7.2	9.9	8.5	8.8	8.7	7.8	8.0	7.5	95	2,258	115	9.9	147
1998	7.8	7.7	6.9	8.0	8.5	9.6	9.0	9.9	9.6	8.4	8.0	7.6	101	2,269	122	9.9	146
1999	7.5	7.4	6.7	7.7	8.1	9.4	8.8	9.3	8.0	6.1	6.0	5.7	91	2,281	109	9.4	138
2000	6.1	5.8	5.4	6.2	6.6	7.9	7.6	9.6	8.3	6.6	6.5	6.4	83	2,292	99	9.6	139
2001	5.9	6.9	5.0	6.2	7.5	8.1	8.6	9.3	9.8	8.9	8.2	8.0	92	2,304	110	9.8	142
Average	7.1	6.8	6.6	7.2	7.9	8.8	8.5	8.9	8.2	7.3	7.1	7.1	91		112.5	9.4	140.1
% Distrib.	7.7%	7.5%	7.2%	7.8%	8.7%	9.6%	9.3%	9.8%	8.9%	8.0%	7.7%	7.8%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996	407,700	21,492	386,208	172	1.53
1997	349,100	34,263	314,837	139	1.24
1998	447,600	47,202	400,398	176	1.57
1999	505,800	60,553	445,247	195	1.74
2000	527,500	66,806	460,694	201	1.79
2001	500,200	86,575	413,625	180	1.60
Average	456,317	52,815	403,501	177	1.58

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	201.0
W. Conservation Reduction =	9.6
Subtotal =	191.4
Peak Daily Demand with WC and	
Water Losses =	223.5
Peak Daily Demand Factor with WC	
and Water Losses =	1.85

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	98	99	105	113	135	155	148	141	113	99	94	95	2,154	116.3
1989	97	100	106	102	117	148	145	133	113	115	109	110	2,166	116.3
1990	123	121	110	126	140	145	143	146	142	121	118	119	2,177	129.7
1991	105	119	100	122	121	129	109	131	118	102	118	117	2,189	115.8
1992	91	101	100	102	117	111	112	114	99	100	96	93	2,200	103.0
1993	100	97	102	104	120	115	107	112	106	95	86	84	2,212	102.4
1994	86	87	94	98	114	133	109	121	105	105	101	118	2,223	106.1
1995	138	146	95	102	100	117	113	118	120	101	109	99	2,235	112.9
1996	101	113	102	115	107	137	129	130	138	112	114	107	2,246	117.1
1997	105	115	94	108	103	147	121	125	128	112	118	108	2,258	115.2
1998	111	120	98	118	121	140	129	141	141	120	117	107	2,269	121.9
1999	105	115	94	113	115	138	124	132	117	86	88	80	2,281	108.9
2000	86	91	75	89	93	115	107	135	121	93	94	90	2,292	99.1
2001	83	107	70	90	105	117	121	130	142	124	119	111	2,304	109.8
Average	102	109	96	107	115	132	123	129	122	106	106	103		112.5

Maximum historic water use month = 155 gpc/d

Lisbon Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = Summer =

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	98	99	105	113	135	155	148	141	113	99	94	95	2,154	101	132
1989	97	100	106	102	117	148	145	133	113	115	109	110	2,166	104	128
1990	123	121	110	126	140	145	143	146	142	121	118	119	2,177	120	140
1991	105	119	100	122	121	129	109	131	118	102	118	117	2,189	113	118
1992	91	101	100	102	117	111	112	114	99	100	96	93	2,200	97	109
1993	100	97	102	104	120	115	107	112	106	95	86	84	2,212	95	109
1994	86	87	94	98	114	133	109	121	105	105	101	118	2,223	97	115
1995	138	146	95	102	100	117	113	118	120	101	109	99	2,235	115	112
1996	101	113	102	115	107	137	129	130	138	112	114	107	2,246	109	126
1997	105	115	94	108	103	147	121	125	128	112	118	108	2,258	108	123
1998	111	120	98	118	121	140	129	141	141	120	117	107	2,269	112	132
1999	105	115	94	113	115	138	124	132	117	86	88	80	2,281	99	119
2000	86	91	75	89	93	115	107	135	121	93	94	90	2,292	88	111
2001	83	107	70	90	105	117	121	130	142	124	119	111	2,304	97	123
Average	102	109	96	107	115	132	123	129	122	106	106	103		103.9	121

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	120
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	155
Estimated Water Losses (%) =	14%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	102	109	96	107	115	132	123	129	122	106	106	103	112.5
Average Monthly Demand w/ WC (gpc/d)	94	101	88	99	105	122	113	120	112	96	97	94	103.5
Average Monthly Demand w/ WC and Losses (gpc/d)	**109**	**118**	**102**	**115**	**123**	**143**	**132**	**140**	**131**	**113**	**114**	**110**	**120.8**
Max Month Data w/o Losses (gpc/d)	138	146	110	126	140	155	148	146	142	124	119	119	134.4
Max Month Data w/ Losses (gpc/d)	**161**	**171**	**129**	**147**	**164**	**181**	**173**	**171**	**166**	**145**	**139**	**139**	**156.9**
Max Month Data w/ WC (gpc/d)	129	138	102	117	131	145	139	137	133	115	110	111	125.4
Max Month Data w/ WC and Losses (gpc/d)	**151**	**161**	**119**	**137**	**153**	**170**	**162**	**160**	**155**	**134**	**129**	**129**	**146.4**

Water Losses = 14.4%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		2,530							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	26.3	25.6	24.6	26.9	29.6	33.3	31.8	33.7	30.5	27.1	26.5	26.5	342
Max Month Data w/ Losses (gpc/d)	38.7	37.1	31.0	34.2	39.4	42.2	41.6	41.2	38.7	35.0	32.3	33.5	445
Max Month Data w/ WC and Losses (gpc/d)	36.3	35.0	28.6	31.9	36.7	39.6	38.9	38.5	36.1	32.3	30.0	31.1	415

Mayville Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	7.7	7.6	7.8	7.9	8.3	8.3	8.4	7.8	7.0	6.3	5.8	5.9	89	2,120	20.0%	1.5	115
1989	6.2	6.0	6.0	6.1	7.0	6.9	7.9	6.4	6.5	6.3	5.5	5.8	77	2,106	20.0%	1.3	100
1990	5.8	5.3	6.2	5.6	6.4	5.6	6.0	7.0	6.3	6.2	6.7	4.5	72	2,092	20.0%	1.2	94
1991	6.1	5.0	5.3	5.6	6.2	5.7	6.2	6.8	6.1	6.5	5.4	5.6	71	2,078	20.0%	1.2	93
1992	5.9	5.9	5.5	6.1	5.9	5.5	6.0	5.7	6.0	5.3	5.3	5.3	68	2,064	20.0%	1.1	91
1993	5.7	5.3	5.6	5.5	6.0	5.8	5.8	6.5	6.7	6.9	6.7	5.3	72	2,050	20.0%	1.2	96
1994	5.7	5.4	5.6	5.5	6.0	6.2	6.0	6.2	6.2	6.0	6.7	5.7	71	2,036	20.0%	1.2	96
1995	6.1	5.6	5.9	5.8	6.0	6.6	6.4	6.7	6.5	6.9	6.2	5.7	74	2,023	20.0%	1.2	101
1996	5.9	5.8	6.4	7.0	6.6	6.6	9.0	8.7	6.9	6.6	6.3	6.2	82	2,009	20.0%	1.4	112
1997	6.5	5.9	6.2	6.7	6.0	6.4	5.7	5.8	6.1	6.1	5.8	5.8	73	1,995	20.0%	1.2	100
1998	5.9	5.6	6.1	6.1	6.2	5.7	6.3	6.9	6.6	6.5	6.1	5.9	74	1,981	20.0%	1.2	102
1999	6.2	7.1	5.7	5.3	5.3	5.6	5.6	6.1	5.7	6.0	5.6	5.5	70	1,967	20.0%	1.2	97
2000	5.7	5.3	5.5	5.4	5.6	5.5	6.3	6.6	5.9	5.8	5.7	5.9	69	1,953	20.0%	1.2	97
2001	6.3	5.4	6.0	5.5	5.7	5.5	5.8	5.8	5.2	5.9	5.4	5.5	68	1,939	20.0%	1.1	96
Average	6.1	5.8	6.0	6.0	6.2	6.1	6.5	6.6	6.3	6.2	5.9	5.6	74		20.0%		99.2

[1] Water loss data was not available so zero% was assumed in analysis

Per Capita Water Use Analysis (Monthly water diversion*without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	6.2	6.1	6.3	6.4	6.8	6.8	6.9	6.3	5.5	4.8	4.3	4.4	71	2,120	92	6.9	109
1989	4.9	4.7	4.7	4.8	5.7	5.6	6.6	5.1	5.2	5.0	4.2	4.5	61	2,106	80	6.6	105
1990	4.6	4.1	5.0	4.4	5.3	4.4	4.8	5.8	5.1	5.0	5.5	3.3	57	2,092	75	5.8	93
1991	4.9	3.8	4.1	4.4	5.0	4.5	5.0	5.6	4.9	5.3	4.2	4.4	56	2,078	74	5.6	90
1992	4.8	4.8	4.4	5.0	4.8	4.4	4.9	4.6	4.9	4.2	4.2	4.2	55	2,064	73	5.0	80
1993	4.5	4.1	4.4	4.3	4.8	4.6	4.6	5.3	5.5	5.7	5.5	4.1	57	2,050	77	5.7	93
1994	4.5	4.2	4.4	4.3	4.8	5.0	4.8	5.0	5.0	4.8	5.5	4.5	57	2,036	77	5.5	90
1995	4.9	4.4	4.7	4.6	4.8	5.4	5.2	5.5	5.3	5.7	5.0	4.5	60	2,023	81	5.7	93
1996	4.5	4.4	5.0	5.6	5.2	5.2	7.6	7.3	5.5	5.2	4.9	4.8	66	2,009	89	7.6	127
1997	5.3	4.7	5.0	5.5	4.8	5.2	4.5	4.6	4.9	4.9	4.6	4.6	58	1,995	80	5.5	92
1998	4.7	4.4	4.9	4.9	5.0	4.5	5.1	5.7	5.4	5.3	4.9	4.7	59	1,981	82	5.7	95
1999	5.0	5.9	4.5	4.1	4.1	4.4	4.4	4.9	4.5	4.8	4.4	4.3	56	1,967	78	5.9	101
2000	4.5	4.1	4.3	4.2	4.4	4.3	5.1	5.4	4.7	4.6	4.5	4.7	55	1,953	78	5.4	93
2001	5.2	4.3	4.9	4.4	4.6	4.4	4.7	4.7	4.1	4.8	4.3	4.4	54	1,939	77	5.2	89
Average	4.9	4.6	4.8	4.8	5.0	4.9	5.3	5.4	5.0	5.0	4.7	4.4	59		79.4	5.9	96.3
% Distrib.	8.3%	7.8%	8.1%	8.1%	8.5%	8.4%	9.0%	9.2%	8.6%	8.5%	8.0%	7.5%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	386,000	48,658	337,342	159	2.00
1989	361,000	41,973	319,027	151	1.91
1990	296,000	39,260	256,740	123	1.55
1991	429,000	38,630	390,370	188	2.37
1992	295,000	37,479	257,521	125	1.57
1993	369,000	39,342	329,658	161	2.03
1994	376,000	39,014	336,986	165	2.08
1995	490,000	40,767	449,233	222	2.80
1996	478,000	44,932	433,068	216	2.72
1997	334,000	40,000	294,000	147	1.86
1998	407,000	40,493	366,507	185	2.33
1999	374,000	38,192	335,808	171	2.15
2000	382,000	37,918	344,082	176	2.22
2001	348,000	37,260	310,740	160	2.02
Average	380,357	40,280	340,077	168	2.11

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses)	222.1
W. Conservation Reduction =	9.6
Subtotal =	212.5
Peak Daily Demand with WC and	
Water Losses =	250.1
Peak Daily Demand Factor with WC	
and Water Losses =	3.02

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	95	103	96	101	104	107	105	96	87	73	68	67	2,120	91.8
1989	75	80	72	76	88	89	101	78	83	77	67	69	2,106	79.7
1990	71	70	77	70	81	70	74	90	81	77	88	51	2,092	75.1
1991	76	66	64	71	78	73	78	87	79	83	68	69	2,078	74.4
1992	74	82	68	80	74	70	76	71	78	65	67	65	2,064	72.6
1993	71	71	69	70	76	75	72	83	89	90	89	65	2,050	76.8
1994	71	74	70	71	76	82	76	79	82	76	90	71	2,036	76.6
1995	78	77	74	75	76	88	82	87	87	90	82	71	2,023	80.6
1996	73	79	81	93	84	87	123	118	92	84	82	78	2,009	89.5
1997	85	84	81	92	77	87	73	74	82	79	77	74	1,995	80.2
1998	76	79	79	82	81	75	83	92	90	86	82	76	1,981	81.8
1999	83	108	74	70	68	75	73	81	77	79	75	71	1,967	77.7
2000	75	76	72	72	73	74	85	90	81	77	78	78	1,953	77.7
2001	86	79	81	75	76	75	78	78	70	79	73	73	1,939	76.9
Average	78	81	76	79	79	81	84	86	83	80	78	70		79.4

Mayville Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) **Winter =** **Summer =**

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	95	103	96	101	104	107	105	96	87	73	68	67	2,120	88	95
1989	75	80	72	76	88	89	101	78	83	77	67	69	2,106	73	86
1990	71	70	77	70	81	70	74	90	81	77	88	51	2,092	71	79
1991	76	66	64	71	78	73	78	87	79	83	68	69	2,078	69	80
1992	74	82	68	80	74	70	76	71	78	65	67	65	2,064	73	73
1993	71	71	69	70	76	75	72	83	89	90	89	65	2,050	73	81
1994	71	74	70	71	76	82	76	79	82	76	90	71	2,036	75	79
1995	78	77	74	75	76	88	82	87	87	90	82	71	2,023	76	85
1996	73	79	81	93	84	87	123	118	92	84	82	78	2,009	81	98
1997	85	84	81	92	77	87	73	74	82	79	77	74	1,995	82	79
1998	76	79	79	82	81	75	83	92	90	86	82	76	1,981	79	85
1999	83	108	74	70	68	75	73	81	77	79	75	71	1,967	80	76
2000	75	76	72	72	73	74	85	90	81	77	78	78	1,953	75	80
2001	86	79	81	75	76	75	78	78	70	79	73	73	1,939	78	76
Average	78	81	76	79	79	81	84	86	83	80	78	70		76.7	82

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	88
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	123
Estimated Water Losses (%) =	15%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	78	81	76	79	79	81	84	86	83	80	78	70	79.4
Average Monthly Demand w WC (gpc/d)	69	72	67	70	70	71	75	77	73	70	69	61	70.4
Average Monthly Demand w/ WC and Losses (gpc/d)	**82**	**85**	**79**	**82**	**82**	**84**	**88**	**90**	**86**	**82**	**81**	**72**	**82.8**
Max Month Data w/o Losses (gpc/d)	95	108	96	101	104	107	123	118	92	90	90	78	100.1
Max Month Data w/ Losses (gpc/d)	**111**	**127**	**113**	**119**	**122**	**126**	**144**	**139**	**108**	**106**	**106**	**92**	**117.8**
Max Month Data w/ WC (gpc/d)	86	99	88	92	94	98	113	108	82	81	82	70	91.1
Max Month Data w/ WC and Losses (gpc/d)	**101**	**117**	**103**	**109**	**111**	**115**	**133**	**127**	**97**	**95**	**96**	**82**	**107.2**

Water Losses = 15.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		1,660							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses	12.9	12.1	12.5	12.6	13.0	12.8	13.9	14.2	13.2	13.0	12.4	11.4	154
Max Month Data w/ Losses	17.6	18.1	17.9	18.2	19.3	19.3	22.8	21.9	16.5	16.8	16.2	14.6	219
Max Month Data w/ WC and Losses	16.0	16.7	16.3	16.6	17.5	17.6	21.0	20.1	14.8	15.0	14.7	13.0	199

Minto Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	1.9	1.9	1.8	1.9	1.9	2.6	2.7	2.7	1.8	1.8	1.6	1.7	24	541	10.0%	0.2	122.9
1989	1.9	2.0	1.9	1.9	1.9	1.7	2.8	2.6	1.8	1.8	1.5	1.5	23	550	10.0%	0.2	116.0
1990	1.6	1.5	1.5	1.5	1.5	1.7	1.7	1.6	1.6	1.6	1.6	1.6	19	560	10.0%	0.2	92.5
1991	1.5	1.5	1.5	1.5	1.5	1.6	1.7	1.7	1.6	1.6	1.5	1.5	19	570	10.0%	0.2	90.3
1992	1.5	1.6	1.5	1.5	1.6	1.7	1.7	1.6	1.6	1.6	1.6	1.5	19	579	10.0%	0.2	89.4
1993	1.6	1.5	1.5	1.6	1.6	1.7	1.8	1.7	1.6	1.6	1.6	1.6	19	589	10.0%	0.2	89.5
1994	1.5	1.6	1.5	1.5	1.6	1.7	1.7	1.8	1.7	1.6	1.6	1.5	19	599	10.0%	0.2	88.4
1995	1.5	1.6	1.5	1.5	1.6	1.6	1.7	1.8	1.7	1.6	1.6	1.9	20	609	10.0%	0.2	88.4
1996	1.5	1.6	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.6	1.6	1.8	20	618	10.0%	0.2	87.6
1997	1.5	1.5	1.6	1.7	1.8	1.7	1.8	1.8	1.8	1.7	1.6	1.7	20	628	10.0%	0.2	87.4
1998	1.5	1.5	1.6	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.6	1.7	20	638	10.0%	0.2	88.0
1999	1.5	1.5	1.6	1.8	1.7	1.9	1.8	1.9	1.8	1.8	1.7	1.7	21	647	10.0%	0.2	87.8
2000	1.5	1.5	1.7	1.8	1.9	2.0	2.0	2.0	1.9	1.9	1.8	1.7	22	657	10.0%	0.2	90.1
2001	1.6	1.5	1.7	1.8	1.9	1.9	1.9	2.1	1.8	1.9	1.9	1.7	22	667	10.0%	0.2	89.1
Average	1.6	1.6	1.6	1.7	1.7	1.8	1.9	1.9	1.7	1.7	1.6	1.6	20		10.0%		93.4

1 Water loss data was not available so zero% was assumed in analysis

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	1.7	1.7	1.6	1.7	1.7	2.4	2.5	2.5	1.6	1.6	1.4	1.5	22	541	111	2.5	154
1989	1.7	1.8	1.7	1.7	1.7	1.5	2.6	2.4	1.6	1.6	1.3	1.3	21	550	104	2.6	158
1990	1.4	1.3	1.4	1.4	1.3	1.5	1.5	1.4	1.4	1.4	1.4	1.4	17	560	83	1.5	91
1991	1.3	1.4	1.4	1.4	1.4	1.5	1.6	1.5	1.4	1.4	1.3	1.3	17	570	81	1.6	91
1992	1.3	1.4	1.4	1.3	1.4	1.5	1.6	1.5	1.4	1.4	1.4	1.3	17	579	80	1.6	91
1993	1.4	1.4	1.3	1.4	1.4	1.5	1.6	1.5	1.5	1.4	1.4	1.4	17	589	81	1.6	91
1994	1.4	1.4	1.4	1.4	1.4	1.5	1.6	1.6	1.5	1.4	1.4	1.4	17	599	80	1.6	91
1995	1.4	1.5	1.3	1.4	1.5	1.4	1.5	1.6	1.5	1.4	1.4	1.7	18	609	80	1.7	92
1996	1.3	1.4	1.4	1.4	1.4	1.5	1.6	1.6	1.6	1.4	1.4	1.6	18	618	79	1.6	88
1997	1.3	1.3	1.4	1.5	1.6	1.5	1.6	1.6	1.6	1.5	1.4	1.5	18	628	79	1.6	87
1998	1.3	1.3	1.5	1.6	1.6	1.6	1.6	1.7	1.6	1.6	1.5	1.5	18	638	79	1.7	87
1999	1.3	1.4	1.5	1.6	1.6	1.7	1.6	1.7	1.7	1.6	1.5	1.5	19	647	79	1.7	89
2000	1.3	1.3	1.6	1.6	1.7	1.8	1.8	1.8	1.7	1.7	1.6	1.6	19	657	81	1.8	92
2001	1.4	1.3	1.5	1.6	1.7	1.7	1.7	1.9	1.6	1.7	1.7	1.5	20	667	80	1.9	95
Average	1.4	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.6	1.5	1.5	1.5	18		84.0	1.8	99.7
% Distrib.	7.6%	7.7%	7.8%	8.2%	8.3%	8.8%	9.5%	9.5%	8.5%	8.2%	7.9%	8.0%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990	120,000	5,181	114,819	205	2.44
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
Average	120,000	5,181	114,819	205	2.44

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	205.0
W. Conservation Reduction =	9.5
Subtotal =	195.6
Peak Daily Demand with WC and	
Water Losses =	217.3
Peak Daily Demand Factor with WC	
and Water Losses =	2.60

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	101	112	95	105	99	148	149	149	99	95	86	89	541	110.6
1989	101	116	100	103	100	91	153	141	97	94	79	77	550	104.4
1990	83	86	78	82	77	89	88	83	85	80	86	83	560	83.3
1991	76	85	77	81	78	87	88	86	84	79	79	76	570	81.2
1992	73	86	77	77	78	86	88	83	82	80	82	75	579	80.5
1993	77	82	73	80	79	84	88	85	84	78	82	76	589	80.6
1994	74	86	73	77	78	83	85	88	83	75	80	74	599	79.6
1995	72	86	71	75	78	79	82	87	83	75	79	89	609	79.5
1996	70	83	71	78	75	80	82	85	87	75	77	84	618	78.8
1997	66	76	71	81	83	81	82	84	86	79	76	79	628	78.7
1998	67	74	74	82	81	85	81	84	86	81	76	77	638	79.2
1999	65	75	73	83	78	89	81	84	86	81	80	75	647	79.0
2000	65	71	76	82	83	92	88	88	87	82	82	76	657	81.1
2001	69	71	74	81	83	85	83	92	81	83	85	74	667	80.1
Average	75	85	77	83	82	90	94	94	86	81	81	79		84.0

Minto Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = (green) **Summer =** (blue)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	101	112	95	105	99	148	149	149	99	95	86	89	541	98	123
1989	101	116	100	103	100	91	153	141	97	94	79	77	550	96	113
1990	83	86	78	82	77	89	88	83	85	80	86	83	560	83	84
1991	76	85	77	81	78	87	88	86	84	79	79	76	570	79	84
1992	73	86	77	77	78	86	88	83	82	80	82	75	579	78	83
1993	77	82	73	80	79	84	88	85	84	78	82	76	589	78	83
1994	74	86	73	77	78	83	85	88	83	75	80	74	599	77	82
1995	72	86	71	75	78	79	82	87	83	75	79	89	609	79	80
1996	70	83	71	78	75	80	82	85	87	75	77	84	618	77	81
1997	66	76	71	81	83	81	82	84	86	79	76	79	628	75	82
1998	67	74	74	82	81	85	81	84	86	81	76	77	638	75	83
1999	65	75	73	83	78	89	81	84	86	81	80	75	647	75	83
2000	65	71	76	82	83	92	88	88	87	82	82	76	657	75	87
2001	69	71	74	81	83	85	83	92	81	83	85	74	667	75	85
Average	75	85	77	83	82	90	94	94	86	81	81	79		80.1	88

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	98
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	153
Estimated Water Losses (%) =	10%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	75	85	77	83	82	90	94	94	86	81	81	79	84.0
Average Monthly Demand w/ WC (gpc/d)	67	77	69	75	73	81	85	85	77	72	72	71	75.2
Average Monthly Demand w/ WC and Losses (gpc/d)	**75**	**85**	**77**	**84**	**81**	**90**	**94**	**94**	**85**	**80**	**81**	**78**	**83.6**
Max Month Data w/o Losses (gpc/d)	101	116	100	105	100	148	153	149	99	95	86	89	111.7
Max Month Data w/ Losses (gpc/d)	**112**	**129**	**111**	**116**	**111**	**164**	**170**	**166**	**109**	**106**	**96**	**99**	**124.1**
Max Month Data w/ WC (gpc/d)	93	108	92	97	91	138	143	140	89	86	78	81	102.9
Max Month Data w/ WC and Losses (gpc/d)	**103**	**120**	**102**	**107**	**101**	**154**	**159**	**155**	**99**	**95**	**87**	**90**	**114.4**

Water Losses = 10.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =				2050 Population =		660							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	4.7	4.8	4.8	5.1	5.1	5.4	5.9	5.9	5.2	5.0	4.9	4.9	62
Max Month Data w/ Losses	7.1	7.3	7.0	7.1	7.0	10.0	10.7	10.4	6.7	6.7	5.8	6.2	92
Max Month Data w/ WC and Losses	6.5	6.8	6.4	6.5	6.3	9.3	10.0	9.7	6.0	6.0	5.3	5.7	85

Moorhead Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1987	111.1	97.5	120.6	130.6	147.2	181.3	165.5	144.9	133.5	124.3	116.3	117.3	1,590	32,327	6.8%	9.0	135
1988	121.7	114.3	124.7	147.1	158.8	203.3	211.6	184.2	174.2	141.2	135.3	129.3	1,846	32,316	9.8%	15.1	156
1989	129.3	136.5	143.4	118.0	151.5	159.1	229.4	177.2	133.0	134.6	132.7	135.9	1,781	32,306	12.9%	19.1	151
1990	125.9	112.4	119.2	109.9	120.7	112.6	158.7	177.8	140.9	140.5	103.1	109.4	1,531	32,295	10.9%	13.9	130
1991	106.2	100.3	120.7	122.0	134.8	134.1	129.0	174.8	135.2	128.0	111.2	116.6	1,513	32,284	11.7%	14.8	128
1992	122.7	111.3	114.5	113.6	144.6	129.4	118.0	138.5	124.2	122.2	106.2	108.7	1,454	32,274	9.8%	11.9	123
1993	110.9	102.8	109.7	109.3	119.6	99.6	103.4	128.6	136.8	124.9	102.2	108.4	1,356	32,263	4.5%	5.1	115
1994	114.6	105.0	113.0	106.8	121.2	141.9	117.9	128.5	118.9	112.7	112.5	104.8	1,398	32,252	3.8%	4.5	119
1995	106.9	112.8	130.3	117.6	129.4	159.6	124.2	147.3	132.5	124.4	111.9	117.5	1,514	32,241	7.7%	9.7	129
1996	122.1	115.9	115.4	107.0	117.9	144.6	162.5	148.0	136.6	128.9	119.2	119.5	1,538	32,231	6.7%	8.6	131
1997	124.6	131.3	141.2	103.9	114.0	137.9	132.1	147.6	136.8	132.7	117.7	120.0	1,540	32,220	9.0%	11.6	131
1998	114.4	104.9	117.6	120.7	128.1	118.9	134.5	168.3	137.5	121.0	114.2	119.1	1,499	32,209	7.3%	9.2	128
1999	122.7	108.4	123.2	117.4	128.6	135.6	140.5	136.4	122.2	127.1	121.6	126.3	1,510	32,198	10.7%	13.4	128
2000	120.1	121.3	111.0	115.0	127.6	116.4	131.3	152.6	129.0	122.1	115.2	122.3	1,484	32,188	9.0%	11.1	126
2001	126.7	124.1	124.4	108.3	134.9	138.9	169.2	157.8	140.9	124.0	112.2	115.7	1,577	32,177	15.0%	19.7	134
Average	111.3	106.8	113.9	107.8	122.1	128.8	137.5	144.5	126.6	119.0	107.7	110.2	1,436		9.0%		122.0

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1987	102.1	88.5	111.6	121.6	138.2	172.3	156.5	135.9	124.5	115.3	107.3	108.3	1,482	32,327	126	172.3	178
1988	106.6	99.2	109.5	131.9	143.6	188.1	196.4	169.0	159.1	126.1	120.2	114.1	1,664	32,316	141	196.4	203
1989	110.2	117.4	124.3	98.9	132.5	140.0	210.4	158.1	114.0	115.6	113.6	116.8	1,552	32,306	132	210.4	217
1990	112.0	98.5	105.3	96.0	106.8	98.7	144.8	163.9	126.9	126.6	89.1	95.4	1,364	32,295	116	163.9	169
1991	91.4	85.5	105.9	107.2	120.0	119.3	114.2	160.0	120.4	113.1	96.4	101.8	1,335	32,284	113	160.0	165
1992	110.7	99.4	102.6	101.7	132.7	117.5	106.1	126.6	112.3	110.2	94.3	96.7	1,311	32,274	111	132.7	137
1993	105.8	97.7	104.6	104.2	114.5	94.5	98.3	123.5	131.7	119.8	97.1	103.3	1,295	32,263	110	131.7	136
1994	110.1	100.5	108.5	102.3	116.8	137.4	113.4	124.1	114.4	108.2	108.0	100.4	1,344	32,252	114	137.4	142
1995	97.3	103.2	120.7	107.9	119.7	149.9	114.5	137.6	122.9	114.7	102.2	107.8	1,398	32,241	119	149.9	155
1996	113.5	107.3	106.8	98.4	109.3	136.0	153.9	139.4	127.9	120.3	110.6	110.9	1,434	32,231	122	153.9	159
1997	113.0	119.7	129.6	92.3	102.4	126.3	120.5	136.0	125.2	121.1	106.1	108.4	1,401	32,220	119	136.0	141
1998	105.2	95.7	108.4	111.5	118.9	109.7	125.3	159.2	128.3	111.9	105.0	109.9	1,389	32,209	118	159.2	165
1999	109.2	95.0	109.8	104.0	115.2	122.2	127.1	123.0	108.8	113.7	108.2	112.9	1,349	32,198	115	127.1	132
2000	109.0	110.2	99.8	103.9	116.5	105.3	120.2	141.5	117.9	110.9	104.0	111.1	1,350	32,188	115	141.5	147
2001	107.0	104.4	104.7	88.6	115.2	119.2	149.5	138.1	121.2	104.3	92.5	96.0	1,340	32,177	114	149.5	155
Average	100.1	95.6	102.7	96.6	110.9	117.6	126.3	133.3	115.4	107.8	96.5	99.0	1,302		119.0	143.3	148.1
% Distrib.	7.7%	7.3%	7.9%	7.4%	8.5%	9.0%	9.7%	10.2%	8.9%	8.3%	7.4%	7.6%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1987	6,150,000	295,801	5,854,199	181	1.52
1988	9,190,000	497,734	8,692,266	269	2.26
1989	8,990,000	627,017	8,362,983	259	2.18
1990	8,370,000	457,961	7,912,039	245	2.06
1991	7,580,000	486,822	7,093,178	220	1.85
1992	6,370,000	391,482	5,978,518	185	1.56
1993	6,410,000	167,764	6,242,236	193	1.63
1994	6,480,000	146,684	6,333,316	196	1.65
1995	7,780,000	317,843	7,462,157	231	1.95
1996	6,310,000	283,014	6,026,986	187	1.57
1997	6,140,000	381,155	5,758,845	179	1.50
1998	7,090,000	301,342	6,788,658	211	1.77
1999	6,810,000	440,808	6,369,192	198	1.66
2000	6,920,000	365,885	6,554,115	204	1.71
2001	7,130,000	647,999	6,482,001	201	1.69
Average	7,181,333	387,287	6,794,046	211	1.77

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	269.0
W. Conservation Reduction =	8.7
Subtotal =	260.3
Peak Daily Demand with WC and	
Water Losses =	289.2
Peak Daily Demand Factor with WC	
and Water Losses =	2.2

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1987	102	88	111	121	138	172	156	136	124	115	107	108	32,327	125.6
1988	106	110	109	136	143	194	196	169	164	126	124	114	32,316	141.1
1989	110	130	124	102	132	144	210	158	118	115	117	117	32,306	131.6
1990	112	109	105	99	107	102	145	164	131	126	92	95	32,295	115.7
1991	91	95	106	111	120	123	114	160	124	113	100	102	32,284	113.3
1992	111	110	103	105	133	121	106	127	116	110	97	97	32,274	111.3
1993	106	108	105	108	115	98	98	124	136	120	100	103	32,263	110.0
1994	110	111	109	106	117	142	113	124	118	108	112	100	32,252	114.2
1995	97	114	121	112	120	155	115	138	127	115	106	108	32,241	118.8
1996	114	119	107	102	109	141	154	140	132	120	114	111	32,231	121.9
1997	113	133	130	95	103	131	121	136	129	121	110	109	32,220	119.1
1998	105	106	109	115	119	114	126	159	133	112	109	110	32,209	118.1
1999	109	105	110	108	115	127	127	123	113	114	112	113	32,198	114.8
2000	109	122	100	108	117	109	120	142	122	111	108	111	32,188	114.9
2001	107	116	105	92	115	123	150	138	126	105	96	96	32,177	114.1
Average	107	112	110	108	120	133	137	142	128	115	107	106		119.0

Maximum historic water use month = 210 gpc/d

Moorhead Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpcd)	Summer Per Capita Use (gpcd)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1987	102	88	111	121	138	172	156	136	124	115	107	108	32,327	106	140
1988	106	110	109	136	143	194	196	169	164	126	124	114	32,316	117	165
1989	110	130	124	102	132	144	210	158	118	115	117	117	32,306	117	146
1990	112	109	105	99	107	102	145	164	131	126	92	95	32,295	102	129
1991	91	95	106	111	120	123	114	160	124	113	100	102	32,284	101	126
1992	111	110	103	105	133	121	106	127	116	110	97	97	32,274	104	119
1993	106	108	105	108	115	98	98	124	136	120	100	103	32,263	105	115
1994	110	111	109	106	117	142	113	124	118	108	112	100	32,252	108	120
1995	97	114	121	112	120	155	115	138	127	115	106	108	32,241	110	128
1996	114	119	107	102	109	141	154	140	132	120	114	111	32,231	111	133
1997	113	133	130	95	103	131	121	136	129	121	110	109	32,220	115	123
1998	105	106	109	115	119	114	126	159	133	112	109	110	32,209	109	127
1999	109	105	110	108	115	127	127	123	113	114	112	113	32,198	110	120
2000	109	122	100	108	117	109	120	142	122	111	108	111	32,188	110	120
2001	107	116	105	92	115	123	150	138	126	105	96	96	32,177	102	126
Average	107	112	110	108	120	133	137	142	128	115	107	106		108.3	129

Historic Annual Per Capita Water Use Data (w/o system losses)

Max Year Annual Water Demand (MG) =	1,664
Max Year Industrial Water Demand (MG)* =	417
Max Year Water Demand Less Industrial Demand (MG) =	1,247

* Industrial water use will not increase proportionately to the population of Moorhead. The max year water demand prorated for a 2050 population, 22.75 gpcd/d, for industries was used in the analysis.

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpcd/d) =

Winter Demand without Losses (gpc/d) =	94
Indoor W. Conservation Reduction (gpc/d) =	7.44
Outdoor W. Conservation Reduction (gpc/d) =	0.63
Peak Monthly Demand w/o System Losses (gpc/d) =	187
Estimated Water Losses (%) =	10%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpcd)
Average Monthly Demand w/o Losses (gpc/d)	84	89	87	85	97	110	114	120	105	93	84	84	96.1
Average Monthly Demand w/ WC (gpc/d)	77	82	80	78	89	102	105	111	96	84	77	76	88.0
Average Monthly Demand w/ WC and Losses (gpc/d)	**85**	**91**	**89**	**86**	**99**	**113**	**117**	**123**	**107**	**93**	**85**	**85**	**97.8**
Max Month Data w/o Losses (gpc/d)	91	110	107	113	121	171	187	146	141	104	101	94	123.9
Max Month Data w/ Losses (gpc/d)	**101**	**122**	**119**	**126**	**134**	**190**	**208**	**162**	**157**	**115**	**112**	**104**	**137.7**
Max Month Data w/ WC (gpc/d)	83	102	100	106	112	163	179	137	133	95	94	86	115.8
Max Month Data w/ WC and Losses (gpc/d)	**93**	**114**	**111**	**118**	**124**	**181**	**198**	**153**	**147**	**106**	**104**	**96**	**128.7**

Water Losses = 10.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		50,211							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	407.2	391.0	424.5	399.3	470.9	521.8	558.9	589.0	493.6	446.0	393.9	403.9	5,499.9
Max Month Data w/ Losses	482.1	526.9	568.2	582.1	640.3	879.9	994.2	774.7	725.8	550.4	519.8	498.3	7,742.8
Max Month Data w/ WC and Losses	442.6	491.2	528.7	543.8	594.1	835.2	948.0	728.5	681.2	504.2	481.6	458.9	7,238.2

Moorheads Annual Water Needs Including Industrial* (acre-ft) =

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		50,211							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	524.5	508.3	541.8	516.6	588.2	639.0	676.2	706.3	610.9	563.3	511.2	521.2	6,907.4
Max Month Data w/ Losses	599.4	644.2	685.5	699.3	757.6	997.2	1,111.5	892.0	843.1	667.7	637.1	615.6	9,150.3
Max Month Data w/ WC and Losses	559.9	608.5	646.0	661.1	711.4	952.5	1,065.3	845.8	798.5	621.5	598.9	576.1	8,645.7

* Industrial water use will not increase proportionately to the population of Moorhead. The max year, 2000, water demand, 417 MG, for industries was used in the analysis.

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		64,432							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	522.5	501.7	544.7	512.4	604.2	669.5	717.2	755.8	633.5	572.3	505.5	518.3	7,057.6
Max Month Data w/ Losses	618.7	676.1	729.2	746.9	821.7	1,129.1	1,275.8	994.1	931.4	706.2	667.1	639.5	9,935.8
Max Month Data w/ WC and Losses	568.0	630.3	678.5	697.9	762.4	1,071.8	1,216.6	934.9	874.1	647.0	618.0	588.8	9,288.2

Moorheads Annual Water Needs Including Industrial* (acre-ft) =

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		64,432							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	639.8	619.0	662.0	629.7	721.5	786.8	834.5	873.1	750.7	689.6	622.8	635.6	8,465.1
Max Month Data w/ Losses	736.0	793.4	846.4	864.2	938.9	1,246.4	1,393.1	1,111.4	1,048.7	823.5	784.4	756.8	11,343.3
Max Month Data w/ WC and Losses	685.3	747.6	795.8	815.2	879.7	1,189.1	1,333.8	1,052.2	991.4	764.3	735.3	706.1	10,695.7

* Industrial water use will not increase proportionately to the population of Moorhead. The max year, 2000, water demand, 417 MG, for industries was used in the analysis.

North Valley Water Users Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	9.6	9.1	9.5	10.5	13.1	15.9	13.9	13.1	11.1	10.9	10.4	10.5	138	4200	30.7%	3.5	89.8
1989	11.2	9.4	10.7	10.0	12.6	13.7	15.5	12.8	10.6	10.6	9.6	9.6	136	4200	29.6%	3.4	89.0
1990	9.3	8.7	9.6	9.9	12.6	12.3	12.8	12.0	11.1	11.0	9.7	9.9	129	4200	26.1%	2.8	84.1
1991	9.7	8.8	10.0	9.8	12.7	11.9	11.2	11.5	9.8	9.7	8.8	9.1	123	4200	25.2%	2.6	80.2
1992	9.4	9.0	10.5	11.9	11.7	13.8	11.2	20.5	15.2	15.9	13.3	15.7	158	5600	22.7%	3.0	77.3
1993	14.2	13.7	15.2	15.5	19.9	19.7	18.1	16.5	15.7	15.7	14.1	14.8	193	5600	22.1%	3.6	94.4
1994	13.5	13.4	14.7	15.4	18.9	18.9	18.9	17.7	15.1	14.7	13.1	14.1	188	5400	21.1%	3.3	95.5
1995	13.8	12.7	14.0	14.0	17.1	23.0	20.1	19.9	16.0	14.9	14.0	14.3	194	5400	21.6%	3.5	98.3
1996	16.4	13.5	14.9	15.0	17.4	22.3	21.2	21.4	16.5	15.9	14.6	14.5	204	5600	21.6%	3.7	99.6
1997	14.4	13.7	16.5	17.0	18.2	23.6	19.8	19.1	17.1	16.6	15.2	15.7	207	5600	23.8%	4.1	101.1
1998	15.3	15.0	14.5	16.5	24.5	22.8	28.4	29.6	25.8	22.9	20.3	20.8	256	7600	20.1%	4.3	92.4
1999	21.0	18.6	21.2	23.3	27.4	29.8	29.6	28.2	22.5	21.1	19.6	19.8	282	7600	14.9%	3.5	101.7
2000	20.1	18.9	20.0	21.2	29.7	27.5	31.6	29.5	25.1	23.2	19.2	19.9	286	7600	18.4%	4.4	103.0
2001	18.3	16.4	18.7	19.0	22.4	27.5	31.5	25.6	20.9	20.5	19.8	21.4	262	7500	17.8%	3.9	95.7
Average	14.0	12.9	14.3	14.9	18.5	20.2	20.3	19.8	16.6	16.0	14.4	15.0	197		22.5%		93.0

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	6.1	5.6	6.0	7.0	9.6	12.3	10.4	9.6	7.6	7.4	6.9	7.0	95	4,200	62	12.3	N/A
1989	7.8	6.1	7.4	6.7	9.3	10.3	12.2	9.5	7.2	7.3	6.2	6.2	96	4,200	63	9.5	N/A
1990	6.5	5.9	6.8	7.1	9.8	9.5	10.0	9.2	8.3	8.2	6.9	7.1	95	4,200	62	9.2	N/A
1991	7.1	6.2	7.4	7.2	10.2	9.3	8.6	8.9	7.3	7.1	6.2	6.5	92	4,200	60	7.3	N/A
1992	6.4	6.1	7.5	8.9	8.7	10.8	8.2	17.5	12.2	12.9	10.3	12.7	122	5,600	60	10.8	N/A
1993	10.6	10.1	11.6	12.0	16.3	16.1	14.5	12.9	12.1	12.1	10.6	11.2	150	5,600	73	16.1	N/A
1994	10.2	10.1	11.4	12.1	15.6	15.6	15.6	14.4	11.8	11.3	9.7	10.8	149	5,400	75	15.6	N/A
1995	10.3	9.2	10.5	10.5	13.6	19.5	16.6	16.4	12.5	11.4	10.5	10.8	152	5,400	77	16.6	N/A
1996	12.7	9.8	11.2	11.3	13.7	18.6	17.6	17.7	12.9	12.2	11.0	10.8	160	5,600	78	17.6	N/A
1997	10.3	9.6	12.4	12.9	14.1	19.5	15.7	15.0	13.0	12.5	11.1	11.6	158	5,600	77	15.7	N/A
1998	11.0	10.7	10.2	12.2	20.3	18.5	24.1	25.3	21.5	18.6	16.0	16.5	205	7,600	74	21.5	N/A
1999	17.5	15.1	17.7	19.8	23.9	26.3	26.1	24.7	19.0	17.6	16.1	16.3	240	7,600	87	26.3	115
2000	15.7	14.5	15.6	16.8	25.4	23.1	27.2	25.1	20.7	18.8	14.8	15.5	233	7,600	84	27.2	119
2001	14.4	12.5	14.8	15.1	18.5	23.6	27.6	21.7	17.0	16.6	15.9	17.5	215	7,500	79	27.6	123
Average	15.9	14.0	16.0	17.2	22.6	24.3	27.0	23.8	18.9	17.7	15.6	16.4	154		72.2	77.8	119.0
% Distrib.	6.9%	6.1%	7.0%	7.5%	9.9%	10.6%	11.8%	10.4%	8.2%	7.7%	6.8%	7.2%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999	1,400,000	115,265	1,284,735	169	2.34
2000	1,400,000	144,371	1,255,629	165	2.29
2001	1,400,000	128,080	1,271,920	170	2.35
Average	1,400,000	129,239	1,270,761	168	2.33

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	169.6
W. Conservation Reduction =	9.5
Subtotal =	160.1
Peak Daily Demand with WC and Water Losses =	206.7
Peak Daily Demand Factor with WC and Water Losses =	2.53

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	47	48	46	56	74	98	80	74	60	57	55	54	4,200	62.2
1989	60	52	57	53	71	82	93	73	57	56	50	48	4,200	62.7
1990	50	50	52	56	75	75	77	71	66	63	55	55	4,200	62.1
1991	54	53	57	57	78	74	66	68	58	55	49	50	4,200	60.0
1992	37	39	43	53	50	64	47	101	73	74	62	73	5,600	59.7
1993	61	64	67	71	94	96	84	74	72	70	63	65	5,600	73.5
1994	61	66	68	75	93	96	93	86	73	68	60	64	5,400	75.3
1995	62	61	63	65	81	120	99	98	77	68	65	64	5,400	77.1
1996	73	63	65	68	79	111	101	102	77	71	65	62	5,600	78.1
1997	60	61	71	77	81	116	91	86	77	72	66	67	5,600	77.1
1998	47	50	43	54	86	81	102	107	94	79	70	70	7,600	73.9
1999	74	71	75	87	102	115	111	105	84	75	71	69	7,600	86.6
2000	67	68	66	74	108	101	116	107	91	80	65	66	7,600	84.0
2001	62	60	64	67	80	105	119	93	76	71	71	75	7,500	78.6
Average	58	58	60	65	82	95	91	89	74	68	62	63		72.2

North Valley Water Users Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) **Winter =** **Summer =**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	47	48	46	56	74	98	80	74	60	57	55	54	4,200	51	74
1989	60	52	57	53	71	82	93	73	57	56	50	48	4,200	53	72
1990	50	50	52	56	75	75	77	71	66	63	55	55	4,200	53	71
1991	54	53	57	57	78	74	66	68	58	55	49	50	4,200	53	66
1992	37	39	43	53	50	64	47	101	73	74	62	73	5,600	51	68
1993	61	64	67	71	94	96	84	74	72	70	63	65	5,600	65	82
1994	61	66	68	75	93	96	93	86	73	68	60	64	5,400	66	85
1995	62	61	63	65	81	120	99	98	77	68	65	64	5,400	63	91
1996	73	63	65	68	79	111	101	102	77	71	65	62	5,600	66	90
1997	60	61	71	77	81	116	91	86	77	72	66	67	5,600	67	87
1998	47	50	43	54	86	81	102	107	94	79	70	70	7,600	56	92
1999	74	71	75	87	102	115	111	105	84	75	71	69	7,600	74	98
2000	67	68	66	74	108	101	116	107	91	80	65	66	7,600	68	100
2001	62	60	64	67	80	105	119	93	76	71	71	75	7,500	66	91
Average	58	58	60	65	82	95	91	89	74	68	62	63		60.9	83

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	74
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	120
Estimated Water Losses (%) =	23%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	58	58	60	65	82	95	91	89	74	68	62	63	72.2
Average Monthly Demand w WC (gpc/d)	50	49	52	57	73	86	82	79	64	59	54	55	63.4
Average Monthly Demand w/ WC and Losses (gpc/d)	**64**	**64**	**67**	**74**	**94**	**111**	**106**	**103**	**83**	**76**	**69**	**71**	**81.9**
Max Month Data w/o Losses (gpc/d)	74	71	75	87	108	120	119	107	94	80	71	75	90.2
Max Month Data w/ Losses (gpc/d)	**96**	**92**	**97**	**112**	**139**	**155**	**153**	**138**	**122**	**103**	**91**	**97**	**116.5**
Max Month Data w/ WC (gpc/d)	66	63	67	79	98	111	109	98	85	70	63	67	81.4
Max Month Data w/ WC and Losses (gpc/d)	**85**	**81**	**86**	**102**	**127**	**143**	**141**	**126**	**110**	**91**	**81**	**87**	**105.1**

Water Losses = 22.5%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		5,101							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses	31.3	27.9	32.3	34.5	45.6	52.1	51.3	49.8	39.0	36.9	32.6	34.4	468
Max Month Data w/ Losses	46.6	40.2	47.0	52.6	67.4	73.0	74.3	67.2	57.2	50.0	43.0	47.2	666
Max Month Data w/ WC and Losses	41.4	35.5	41.9	47.7	61.5	67.2	68.4	61.3	51.5	44.1	38.0	42.1	601

Annual Water Needs prorated to include North Valley demands (acre-feet) =			Reclamation 2050 Pop =		5,101							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses	32.0	28.6	33.0	35.3	46.7	53.3	52.5	51.0	39.9	37.8	33.3	35.2	478.7
Max Month Data w/ Losses	48.4	41.8	48.9	54.7	70.1	75.9	77.3	69.9	59.5	52.0	44.7	49.0	692.1
Max Month Data w/ WC and Losses	43.1	37.0	43.6	49.6	64.0	69.9	71.1	63.7	53.6	45.8	39.5	43.7	624.6

Annual Water Needs prorated to include North Valley demands (acre-feet) =			Water User 2050 Pop =		8,900							Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses	55.9	49.9	57.6	61.6	81.5	93.0	91.6	88.9	69.7	65.9	58.1	61.4	835.1
Max Month Data w/ Losses	84.5	72.9	85.3	95.5	122.3	132.4	134.8	122.0	103.8	90.7	77.9	85.6	1,207.6
Max Month Data w/ WC and Losses	75.2	64.5	76.0	86.5	111.6	122.0	124.0	111.2	93.4	79.9	69.0	76.3	1,089.7

Park River Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses	Estimated Monthly Water Losses	Annual Per Capita Use
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total		(%)	(10^6-gals)	(gpc/d)
1988	7.1	6.8	7.2	7.3	7.6	9.1	9.5	7.6	7.0	7.4	7.3	7.8	92	1,753	20.7%	1.6	143
1989	6.8	6.9	7.3	6.2	7.5	7.5	9.2	7.7	6.0	6.0	5.7	5.4	82	1,739	17.4%	1.2	129
1990	6.2	6.1	6.9	5.6	6.6	7.1	7.2	6.8	5.4	5.7	5.0	5.3	74	1,725	18.1%	1.1	117
1991	5.7	6.2	7.0	6.6	5.9	5.6	6.1	6.0	5.2	5.5	5.3	5.9	71	1,711	16.7%	1.0	113
1992	5.1	4.9	4.6	5.1	5.0	5.7	6.1	6.2	6.2	5.3	5.6	5.8	66	1,697	16.5%	0.9	106
1993	5.8	6.2	7.8	7.0	6.7	7.4	6.5	6.1	5.1	4.9	6.4	7.4	77	1,683	26.3%	1.7	126
1994	7.1	6.1	6.7	6.8	6.6	6.5	6.4	6.1	5.3	6.1	6.0	5.7	76	1,669	25.0%	1.6	124
1995	6.9	5.7	6.2	6.2	6.8	7.4	7.9	6.6	5.6	6.6	6.3	6.6	79	1,655	26.8%	1.8	130
1996	7.2	7.1	6.7	6.8	6.3	7.7	6.3	6.9	5.6	5.7	6.2	6.3	79	1,641	23.5%	1.5	131
1997	6.5	6.2	6.2	6.2	7.2	8.2	6.7	6.4	5.7	5.6	4.8	5.9	76	1,627	21.9%	1.4	127
1998	5.6	4.7	5.1	5.3	6.4	7.1	7.3	6.1	5.3	5.3	4.7	5.3	68	1,613	13.7%	0.8	116
1999	5.1	4.8	5.4	5.4	5.6	7.0	7.1	6.7	5.7	5.8	5.5	5.9	70	1,599	27.6%	1.6	120
2000	5.8	5.6	4.9	5.6	5.2	7.1	7.1	7.7	6.8	5.5	5.9	5.3	72	1,535	24.5%	1.5	129
2001	5.4	4.9	5.3	5.3	6.0	6.8	7.1	6.6	5.6	5.8	4.9	5.3	69	1,521	29.9%	1.7	124
Average	6.2	5.9	6.2	6.1	6.4	7.2	7.2	6.7	5.7	5.8	5.7	6.0	75		22.1%		124.1

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use	High Monthly Water Use	Monthly High Per Capita Use
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total		(gpc/d)	(10^6-gals)	(gpc/d)
1988	5.5	5.2	5.6	5.7	6.1	7.5	7.9	6.0	5.4	5.8	5.7	6.2	73	1,753	114	7.9	150
1989	5.6	5.7	6.1	5.0	6.3	6.3	8.0	6.5	4.8	4.8	4.5	4.3	68	1,739	107	8.0	153
1990	5.1	5.0	5.8	4.4	5.4	6.0	6.1	5.7	4.3	4.5	3.9	4.2	60	1,725	96	6.1	118
1991	4.7	5.2	6.0	5.6	4.9	4.6	5.1	5.0	4.2	4.5	4.3	4.9	59	1,711	94	6.0	117
1992	4.2	4.0	3.7	4.2	4.1	4.8	5.2	5.3	5.3	4.4	4.7	4.9	55	1,697	88	5.3	105
1993	4.1	4.5	6.1	5.3	5.0	5.8	4.8	4.4	3.4	3.2	4.7	5.7	57	1,683	93	6.1	120
1994	5.5	4.6	5.1	5.2	5.1	4.9	4.9	4.5	3.8	4.6	4.4	4.2	57	1,669	93	5.5	110
1995	5.1	3.9	4.5	4.5	5.0	5.6	6.1	4.9	3.8	4.8	4.6	4.8	58	1,655	95	6.1	124
1996	5.6	5.5	5.2	5.2	4.7	6.1	4.7	5.4	4.0	4.2	4.6	4.7	60	1,641	100	6.1	125
1997	5.1	4.8	4.9	4.8	5.8	6.8	5.3	5.1	4.3	4.2	3.5	4.5	59	1,627	99	6.8	140
1998	4.8	3.9	4.3	4.5	5.6	6.3	6.6	5.3	4.5	4.6	3.9	4.5	59	1,613	100	6.6	135
1999	3.5	3.2	3.8	3.8	4.0	5.4	5.5	5.1	4.1	4.2	3.9	4.3	51	1,599	87	5.5	115
2000	4.4	4.2	3.4	4.1	3.7	5.6	5.6	6.2	5.4	4.0	4.4	3.8	55	1,535	98	6.2	135
2001	3.7	3.2	3.5	3.6	4.3	5.1	5.4	4.9	3.8	4.1	3.2	3.6	48	1,521	87	5.4	118
Average	4.8	4.5	4.9	4.7	5.0	5.8	5.8	5.3	4.4	4.4	4.3	4.6	58		96.6	6.3	126.0
% Distrib.	8.2%	7.7%	8.3%	8.1%	8.6%	9.9%	9.9%	9.1%	7.5%	7.6%	7.4%	7.9%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	587,000	51,957	535,043	305	3.16
1989	597,000	39,138	557,862	321	3.32
1990	532,000	36,723	495,277	287	2.97
1991	506,000	32,478	473,522	277	2.87
1992	437,000	29,575	407,425	240	2.49
1993	422,000	55,714	366,286	218	2.25
1994	398,000	51,678	346,322	208	2.15
1995	516,000	57,928	458,072	277	2.87
1996	566,000	50,765	515,235	314	3.25
1997	495,000	45,497	449,503	276	2.86
1998	435,000	25,681	409,319	254	2.63
1999	405,000	52,924	352,076	220	2.28
2000	540,000	48,662	491,338	320	3.31
2001	450,000	56,638	393,362	259	2.68
Average	491,857	45,383	446,474	270	2.79

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	320.8
W. Conservation Reduction =	9.6
Subtotal =	311.2
Peak Daily Demand with WC and	
Water Losses =	399.3
Peak Daily Demand Factor with WC	
and Water Losses =	3.56

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		(gpc/d)
1988	101	106	104	109	112	143	145	110	103	107	109	114	1,753	113.5
1989	103	116	114	95	117	120	148	120	93	90	86	79	1,739	106.8
1990	96	103	108	86	102	116	114	106	84	85	74	79	1,725	96.0
1991	89	108	113	110	92	90	95	94	81	84	85	92	1,711	94.5
1992	80	85	70	83	77	94	98	102	103	83	93	92	1,697	88.4
1993	79	95	116	105	96	114	93	84	68	62	93	110	1,683	92.8
1994	106	98	99	104	98	98	94	88	75	88	88	80	1,669	93.0
1995	99	85	87	90	98	113	120	95	76	93	92	94	1,655	95.4
1996	111	120	102	107	93	125	93	106	82	82	94	93	1,641	100.5
1997	101	106	96	98	115	140	106	100	89	83	71	90	1,627	99.5
1998	97	87	86	93	112	131	131	107	93	91	81	90	1,613	100.0
1999	71	72	77	79	81	113	112	103	84	84	80	87	1,599	86.9
2000	92	97	71	89	77	122	117	130	116	85	96	80	1,535	97.6
2001	79	74	75	79	90	112	114	104	84	86	71	76	1,521	87.2
Average	93	97	94	95	97	117	113	104	88	86	87	90		96.6

Maximum historic water use month = 148 gpc/d

Park River Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) **Winter =** **Summer =**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	101	106	104	109	112	143	145	110	103	107	109	114	1,753	107	120
1989	103	116	114	95	117	120	148	120	93	90	86	79	1,739	99	115
1990	96	103	108	86	102	116	114	106	84	85	74	79	1,725	91	101
1991	89	108	113	110	92	90	95	94	81	84	85	92	1,711	100	90
1992	80	85	70	83	77	94	98	102	103	83	93	92	1,697	84	93
1993	79	95	116	105	96	114	93	84	68	62	93	110	1,683	100	86
1994	106	98	99	104	98	98	94	88	75	88	88	80	1,669	96	90
1995	99	85	87	90	98	113	120	95	76	93	92	94	1,655	91	99
1996	111	120	102	107	93	125	93	106	82	82	94	93	1,641	104	97
1997	101	106	96	98	115	140	106	100	89	83	71	90	1,627	94	105
1998	97	87	86	93	112	131	131	107	93	91	81	90	1,613	89	111
1999	71	72	77	79	81	113	112	103	84	84	80	87	1,599	77	96
2000	92	97	71	89	77	122	117	130	116	85	96	80	1,535	87	108
2001	79	74	75	79	90	112	114	104	84	86	71	76	1,521	76	99
Average	93	97	94	95	97	117	113	104	88	86	87	90		92.5	101

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	107
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	148
Estimated Water Losses (%) =	22%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	93	97	94	95	97	117	113	104	88	86	87	90	96.6
Average Monthly Demand w/ WC (gpc/d)	85	88	86	86	88	107	103	94	78	76	78	81	87.5
Average Monthly Demand w/ WC and Losses (gpc/d)	**109**	**113**	**110**	**111**	**112**	**137**	**133**	**121**	**101**	**98**	**100**	**104**	**112.3**
Max Month Data w/o Losses (gpc/d)	111	120	116	110	117	143	148	130	116	107	109	114	120.0
Max Month Data w/ Losses (gpc/d)	**142**	**154**	**149**	**141**	**150**	**184**	**190**	**167**	**149**	**137**	**139**	**146**	**154.0**
Max Month Data w/ WC (gpc/d)	102	112	108	101	107	134	139	121	107	97	100	105	111.0
Max Month Data w/ WC and Losses (gpc/d)	**131**	**143**	**138**	**130**	**137**	**171**	**178**	**155**	**137**	**124**	**129**	**135**	**142.4**

Water Losses = 22.1%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		1,540								**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	15.9	15.0	16.1	15.7	16.5	19.5	19.4	17.7	14.3	14.4	14.2	15.3	194
Max Month Data w/ Losses (gpc/d)	20.8	20.4	21.8	20.0	21.9	26.0	27.8	24.5	21.2	20.0	19.8	21.4	266
Max Month Data w/ WC and Losses (gpc/d)	19.2	19.0	20.2	18.4	20.1	24.3	26.0	22.7	19.4	18.2	18.2	19.8	246

Pembina Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	1.2	1.2	1.3	1.4	1.5	1.5	1.5	1.5	1.5	1.4	1.3	1.4	17	642	0.0%	0.0	71.1
1989	1.6	1.3	1.7	1.6	1.7	2.2	2.1	2.2	1.8	1.6	1.6	1.3	20	642	0.0%	0.0	87.4
1990	1.4	1.3	1.5	1.5	1.6	1.7	1.7	1.7	1.7	1.5	1.4	1.5	19	642	0.0%	0.0	79.8
1991	1.6	0.8	0.8	1.1	1.0	1.1	1.8	1.2	1.8	1.1	0.8	1.5	15	642	0.0%	0.0	62.4
1992	1.9	2.2	2.3	2.5	2.4	2.4	2.1	2.3	2.4	2.0	2.4	2.5	27	642	0.0%	0.0	116.3
1993	1.7	1.6	1.6	2.8	2.2	3.4	2.6	2.4	2.4	1.9	1.7	1.9	26	642	0.0%	0.0	111.9
1994	2.1	1.8	2.1	2.5	3.0	2.3	3.0	2.5	2.6	2.0	2.0	2.3	28	642	0.0%	0.0	120.2
1995	2.1	2.2	2.2	2.1	2.5	2.7	3.0	2.7	2.2	2.7	1.6	2.5	29	642	0.0%	0.0	121.8
1996	1.9	1.8	2.3	1.9	1.9	3.0	2.2	2.9	2.9	1.9	2.0	2.4	27	642	0.0%	0.0	115.3
1997	1.7	1.8	2.4	2.2	2.3	2.5	2.3	2.2	2.7	2.0	2.3	1.9	27	642	0.0%	0.0	113.2
1998	1.9	2.0	2.7	2.3	3.1	2.7	2.4	3.2	2.4	2.4	2.9	2.2	30	642	0.0%	0.0	129.1
1999	2.5	2.1	2.0	2.1	2.9	2.6	1.7	2.7	2.3	3.0	2.2	2.2	28	642	0.0%	0.0	120.4
2000	1.9	2.0	1.9	2.6	2.3	2.1	2.7	2.1	2.1	2.8	2.1	2.8	27	642	0.0%	0.0	116.7
2001	2.2	2.4	2.3	2.2	2.3	1.8	2.5	2.0	2.4	2.1	2.0	2.3	27	642	0.0%	0.0	113.2
Average	1.8	1.7	1.9	2.0	2.2	2.3	2.3	2.3	2.2	2.0	1.9	2.1	25		0.0%		105.6

1 Water loss data was not available so zero% was assumed in analysis

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	1.2	1.2	1.3	1.4	1.5	1.5	1.5	1.5	1.5	1.4	1.3	1.4	17	642	71	1.5	80
1989	1.6	1.3	1.7	1.6	1.7	2.2	2.1	2.2	1.8	1.6	1.6	1.3	20	642	87	2.2	113
1990	1.4	1.3	1.5	1.5	1.6	1.7	1.7	1.7	1.7	1.5	1.4	1.5	19	642	80	1.7	90
1991	1.6	0.8	0.8	1.1	1.0	1.1	1.8	1.2	1.8	1.1	0.8	1.5	15	642	62	1.8	94
1992	1.9	2.2	2.3	2.5	2.4	2.4	2.1	2.3	2.4	2.0	2.4	2.5	27	642	116	2.5	129
1993	1.7	1.6	1.6	2.8	2.2	3.4	2.6	2.4	2.4	1.9	1.7	1.9	26	642	112	3.4	175
1994	2.1	1.8	2.1	2.5	3.0	2.3	3.0	2.5	2.6	2.0	2.0	2.3	28	642	120	3.0	154
1995	2.1	2.2	2.2	2.1	2.5	2.7	3.0	2.7	2.2	2.7	1.6	2.5	29	642	122	3.0	157
1996	1.9	1.8	2.3	1.9	1.9	3.0	2.2	2.9	2.9	1.9	2.0	2.4	27	642	115	3.0	154
1997	1.7	1.8	2.4	2.2	2.3	2.5	2.3	2.2	2.7	2.0	2.3	1.9	27	642	113	2.7	142
1998	1.9	2.0	2.7	2.3	3.1	2.7	2.4	3.2	2.4	2.4	2.9	2.2	30	642	129	3.2	167
1999	2.5	2.1	2.0	2.1	2.9	2.6	1.7	2.7	2.3	3.0	2.2	2.2	28	642	120	3.0	157
2000	1.9	2.0	1.9	2.6	2.3	2.1	2.7	2.1	2.1	2.8	2.1	2.8	27	642	117	2.8	147
2001	2.2	2.4	2.3	2.2	2.3	1.8	2.5	2.0	2.4	2.1	2.0	2.3	27	642	113	2.5	131
Average	1.8	1.7	1.9	2.0	2.2	2.3	2.3	2.3	2.2	2.0	1.9	2.1	25		105.6	2.6	135.0
% Distrib.	7.5%	7.0%	7.8%	8.2%	8.8%	9.3%	9.1%	9.2%	9.0%	8.3%	7.6%	8.3%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
Average	0	0	0	0	0.00

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses)	
W. Conservation Reduction =	
Subtotal =	
Peak Daily Demand with WC and Water Losses =	
Peak Daily Demand Factor with WC and Water Losses =	

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	62	65	65	71	74	80	76	77	78	69	66	69	642	71.1
1989	78	70	86	84	84	113	106	109	93	78	82	65	642	87.4
1990	70	73	74	80	83	90	86	86	87	78	74	78	642	79.8
1991	81	43	40	55	48	59	91	62	92	57	43	75	642	62.4
1992	97	123	113	129	118	124	104	117	123	100	126	125	642	116.3
1993	87	89	79	145	110	175	132	122	124	96	90	94	642	111.9
1994	107	99	106	129	149	121	149	126	134	103	102	116	642	120.2
1995	107	120	111	107	126	141	152	137	116	134	85	125	642	121.8
1996	94	98	117	98	95	154	111	147	151	98	101	119	642	115.3
1997	88	102	122	112	117	131	113	112	142	103	119	98	642	113.2
1998	94	109	136	119	155	143	122	162	127	123	149	109	642	129.1
1999	125	116	100	108	144	134	88	133	117	152	113	113	642	120.4
2000	95	109	97	133	113	111	134	107	109	142	110	139	642	116.7
2001	113	131	117	112	114	91	127	101	123	107	106	117	642	113.2
Average	93	96	97	106	109	119	114	114	115	103	98	103		105.6

Pembina Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	62	65	65	71	74	80	76	77	78	69	66	69	642	66	76
1989	78	70	86	84	84	113	106	109	93	78	82	65	642	77	97
1990	70	73	74	80	83	90	86	86	87	78	74	78	642	75	85
1991	81	43	40	55	48	59	91	62	92	57	43	75	642	56	68
1992	97	123	113	129	118	124	104	117	123	100	126	125	642	119	114
1993	87	89	79	145	110	175	132	122	124	96	90	94	642	97	127
1994	107	99	106	129	149	121	149	126	134	103	102	116	642	110	130
1995	107	120	111	107	126	141	152	137	116	134	85	125	642	109	134
1996	94	98	117	98	95	154	111	147	151	98	101	119	642	105	126
1997	88	102	122	112	117	131	113	112	142	103	119	98	642	107	120
1998	94	109	136	119	155	143	122	162	127	123	149	109	642	119	138
1999	125	116	100	108	144	134	88	133	117	152	113	113	642	113	128
2000	95	109	97	133	113	111	134	107	109	142	110	139	642	114	119
2001	113	131	117	112	114	91	127	101	123	107	106	117	642	116	111
Average	93	96	97	106	109	119	114	114	115	103	98	103		98.8	112

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	119
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	175
Estimated Water Losses (%) =	0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	93	96	97	106	109	119	114	114	115	103	98	103	105.6
Average Monthly Demand w/ WC (gpc/d)	85	88	89	98	100	110	104	105	106	93	89	95	96.8
Average Monthly Demand w/ WC and Losses (gpc/d)	**85**	**88**	**89**	**98**	**100**	**110**	**104**	**105**	**106**	**93**	**89**	**95**	**96.8**
Max Month Data w/o Losses (gpc/d)	125	131	136	145	155	175	152	162	151	152	149	139	147.6
Max Month Data w/ Losses (gpc/d)	**125**	**131**	**136**	**145**	**155**	**175**	**152**	**162**	**151**	**152**	**149**	**139**	**147.6**
Max Month Data w/ WC (gpc/d)	117	123	128	137	145	166	142	152	141	143	141	130	138.8
Max Month Data w/ WC and Losses (gpc/d)	**117**	**123**	**128**	**137**	**145**	**166**	**142**	**152**	**141**	**143**	**141**	**130**	**138.8**

Water Losses = 0.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		640							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	5.1	4.8	5.4	5.8	6.1	6.5	6.3	6.4	6.2	5.7	5.3	5.8	69
Max Month Data w/ Losses	7.6	7.2	8.3	8.5	9.4	10.3	9.2	9.9	8.9	9.3	8.8	8.4	106
Max Month Data w/ WC and Losses	7.1	6.7	7.8	8.1	8.8	9.8	8.7	9.3	8.3	8.7	8.3	7.9	100

Ransom-Sargent Rural Water Users Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0.0%	0.0	0
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0		10.0%		0.0

1 Water loss data was incomplete and possible in error so assumed 0%

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1,963	0	0.0	0
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0		0.0	0.0	0.0
% Distrib.	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
Average					

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	142.9
W. Conservation Reduction =	9.5
Subtotal =	133.5
Peak Daily Demand with WC and	
Water Losses =	148.3
Peak Daily Demand Factor with WC	
and Water Losses =	1.83

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1989	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1990	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1991	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1992	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1993	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1994	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1995	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1996	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1997	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1998	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
1999	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
2000	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
2001	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0.0
Average	0	0	0	0	0	0	0	0	0	0	0	0		0.0

Ransom-Sargent Rural Water Users Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) **Winter =** **Summer =**

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	1,963	0	0
Average	0	0	0	0	0	0	0	0	0	0	0	0		0.0	0

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	0
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	110
Estimated Water Losses (%) =	10%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	82	82	82	82	82	82	82	82	82	82	82	82	81.6
Average Monthly Demand w WC (gpc/d)	73	73	73	73	72	72	72	72	72	72	73	73	72.8
Average Monthly Demand w/ WC and Losses (gpc/d)	**82**	**82**	**82**	**82**	**80**	**80**	**80**	**80**	**80**	**80**	**82**	**82**	**80.9**
Max Month Data w/o Losses (gpc/d)	80	80	80	90	100	110	110	100	90	80	80	80	90.1
Max Month Data w/ Losses (gpc/d)	**89**	**89**	**89**	**100**	**111**	**122**	**122**	**111**	**100**	**89**	**89**	**89**	**100.1**
Max Month Data w/ WC (gpc/d)	72	72	72	82	91	101	101	91	81	71	72	72	81.2
Max Month Data w/ WC and Losses (gpc/d)	**80**	**80**	**80**	**91**	**101**	**112**	**112**	**101**	**90**	**78**	**80**	**80**	**90.3**

Water Losses = 10.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =	1,036								**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses	8.0	7.3	8.0	7.8	7.9	7.6	7.9	7.9	7.6	7.9	7.8	8.0	93.9
Max Month Data w/ Losses	8.8	7.9	8.8	9.5	11.0	11.7	12.0	11.0	9.5	8.8	8.5	8.8	116.1
Max Month Data w/ WC and Losses	7.9	7.1	7.9	8.7	9.9	10.7	11.0	9.9	8.5	7.7	7.6	7.9	104.8

Annual Water Needs (acre-feet) =			Water User 2050 Pop =	2,673								**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses	20.8	18.7	20.8	20.1	20.4	19.7	20.4	20.4	19.7	20.4	20.1	20.8	242.2
Max Month Data w/ Losses	22.6	20.4	22.6	24.6	28.3	30.1	31.1	28.3	24.6	22.6	21.9	22.6	299.6
Max Month Data w/ WC and Losses	20.3	18.3	20.3	22.4	25.6	27.5	28.4	25.6	22.0	19.9	19.6	20.3	270.3

Southeast Water Users Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	6.1	6.2	8.0	7.2	9.1	10.2	9.3	7.5	6.6	5.4	5.3	6.1	87	2,915	32.2%	2.3	82
1989	7.2	6.2	7.8	8.1	10.0	10.6	9.9	8.3	6.9	6.8	6.7	8.7	97	2,971	41.7%	3.4	90
1990	5.9	5.7	6.4	6.8	9.0	9.0	9.0	8.9	7.8	7.2	6.8	7.9	90	3,445	34.7%	2.6	72
1991	6.8	5.5	6.0	8.9	8.6	7.4	8.8	11.3	11.4	10.3	8.7	8.3	102	4,275	33.9%	2.9	65
1992	8.3	7.8	8.9	8.1	11.0	10.8	8.3	9.9	9.0	8.5	8.7	8.7	108	4,400	11.8%	1.1	67
1993	10.1	8.6	10.4	9.9	11.1	12.0	12.6	12.5	11.7	10.2	9.1	10.2	128	4,518	12.7%	1.4	78
1994	9.8	10.3	10.6	10.9	15.7	15.8	13.8	12.3	11.3	10.0	11.0	11.2	143	4,593	22.9%	2.7	85
1995	9.9	10.0	10.5	11.0	11.5	15.9	15.9	13.2	11.6	11.7	12.5	12.3	146	4,715	18.9%	2.3	85
1996	10.0	10.6	11.3	11.1	12.6	15.1	14.4	14.6	12.6	11.9	11.4	11.7	147	4,805	11.7%	1.4	84
1997	10.3	9.5	10.2	12.5	16.7	17.9	14.1	14.0	12.4	11.3	10.8	9.8	149	4,911	15.0%	1.9	83
1998	12.4	8.5	8.4	10.2	17.4	16.4	18.3	16.7	10.4	12.2	10.9	10.5	152	5,032	16.2%	2.1	83
1999	11.3	10.8	10.2	12.5	16.5	17.4	16.4	15.4	13.2	13.2	12.7	12.9	162	5,149	16.0%	2.2	86
2000	12.3	10.8	11.8	11.9	16.3	16.7	14.5	17.4	13.8	12.1	10.8	12.3	161	5,224	14.2%	1.9	84
2001	11.3	11.3	12.6	12.6	15.5	15.9	18.4	16.9	14.4	14.2	12.6	13.5	169	5,310	17.3%	2.4	87
Average	9.4	8.7	9.5	10.1	12.9	13.7	13.1	12.8	10.9	10.3	9.9	10.3	132		21.4%		80.9

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	3.8	3.9	5.6	4.9	6.8	7.8	6.9	5.1	4.3	3.0	3.0	3.8	59	2,915	55	7.8	90
1989	3.8	2.9	4.5	4.7	6.6	7.2	6.5	4.9	3.5	3.4	3.3	5.3	57	2,971	52	7.2	81
1990	3.3	3.1	3.7	4.2	6.4	6.4	6.4	6.3	5.2	4.5	4.2	5.3	59	3,445	47	6.4	62
1991	3.9	2.7	3.2	6.1	5.8	4.5	5.9	8.4	8.5	7.4	5.8	5.5	68	4,275	43	8.5	67
1992	7.2	6.7	7.8	7.1	9.9	9.7	7.3	8.9	8.0	7.5	7.6	7.6	95	4,400	59	9.9	75
1993	8.7	7.2	9.0	8.5	9.8	10.6	11.3	11.1	10.3	8.8	7.8	8.9	112	4,518	68	11.3	83
1994	7.0	7.6	7.8	8.2	13.0	13.1	11.1	9.6	8.6	7.2	8.3	8.4	110	4,593	66	13.1	95
1995	7.6	7.7	8.2	8.7	9.2	13.6	13.6	10.9	9.3	9.4	10.2	10.0	119	4,715	69	13.6	96
1996	8.5	9.1	9.9	9.7	11.2	13.7	13.0	13.1	11.2	10.4	10.0	10.2	130	4,805	74	13.7	95
1997	8.4	7.6	8.4	10.6	14.9	16.1	12.3	12.1	10.5	9.4	8.9	7.9	127	4,911	71	16.1	109
1998	10.3	6.4	6.4	8.2	15.4	14.3	16.2	14.7	8.3	10.2	8.9	8.4	128	5,032	70	16.2	107
1999	9.1	8.7	8.1	10.3	14.4	15.2	14.2	13.2	11.0	11.1	10.5	10.7	137	5,149	73	15.2	99
2000	10.4	8.9	9.9	10.0	14.4	14.8	12.6	15.5	11.9	10.2	8.9	10.4	138	5,224	72	15.5	99
2001	8.8	8.9	10.1	10.2	13.0	13.5	16.0	14.5	11.9	11.8	10.2	11.0	140	5,310	72	16.0	100
Average	7.2	6.5	7.3	8.0	10.8	11.5	10.9	10.6	8.8	8.2	7.7	8.1	106		63.7	12.2	89.8
% Distrib.	6.8%	6.2%	7.0%	7.5%	10.2%	10.9%	10.4%	10.0%	8.3%	7.7%	7.3%	7.7%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	351,000	76,849	274,151	94	1.48
1989	388,000	110,860	277,140	93	1.47
1990	421,000	85,899	335,101	97	1.53
1991	449,000	94,791	354,209	83	1.30
1992	477,000	34,774	442,226	101	1.58
1993	499,000	44,630	454,370	101	1.58
1994	551,000	89,479	461,521	100	1.58
1995	545,000	75,570	469,430	100	1.56
1996	589,000	47,150	541,850	113	1.77
1997	594,000	61,586	532,414	108	1.70
1998	601,000	67,847	533,153	106	1.66
1999	647,000	71,104	575,896	112	1.76
2000	635,000	62,611	572,389	110	1.72
2001	666,000	79,972	586,028	110	1.73
Average	529,500	71,652	457,848	102	1.60

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	112.8
W. Conservation Reduction =	9.5
Subtotal =	103.3
Peak Daily Demand with WC and	
Water Losses =	121.6
Peak Daily Demand Factor with WC	
and Water Losses =	1.88

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	42	48	62	56	75	90	76	57	49	34	34	42	2,915	55.5
1989	42	34	48	53	72	81	71	53	40	37	37	57	2,971	52.2
1990	31	32	35	41	60	62	60	59	50	43	40	50	3,445	46.9
1991	29	22	24	47	43	35	44	63	67	56	45	41	4,275	43.3
1992	53	54	57	53	73	74	53	65	60	55	58	56	4,400	59.3
1993	62	57	64	63	70	79	81	80	76	63	57	63	4,518	68.0
1994	49	59	55	59	91	95	78	67	63	51	60	59	4,593	65.6
1995	52	58	56	62	63	96	93	74	66	65	72	68	4,715	68.9
1996	57	68	66	67	75	95	87	88	78	70	69	69	4,805	74.1
1997	55	55	55	72	98	109	81	80	71	62	61	52	4,911	70.9
1998	66	46	41	54	99	95	104	94	55	65	59	54	5,032	69.5
1999	57	60	51	67	90	99	89	83	71	69	68	67	5,149	72.6
2000	64	61	61	64	89	95	78	96	76	63	56	64	5,224	72.4
2001	54	60	62	64	79	85	97	88	75	72	64	67	5,310	72.2
Average	51	51	53	59	77	85	78	75	64	57	56	58		63.7

Southeast Water Users Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	42	48	62	56	75	90	76	57	49	34	34	42	2,915	47	63
1989	42	34	48	53	72	81	71	53	40	37	37	57	2,971	45	59
1990	31	32	35	41	60	62	60	59	50	43	40	50	3,445	38	55
1991	29	22	24	47	43	35	44	63	67	56	45	41	4,275	35	51
1992	53	54	57	53	73	74	53	65	60	55	58	56	4,400	55	63
1993	62	57	64	63	70	79	81	80	76	63	57	63	4,518	61	75
1994	49	59	55	59	91	95	78	67	63	51	60	59	4,593	57	74
1995	52	58	56	62	63	96	93	74	66	65	72	68	4,715	61	76
1996	57	68	66	67	75	95	87	88	78	70	69	69	4,805	66	82
1997	55	55	55	72	98	109	81	80	71	62	61	52	4,911	58	83
1998	66	46	41	54	99	95	104	94	55	65	59	54	5,032	53	85
1999	57	60	51	67	90	99	89	83	71	69	68	67	5,149	62	84
2000	64	61	61	64	89	95	78	96	76	63	56	64	5,224	62	83
2001	54	60	62	64	79	85	97	88	75	72	64	67	5,310	62	83
Average	51	51	53	59	77	85	78	75	64	57	56	58		54.6	73

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	66
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	109
Estimated Water Losses (%) =	15%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	51	51	53	59	77	85	78	75	64	57	56	58	63.7
Average Monthly Demand w/ WC (gpc/d)	43	43	45	51	67	75	69	65	55	48	48	50	54.9
Average Monthly Demand w/ WC and Losses (gpc/d)	**51**	**51**	**52**	**59**	**79**	**89**	**81**	**77**	**64**	**56**	**56**	**58**	**64.5**
Max Month Data w/o Losses (gpc/d)	66	68	66	72	99	109	104	96	78	72	72	69	80.9
Max Month Data w/ Losses (gpc/d)	**78**	**80**	**78**	**85**	**116**	**128**	**122**	**113**	**91**	**84**	**85**	**81**	**95.2**
Max Month Data w/ WC (gpc/d)	58	60	58	64	89	100	94	86	68	62	64	61	72.1
Max Month Data w/ WC and Losses (gpc/d)	**68**	**70**	**68**	**75**	**105**	**117**	**111**	**102**	**80**	**73**	**75**	**71**	**84.8**

Water Losses = 15.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =	7,273								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	34.9	31.6	36.3	39.8	54.9	59.4	55.8	53.2	43.0	39.0	37.6	40.5	526
Max Month Data w/ Losses	54.0	50.0	54.0	56.6	80.2	85.8	84.6	78.0	61.1	58.3	56.9	55.9	775
Max Month Data w/ WC and Losses	47.3	44.0	47.4	50.2	72.6	78.4	76.9	70.3	53.7	50.6	50.5	49.3	691

Annual Water Needs prorated to include additional cities (acre-feet) =			Reclamation 2050 Pop =	7,273								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	45.1	40.8	46.9	51.5	70.9	76.7	72.1	68.7	55.5	50.3	48.5	52.3	679.2
Max Month Data w/ Losses	68.2	63.2	68.3	71.6	101.4	108.5	106.9	98.6	77.2	73.7	72.0	70.7	980.3
Max Month Data w/ WC and Losses	59.9	55.6	59.9	63.5	91.7	99.1	97.2	88.9	67.8	64.0	63.8	62.3	873.6

Annual Water Needs (acre-feet) =			Water User 2050 Pop =	7,500								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	46.5	42.1	48.3	53.1	73.1	79.1	74.3	70.9	57.2	51.9	50.0	53.9	700.4
Max Month Data w/ Losses	70.4	65.1	70.4	73.8	104.6	111.9	110.3	101.7	79.7	76.0	74.2	72.9	1,010.9
Max Month Data w/ WC and Losses	61.7	57.3	61.7	65.4	94.6	102.2	100.2	91.7	70.0	66.0	65.8	64.2	900.9

Traill County Water Users Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	10.9	11.7	13.1	13.6	15.8	16.7	14.5	14.7	12.9	13.3	11.7	11.2	160	2,800	37.0%	4.9	157
1989	7.6	7.6	9.1	8.6	11.3	12.1	11.6	10.1	8.4	9.1	7.9	7.8	111	2,800	37.0%	3.4	109
1990	7.7	6.7	6.8	8.3	10.2	9.6	8.6	9.8	8.1	8.3	8.1	7.7	100	2,800	37.0%	3.1	98
1991	8.0	7.9	7.5	8.0	8.5	10.9	8.7	9.9	9.8	8.6	8.4	10.1	106	2,800	37.0%	3.3	104
1992	8.5	7.2	9.2	9.4	12.4	9.5	9.7	8.6	8.8	9.0	8.5	8.0	109	2,800	37.0%	3.4	106
1993	7.7	7.7	10.8	8.2	11.4	11.1	10.8	14.0	11.5	11.9	10.1	11.8	127	2,800	37.0%	3.9	124
1994	10.9	10.1	11.2	10.3	13.3	11.1	11.5	11.8	11.8	11.2	11.9	11.4	136	2,800	37.0%	4.2	134
1995	14.1	9.1	13.1	11.6	13.4	15.4	11.8	12.6	11.4	12.4	11.1	10.8	147	2,800	37.0%	4.5	144
1996	10.6	10.0	10.1	11.5	12.0	13.7	12.3	11.4	11.8	9.3	10.4	10.9	134	2,800	37.0%	4.1	131
1997	9.5	8.6	10.8	12.0	12.5	16.1	12.8	11.8	10.9	11.7	8.3	16.0	141	2,800	37.0%	4.3	138
1998	9.7	9.7	11.5	11.4	15.6	13.8	13.2	13.3	11.6	11.8	9.9	10.6	142	2,800	37.0%	4.4	139
1999	9.5	8.5	10.3	10.8	12.1	14.5	15.2	13.0	11.7	13.7	12.5	12.8	144	2,800	37.0%	4.5	141
2000	11.2	10.8	12.0	12.0	13.7	14.2	13.0	13.1	12.2	14.6	12.1	12.6	152	2,800	37.0%	4.7	148
2001	10.3	10.8	12.4	11.9	13.5	14.0	13.1	13.1	12.0	12.3	13.2	13.2	150	2,800	37.0%	4.6	147
Average	9.7	9.0	10.6	10.5	12.6	13.0	11.9	12.0	10.9	11.2	10.3	11.1	133		37.0%		130.0

[1] Water loss data was incomplete so assumed 0%

Per Capita Water Use Analysis (Monthly water diversion*without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	6.0	6.8	8.1	8.6	10.8	11.8	9.6	9.8	8.0	8.3	6.8	6.3	101	2,800	99	11.8	140
1989	4.2	4.2	5.7	5.1	7.9	8.6	8.2	6.7	5.0	5.7	4.4	4.3	70	2,800	69	8.6	103
1990	4.6	3.6	3.7	5.3	7.1	6.5	5.5	6.7	5.0	5.2	5.0	4.6	63	2,800	62	7.1	85
1991	4.7	4.6	4.2	4.7	5.2	7.7	5.4	6.6	6.5	5.3	5.1	6.9	67	2,800	66	7.7	91
1992	5.1	3.9	5.9	6.0	9.0	6.1	6.4	5.3	5.4	5.6	5.1	4.6	69	2,800	67	9.0	108
1993	3.7	3.8	6.9	4.3	7.5	7.2	6.9	10.1	7.5	8.0	6.2	7.9	80	2,800	78	10.1	120
1994	6.7	5.9	7.0	6.1	9.1	6.9	7.3	7.6	7.6	7.0	7.7	7.2	86	2,800	84	9.1	108
1995	9.6	4.5	8.6	7.1	8.9	10.9	7.3	8.1	6.8	7.9	6.5	6.2	92	2,800	90	10.9	129
1996	6.5	5.8	6.0	7.3	7.8	9.6	8.2	7.3	7.7	5.1	6.2	6.8	84	2,800	83	9.6	114
1997	5.1	4.2	6.4	7.6	8.2	11.7	8.4	7.4	6.6	7.3	4.0	11.7	89	2,800	87	11.7	140
1998	5.3	5.3	7.1	7.0	11.2	9.4	8.8	8.9	7.2	7.5	5.6	6.2	90	2,800	88	11.2	134
1999	5.1	4.1	5.8	6.3	7.6	10.0	10.7	8.5	7.2	9.3	8.0	8.3	91	2,800	89	10.7	128
2000	6.5	6.1	7.4	7.3	9.1	9.5	8.4	8.4	7.6	9.9	7.4	7.9	95	2,800	93	9.9	118
2001	5.7	6.1	7.8	7.3	8.8	9.4	8.5	8.5	7.4	7.7	8.6	8.6	94	2,800	92	9.4	112
Average	5.6	4.9	6.5	6.4	8.5	8.9	7.8	7.9	6.8	7.1	6.2	7.0	84		81.9	9.8	116.4
% Distrib.	6.7%	5.9%	7.7%	7.7%	10.1%	10.7%	9.4%	9.4%	8.2%	8.5%	7.4%	8.3%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001	1,000,000	151,919	848,081	303	3.70
Average	1,000,000	151,919	848,081	303	3.70

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	302.9
W. Conservation Reduction =	9.5
Subtotal =	293.4
Peak Daily Demand with WC and	
Water Losses =	465.8
Peak Daily Demand Factor with WC	
and Water Losses =	4.02

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	69	87	94	103	125	140	111	113	95	96	80	72	2,800	98.7
1989	48	54	65	61	91	103	94	77	59	66	53	50	2,800	68.5
1990	53	46	42	63	82	78	63	77	60	60	60	53	2,800	61.6
1991	54	59	48	56	60	91	63	76	78	61	61	79	2,800	65.6
1992	59	49	68	72	104	73	73	61	65	65	61	53	2,800	67.0
1993	43	48	80	51	86	85	79	116	90	92	74	91	2,800	78.3
1994	77	75	80	72	105	82	84	88	90	81	92	83	2,800	84.1
1995	110	58	99	85	102	129	84	94	81	91	78	72	2,800	90.5
1996	75	75	69	87	90	114	95	84	91	59	74	79	2,800	82.7
1997	59	54	74	91	94	140	97	86	78	85	47	134	2,800	86.8
1998	61	67	82	84	129	112	101	103	86	86	66	71	2,800	87.6
1999	58	52	67	75	88	119	123	98	86	107	95	96	2,800	89.1
2000	75	78	85	87	104	114	96	97	90	114	88	91	2,800	93.4
2001	65	78	90	86	102	112	98	98	88	89	102	99	2,800	92.4
Average	65	63	75	77	97	107	90	91	81	82	74	80		81.9

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = Summer =

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	69	87	94	103	125	140	111	113	95	96	80	72	2,800	84	113
1989	48	54	65	61	91	103	94	77	59	66	53	50	2,800	55	82
1990	53	46	42	63	82	78	63	77	60	60	60	53	2,800	53	70
1991	54	59	48	56	60	91	63	76	78	61	61	79	2,800	60	72
1992	59	49	68	72	104	73	73	61	65	65	61	53	2,800	60	73
1993	43	48	80	51	86	85	79	116	90	92	74	91	2,800	64	92
1994	77	75	80	72	105	82	84	88	90	81	92	83	2,800	80	88
1995	110	58	99	85	102	129	84	94	81	91	78	72	2,800	84	97
1996	75	75	69	87	90	114	95	84	91	59	74	79	2,800	76	89
1997	59	54	74	91	94	140	97	86	78	85	47	134	2,800	77	97
1998	61	67	82	84	129	112	101	103	86	86	66	71	2,800	72	103
1999	58	52	67	75	88	119	123	98	86	107	95	96	2,800	74	104
2000	75	78	85	87	104	114	96	97	90	114	88	91	2,800	84	103
2001	65	78	90	86	102	112	98	98	88	89	102	99	2,800	87	98
Average	65	63	75	77	97	107	90	91	81	82	74	80		72	91

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = Summer =

Year	Historic Monthly Metered Water Usage American Crystal Sugar (gallons per capita/day)												Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1988	12	13	12	12	4	4	4	12	12	12	12	12	2,800	12	8
1989	12	13	12	12	4	4	4	12	12	12	12	12	2,800	12	8
1990	12	13	12	12	4	4	4	12	12	12	12	12	2,800	12	8
1991	12	13	12	12	4	4	4	12	12	12	12	12	2,800	12	8
1992	12	13	12	12	4	4	4	12	12	12	12	12	2,800	12	8
1993	12	13	12	12	4	4	4	12	12	12	12	12	2,800	12	8
1994	12	13	12	12	4	4	4	12	12	12	12	12	2,800	12	8
1995	17	19	17	18	4	4	4	17	18	17	18	17	2,800	18	11
1996	17	19	17	18	4	4	4	17	18	17	18	17	2,800	18	11
1997	17	19	17	18	4	4	4	17	18	17	18	17	2,800	18	11
1998	17	19	17	18	4	4	4	17	18	17	18	17	2,800	18	11
1999	17	19	17	18	4	4	4	17	18	17	18	17	2,800	18	11
2000	17	19	17	18	4	4	4	17	18	17	18	17	2,800	18	11
2001	17	19	17	18	4	4	4	17	18	17	18	17	2,800	18	11
Average	14	16	14	15	4	4	4	14	15	14	15	14		15	9

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = Summer =

Traill County Water Users Water Demand Calculations
Maximum Month Method

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage Less American Crystal Sugar (gallons per capita/day)														
1988	57	74	82	91	121	136	107	101	83	84	68	61	2,800	72	105
1989	37	41	54	49	87	99	90	65	47	54	41	38	2,800	43	74
1990	42	33	31	51	78	73	59	66	48	48	48	42	2,800	41	62
1991	43	46	37	44	56	87	59	65	66	50	49	68	2,800	48	64
1992	48	37	56	60	100	69	69	49	53	53	49	42	2,800	49	66
1993	32	35	68	39	82	81	75	105	78	81	62	79	2,800	53	84
1994	66	62	69	60	101	78	80	76	78	69	80	71	2,800	68	80
1995	93	39	82	67	98	125	80	76	63	74	60	54	2,800	66	86
1996	57	55	52	69	86	110	91	67	73	42	56	61	2,800	59	78
1997	42	35	57	73	90	135	93	68	61	67	29	117	2,800	59	86
1998	44	48	65	66	125	108	97	85	68	69	48	54	2,800	54	92
1999	41	33	50	57	84	115	119	81	68	90	78	79	2,800	56	93
2000	58	59	68	70	100	109	92	79	72	97	70	74	2,800	66	92
2001	48	59	73	68	98	108	94	81	70	72	85	82	2,800	69	87
Average	50	47	60	62	93	102	86	76	66	68	59	66		57	82

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation Less American Crystal Sugar (gpc/d) =

Winter Demand without Losses (gpc/d) = 84
Indoor W. Conservation Reduction (gpc/d) = 8.15
Outdoor W. Conservation Reduction (gpc/d) = 0.65
Peak Monthly Demand w/o System Losses (gpc/d) = 136
Estimated Water Losses (%) = 37%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	50	47	60	62	93	102	86	76	66	68	59	66	69.8
Average Monthly Demand w/ WC (gpc/d)	42	39	52	54	84	93	77	67	57	58	51	58	61.0
Average Monthly Demand w/ WC and Losses (gpc/d)	**67**	**61**	**83**	**85**	**133**	**147**	**122**	**106**	**90**	**93**	**81**	**92**	**96.9**
Max Month Data w/o Losses (gpc/d)	93	74	82	91	125	136	119	105	83	97	85	117	100.8
Max Month Data w/ Losses (gpc/d)	**147**	**117**	**130**	**144**	**199**	**215**	**190**	**166**	**132**	**153**	**134**	**186**	**160.0**
Max Month Data w/ WC (gpc/d)	85	66	74	83	116	126	110	95	74	87	76	109	92.0
Max Month Data w/ WC and Losses (gpc/d)	**134**	**104**	**117**	**131**	**184**	**200**	**175**	**151**	**117**	**138**	**121**	**173**	**146.0**

Water Losses = 37.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		4,527							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	28.9	23.9	35.5	35.4	57.4	61.5	52.4	45.6	37.7	39.9	33.6	39.5	491
Max Month Data w/ Losses	63.5	45.6	56.2	60.0	85.7	89.8	81.6	71.7	55.2	66.1	56.0	80.0	811
Max Month Data w/ WC and Losses	57.9	40.5	50.6	54.6	79.2	83.6	75.2	65.2	48.9	59.6	50.6	74.4	740

Maximum Month Water Demand with Water Conservation American Crystal Sugar (gpc/d) =

Winter Demand without Losses (gpc/d) = 18
Indoor W. Conservation Reduction (gpc/d) = 0
Outdoor W. Conservation Reduction (gpc/d) = 0
Peak Monthly Demand w/o System Losses (gpc/d) = 19
Estimated Water Losses (%) = 37%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	14	16	14	15	4	4	4	14	15	14	15	14	12.0
Average Monthly Demand w/ WC (gpc/d)	14	16	14	15	4	4	4	14	15	14	15	14	12.0
Average Monthly Demand w/ WC and Losses (gpc/d)	**23**	**25**	**23**	**24**	**6**	**7**	**6**	**23**	**24**	**23**	**24**	**23**	**19.1**
Max Month Data w/o Losses (gpc/d)	17	19	17	18	4	4	4	17	18	17	18	17	14.2
Max Month Data w/ Losses (gpc/d)	**27**	**30**	**27**	**28**	**6**	**7**	**6**	**27**	**28**	**27**	**28**	**27**	**22.6**
Max Month Data w/ WC (gpc/d)	17	19	17	18	4	4	4	17	18	17	18	17	14.2
Max Month Data w/ WC and Losses (gpc/d)	**27**	**30**	**27**	**28**	**6**	**7**	**6**	**27**	**28**	**27**	**28**	**27**	**22.6**

Water Losses = 37.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		4,527							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	9.8	9.8	9.8	9.8	2.8	2.8	2.8	9.8	9.8	9.8	9.8	9.8	97
Max Month Data w/ Losses	11.8	11.8	11.8	11.8	2.8	2.8	2.8	11.8	11.8	11.8	11.8	11.8	115
Max Month Data w/ WC and Losses	11.8	11.8	11.8	11.8	2.8	2.8	2.8	11.8	11.8	11.8	11.8	11.8	115

Traill County Water Users Annual Water Needs Including American Crystal Sugar and Service to Hillsboro and Mayville (acre-ft) =

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		4,527							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	35.2	30.7	41.2	41.2	54.6	58.4	50.2	50.4	43.2	45.2	39.4	44.8	534.4
Max Month Data w/ Losses (gpc/d)	64.1	48.8	57.8	61.1	75.2	78.7	71.8	71.0	57.0	66.3	57.6	78.1	787.4
Max Month Data w/ WC and Losses (gpc/d)	59.3	44.5	53.1	56.5	69.7	73.4	66.3	65.5	51.6	60.8	53.1	73.3	727.1

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		2,800							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	21.8	19.0	25.5	25.5	33.8	36.1	31.0	31.1	26.7	27.9	24.4	27.7	330.5
Max Month Data w/ Losses	39.6	30.2	35.8	37.8	46.5	48.7	44.4	43.9	35.2	41.0	35.6	48.3	487.0
Max Month Data w/ WC and Losses	36.7	27.5	32.8	34.9	43.1	45.4	41.0	40.5	31.9	37.6	32.8	45.4	449.7

Tri-County Water Users Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	7.2	5.4	6.6	6.6	5.6	5.2	4.0	5.2	6.0	4.4	3.8	3.9	64	2,800	0.0%	0.0	63
1989	6.2	6.9	8.2	7.6	7.7	9.5	8.0	10.1	6.6	6.6	6.3	6.6	90	2,800	0.0%	0.0	88
1990	7.1	5.7	8.4	5.6	8.1	10.5	10.3	8.9	6.9	6.0	9.0	9.1	96	2,800	0.0%	0.0	94
1991	7.4	7.9	10.4	9.8	10.3	8.7	8.4	10.3	7.7	6.9	6.7	8.7	103	2,800	0.0%	0.0	101
1992	4.6	5.8	8.2	9.3	8.5	8.2	8.3	8.5	7.2	9.5	7.4	8.7	94	2,800	0.0%	0.0	92
1993	7.5	6.6	9.6	9.0	9.7	12.8	7.8	4.4	4.5	8.1	8.3	8.0	96	2,800	0.0%	0.0	94
1994	9.4	6.8	9.7	6.7	8.1	8.1	9.2	8.8	8.1	7.8	10.8	6.4	100	2,800	0.0%	0.0	98
1995	6.2	6.2	6.2	6.6	7.0	5.8	17.8	9.2	3.5	9.6	5.0	10.2	93	2,800	0.0%	0.0	91
1996	9.1	9.8	9.3	6.0	11.6	9.6	11.7	3.4	7.1	16.4	2.9	2.0	99	2,800	0.0%	0.0	97
1997	8.2	8.2	8.4	9.8	10.6	11.2	10.1	10.5	8.9	10.0	11.5	9.8	117	2,800	0.0%	0.0	115
1998	4.4	4.3	4.1	4.2	4.7	6.6	6.3	6.6	5.8	6.1	4.9	5.1	63	2,800	0.0%	0.0	62
1999	5.8	5.1	5.1	5.3	6.1	6.2	6.2	6.8	5.1	5.0	5.1	4.6	66	2,800	0.0%	0.0	65
2000	5.5	5.0	4.9	5.3	5.1	6.8	5.9	5.1	5.9	4.8	4.4	5.4	64	2,800	0.0%	0.0	63
2001	5.8	5.0	4.7	6.0	5.7	5.8	5.8	6.6	5.6	4.8	4.9	5.8	66	2,800	0.0%	0.0	65
Average	6.7	6.3	7.4	7.0	7.8	8.2	8.6	7.5	6.3	7.6	6.5	6.7	87		0.0%		84.8

[1] No water loss data was provided so assumed 0%

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	7.2	5.4	6.6	6.6	5.6	5.2	4.0	5.2	6.0	4.4	3.8	3.9	64	2,800	63	7.2	86
1989	6.2	6.9	8.2	7.6	7.7	9.5	8.0	10.1	6.6	6.6	6.3	6.6	90	2,800	88	10.1	121
1990	7.1	5.7	8.4	5.6	8.1	10.5	10.3	8.9	6.9	6.0	9.0	9.1	96	2,800	94	10.5	125
1991	7.4	7.9	10.4	9.8	10.3	8.7	8.4	10.3	7.7	6.9	6.7	8.7	103	2,800	101	10.4	124
1992	4.6	5.8	8.2	9.3	8.5	8.2	8.3	8.5	7.2	9.5	7.4	8.7	94	2,800	92	9.5	113
1993	7.5	6.6	9.6	9.0	9.7	12.8	7.8	4.4	4.5	8.1	8.3	8.0	96	2,800	94	12.8	153
1994	9.4	6.8	9.7	6.7	8.1	8.1	9.2	8.8	8.1	7.8	10.8	6.4	100	2,800	98	10.8	129
1995	6.2	6.2	6.2	6.6	7.0	5.8	17.8	9.2	3.5	9.6	5.0	10.2	93	2,800	91	17.8	212
1996	9.1	9.8	9.3	6.0	11.6	9.6	11.7	3.4	7.1	16.4	2.9	2.0	99	2,800	97	16.4	195
1997	8.2	8.2	8.4	9.8	10.6	11.2	10.1	10.5	8.9	10.0	11.5	9.8	117	2,800	115	11.5	136
1998	4.4	4.3	4.1	4.2	4.7	6.6	6.3	6.6	5.8	6.1	4.9	5.1	63	2,800	62	6.6	79
1999	5.8	5.1	5.1	5.3	6.1	6.2	6.2	6.8	5.1	5.0	5.1	4.6	66	2,800	65	6.8	81
2000	5.5	5.0	4.9	5.3	5.1	6.8	5.9	5.1	5.9	4.8	4.4	5.4	64	2,800	63	6.8	81
2001	5.8	5.0	4.7	6.0	5.7	5.8	5.8	6.6	5.6	4.8	4.9	5.8	66	2,800	65	6.6	79
Average	6.7	6.3	7.4	7.0	7.8	8.2	8.6	7.5	6.3	7.6	6.5	6.7	87		84.8	10.3	122.4
% Distrib.	7.8%	7.3%	8.6%	8.1%	9.0%	9.5%	9.9%	8.6%	7.3%	8.7%	7.5%	7.8%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
Average					

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	
W. Conservation Reduction =	
Subtotal =	
Peak Daily Demand with WC and	
Water Losses =	
Peak Daily Demand Factor with WC	
and Water Losses =	

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	83	69	76	79	65	62	46	60	71	51	45	45	2,800	62.7
1989	71	88	94	90	89	114	92	117	78	76	75	76	2,800	88.4
1990	82	73	97	66	94	125	119	103	82	69	107	105	2,800	93.5
1991	85	101	120	116	119	103	97	119	92	79	79	101	2,800	100.9
1992	53	74	95	111	98	98	96	97	86	109	88	100	2,800	92.1
1993	86	84	111	107	112	153	90	51	54	93	99	92	2,800	94.2
1994	108	87	112	80	93	97	106	102	96	90	129	74	2,800	97.9
1995	71	79	71	79	81	69	206	105	41	111	59	117	2,800	91.2
1996	104	125	107	72	134	115	135	39	84	189	34	23	2,800	96.7
1997	95	104	97	117	122	134	116	121	106	115	136	113	2,800	114.7
1998	50	55	48	50	54	79	73	76	69	70	58	58	2,800	61.7
1999	67	66	58	63	71	74	71	78	61	57	61	53	2,800	64.9
2000	63	63	57	63	59	81	68	59	70	55	52	62	2,800	62.7
2001	67	63	54	71	66	69	67	76	67	55	59	66	2,800	65.0
Average	78	81	85	83	90	98	99	86	76	87	77	77		84.8

Tri-County Water Users Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) Winter = Summer =

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	83	69	76	79	65	62	46	60	71	51	45	45	2,800	66	59
1989	71	88	94	90	89	114	92	117	78	76	75	76	2,800	82	94
1990	82	73	97	66	94	125	119	103	82	69	107	105	2,800	88	98
1991	85	101	120	116	119	103	97	119	92	79	79	101	2,800	100	101
1992	53	74	95	111	98	98	96	97	86	109	88	100	2,800	87	97
1993	86	84	111	107	112	153	90	51	54	93	99	92	2,800	97	92
1994	108	87	112	80	93	97	106	102	96	90	129	74	2,800	98	97
1995	71	79	71	79	81	69	206	105	41	111	59	117	2,800	79	102
1996	104	125	107	72	134	115	135	39	84	189	34	23	2,800	77	116
1997	95	104	97	117	122	134	116	121	106	115	136	113	2,800	110	119
1998	50	55	48	50	54	79	73	76	69	70	58	58	2,800	53	70
1999	67	66	58	63	71	74	71	78	61	57	61	53	2,800	61	69
2000	63	63	57	63	59	81	68	59	70	55	52	62	2,800	60	65
2001	67	63	54	71	66	69	67	76	67	55	59	66	2,800	63	67
Average	78	81	85	83	90	98	99	86	76	87	77	77		80.3	89

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	110
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	206
Estimated Water Losses (%) =	0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/ Losses (gpc/d)	78	81	85	83	90	98	99	86	76	87	77	77	84.8
Average Monthly Demand w/ WC (gpc/d)	69	73	77	75	80	88	89	76	66	78	69	69	75.9
Average Monthly Demand w/ WC and Losses (gpc/d)	**69**	**73**	**77**	**75**	**80**	**88**	**89**	**76**	**66**	**78**	**69**	**69**	**75.9**
Max Month Data w/o Losses (gpc/d)	108	125	120	117	134	153	206	121	106	189	136	117	136.3
Max Month Data w/ Losses (gpc/d)	**108**	**125**	**120**	**117**	**134**	**153**	**206**	**121**	**106**	**189**	**136**	**117**	**136.3**
Max Month Data w/ WC (gpc/d)	100	117	112	109	125	143	196	112	97	179	128	109	127.5
Max Month Data w/ WC and Losses (gpc/d)	**100**	**117**	**112**	**109**	**125**	**143**	**196**	**112**	**97**	**179**	**128**	**109**	**127.5**

Water Losses = 0.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =	2,185								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	14.4	13.7	16.1	15.1	16.7	17.8	18.6	15.9	13.3	16.1	13.9	14.4	185.9
Max Month Data w/ Losses	22.5	23.5	25.0	23.6	27.9	30.7	42.8	25.2	21.4	39.2	27.4	24.4	333.6
Max Month Data w/ WC and Losses	20.8	22.0	23.3	21.9	25.9	28.8	40.8	23.2	19.5	37.3	25.8	22.7	312.0

Annual Water Needs (acre-feet) =			Water User 2050 Pop =	2,800								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	18.5	17.5	20.6	19.3	21.4	22.8	23.8	20.4	17.0	20.7	17.9	18.5	238.2
Max Month Data w/ Losses	28.8	30.1	32.0	30.2	35.7	39.3	54.8	32.3	27.4	50.3	35.2	31.3	427.5
Max Month Data w/ WC and Losses	26.6	28.2	29.9	28.1	33.2	36.9	52.3	29.8	25.0	47.7	33.1	29.1	399.8

Valley City Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Percent Unaccounted for Losses (%)	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
1988	25.6	25.1	27.9	32.8	35.1	51.9	46.8	34.4	32.9	28.1	28.6	30.1	399	7,230	30.9%	10.3	151
1989	30.5	30.7	20.4	22.3	30.1	32.2	43.9	46.2	25.3	24.9	25.1	21.6	353	7,197	22.4%	6.6	134
1990	26.6	18.6	21.1	24.0	29.0	25.0	33.5	38.1	24.9	23.7	22.8	22.4	310	7,163	11.9%	3.1	118
1991	23.2	20.0	23.9	23.2	27.3	30.0	32.7	40.9	27.3	27.6	25.3	24.9	326	7,129	23.1%	6.3	125
1992	20.0	18.5	20.7	21.7	26.8	26.2	25.6	27.4	21.3	22.5	19.1	20.1	270	7,096	8.6%	1.9	104
1993	19.4	17.9	20.5	21.0	30.2	23.7	23.5	27.5	24.7	22.8	20.3	20.8	272	7,062	6.9%	1.6	106
1994	20.2	19.7	21.5	21.4	28.6	29.6	24.4	28.6	22.7	21.8	19.9	21.1	280	7,028	10.1%	2.3	109
1995	21.1	19.7	21.7	20.9	25.0	34.3	26.7	32.3	24.0	22.0	20.9	21.0	290	6,995	19.6%	4.7	113
1996	21.9	24.1	22.1	21.5	26.6	27.1	28.6	33.7	24.2	22.7	21.1	21.1	295	6,961	16.5%	4.0	116
1997	21.4	19.8	22.0	22.7	25.4	28.3	29.2	32.8	24.1	23.3	20.5	22.0	291	6,927	21.0%	5.1	115
1998	21.5	21.4	25.3	23.4	26.3	24.7	32.9	33.9	27.5	23.3	19.3	20.0	299	6,893	15.4%	3.8	119
1999	21.0	19.2	21.2	23.9	24.7	28.6	28.8	26.9	22.3	20.6	18.9	19.0	275	6,860	12.4%	2.8	110
2000	18.0	17.4	19.0	18.4	23.9	23.3	27.7	30.2	24.1	20.3	18.8	19.9	261	6,826	8.9%	1.9	105
2001	18.6	16.5	19.1	18.4	23.0	21.2	28.4	25.6	24.1	21.3	18.7	19.4	254	6,792	13.1%	2.8	103
Average	22.1	20.6	21.9	22.5	27.3	29.0	30.9	32.7	24.9	23.2	21.4	21.7	298		15.8%		116.4

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
1988	15.3	14.8	17.6	22.5	24.8	41.7	36.5	24.1	22.6	17.8	18.3	19.8	276	7,230	104	41.7	192
1989	23.8	24.1	13.8	15.7	23.5	25.6	37.3	39.6	18.7	18.3	18.5	15.0	274	7,197	104	39.6	183
1990	23.6	15.5	18.1	21.0	25.9	21.9	30.4	35.0	21.8	20.6	19.7	19.4	273	7,163	104	35.0	163
1991	16.9	13.7	17.6	16.9	21.0	23.7	26.4	34.6	21.0	21.4	19.1	18.6	251	7,129	96	34.6	162
1992	18.0	16.6	18.8	19.7	24.9	24.3	23.7	25.4	19.3	20.6	17.1	18.2	247	7,096	95	25.4	119
1993	17.9	16.3	18.9	19.4	28.6	22.1	21.9	25.9	23.1	21.2	18.7	19.2	253	7,062	98	28.6	135
1994	17.9	17.4	19.2	19.1	26.3	27.3	22.1	26.3	20.4	19.5	17.5	18.8	251	7,028	98	27.3	129
1995	16.3	14.9	16.9	16.1	20.3	29.6	22.0	27.6	19.3	17.3	16.2	16.3	233	6,995	91	29.6	141
1996	17.8	20.0	18.1	17.5	22.5	23.0	24.5	29.6	20.2	18.6	17.0	17.1	246	6,961	97	29.6	142
1997	16.3	14.7	16.9	17.6	20.3	23.2	24.1	27.7	19.0	18.2	15.4	16.9	230	6,927	91	27.7	133
1998	17.7	17.6	21.5	19.5	22.4	20.8	29.0	30.1	23.6	19.5	15.4	16.2	253	6,893	101	30.1	145
1999	18.2	16.3	18.4	21.1	21.8	25.8	26.0	24.0	19.4	17.7	16.0	16.1	241	6,860	96	26.0	126
2000	16.1	15.5	17.0	16.5	22.0	21.4	25.7	28.2	22.1	18.4	16.9	17.9	238	6,826	95	28.2	138
2001	15.8	13.7	16.3	15.7	20.2	18.4	25.7	22.8	21.3	18.5	15.9	16.6	221	6,792	89	25.7	126
Average	18.0	16.5	17.8	18.5	23.2	24.9	26.8	28.6	20.8	19.1	17.3	17.6	249		97.2	30.6	145.4
% Distrib.	7.2%	6.6%	7.1%	7.4%	9.3%	10.0%	10.8%	11.5%	8.4%	7.7%	6.9%	7.1%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	2,070,000	338,055	1,731,945	240	2.46
1989	2,110,000	217,137	1,892,863	263	2.70
1990	1,900,000	101,359	1,798,641	251	2.58
1991	1,660,000	206,573	1,453,427	204	2.10
1992	1,310,000	63,488	1,246,512	176	1.81
1993	1,370,000	51,737	1,318,263	187	1.92
1994	1,440,000	77,216	1,362,784	194	1.99
1995	1,780,000	155,225	1,624,775	232	2.39
1996	1,470,000	133,093	1,336,907	192	1.98
1997	1,400,000	167,515	1,232,485	178	1.83
1998	1,630,000	126,499	1,503,501	218	2.24
1999	2,390,000	93,132	2,296,868	335	3.44
2000	1,600,000	63,844	1,536,156	225	2.31
2001	1,460,000	90,973	1,369,027	202	2.07
Average	1,685,000	134,703	1,550,297	221	2.27

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	334.8
W. Conservation Reduction =	9.6
Subtotal =	325.3
Peak Daily Demand with WC and Water Losses =	386.2
Peak Daily Demand Factor with WC and Water Losses =	3.69

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Average Per Capita Use (gpc/d)
1988	68	73	79	104	110	192	163	108	104	80	84	88	7,230	104.5
1989	107	119	62	73	105	118	167	177	87	82	86	67	7,197	104.3
1990	106	77	81	98	117	102	137	158	101	93	92	87	7,163	104.3
1991	76	69	80	79	95	111	119	157	98	97	89	84	7,129	96.4
1992	82	83	85	93	113	114	108	116	91	94	81	83	7,096	95.2
1993	82	83	86	92	131	105	100	118	109	97	88	88	7,062	98.3
1994	82	88	88	90	121	129	101	121	97	89	83	86	7,028	98.0
1995	75	76	78	77	93	141	101	127	92	80	77	75	6,995	91.2
1996	83	103	84	84	104	110	114	137	97	86	82	79	6,961	96.8
1997	76	76	79	85	94	111	112	129	91	85	74	78	6,927	91.0
1998	83	91	100	94	105	101	136	141	114	91	74	76	6,893	100.6
1999	86	85	86	102	103	125	122	113	94	83	78	76	6,860	96.2
2000	76	81	81	81	104	104	122	133	108	87	82	85	6,826	95.4
2001	75	72	78	77	96	90	122	108	105	88	78	79	6,792	89.1
Average	83	84	82	88	107	118	123	132	99	88	82	81		97.2

Maximum historic water use month = 192 gpc/d

Valley City Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) **Winter =** **Summer =**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	68	73	79	104	110	192	163	108	104	80	84	88	7,230	83	126
1989	107	119	62	73	105	118	167	177	87	82	86	67	7,197	86	123
1990	106	77	81	98	117	102	137	158	101	93	92	87	7,163	90	118
1991	76	69	80	79	95	111	119	157	98	97	89	84	7,129	80	113
1992	82	83	85	93	113	114	108	116	91	94	81	83	7,096	84	106
1993	82	83	86	92	131	105	100	118	109	97	88	88	7,062	86	110
1994	82	88	88	90	121	129	101	121	97	89	83	86	7,028	86	110
1995	75	76	78	77	93	141	101	127	92	80	77	75	6,995	77	106
1996	83	103	84	84	104	110	114	137	97	86	82	79	6,961	86	108
1997	76	76	79	85	94	111	112	129	91	85	74	78	6,927	78	104
1998	83	91	100	94	105	101	136	141	114	91	74	76	6,893	86	115
1999	86	85	86	102	103	125	122	113	94	83	78	76	6,860	86	107
2000	76	81	81	81	104	104	122	133	108	87	82	85	6,826	81	110
2001	75	72	78	77	96	90	122	108	105	88	78	79	6,792	76	101
Average	83	84	82	88	107	118	123	132	99	88	82	81		83.2	111

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	83
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	192
Estimated Water Losses (%) =	16%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	83	84	82	88	107	118	123	132	99	88	82	81	97.2
Average Monthly Demand w/ WC (gpc/d)	74	76	73	79	97	109	114	122	90	78	74	72	88.2
Average Monthly Demand w/ WC and Losses (gpc/d)	**88**	**90**	**87**	**94**	**115**	**129**	**135**	**145**	**106**	**93**	**87**	**86**	**104.7**
Max Month Data w/o Losses (gpc/d)	107	119	100	104	131	192	167	177	114	97	92	88	124.1
Max Month Data w/ Losses (gpc/d)	**127**	**142**	**119**	**123**	**155**	**228**	**198**	**211**	**136**	**115**	**109**	**105**	**147.3**
Max Month Data w/ WC (gpc/d)	98	111	92	95	121	182	158	168	105	87	83	80	115.0
Max Month Data w/ WC and Losses (gpc/d)	**117**	**132**	**109**	**113**	**144**	**217**	**187**	**199**	**124**	**104**	**99**	**95**	**136.6**

Water Losses = 15.8%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		5,840							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	48.9	45.0	48.5	50.6	64.0	69.3	74.9	80.5	57.2	51.7	47.0	47.7	685
Max Month Data w/ Losses (gpc/d)	70.5	71.2	66.3	66.2	86.1	122.6	110.3	117.1	72.9	63.9	58.4	58.2	964
Max Month Data w/ WC and Losses (gpc/d)	64.9	66.1	60.7	60.8	79.8	116.5	103.9	110.7	66.8	57.6	53.0	52.7	894

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		7,500							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	62.8	57.8	62.2	65.0	82.1	89.0	96.2	103.4	73.4	66.4	60.3	61.3	880.0
Max Month Data w/ Losses (gpc/d)	90.6	91.4	85.1	85.1	110.6	157.5	141.6	150.3	93.6	82.1	75.0	74.8	1,237.6
Max Month Data w/ WC and Losses (gpc/d)	83.4	84.9	78.0	78.1	102.5	149.6	133.5	142.2	85.7	74.0	68.1	67.6	1,147.6

Wahpeton Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	29.1	27.9	29.5	31.7	35.8	48.3	42.5	35.4	33.8	30.4	27.8	29.4	402	8,784	19.6%	6.5	125
1989	30.6	27.2	29.6	30.3	34.7	36.3	50.1	41.6	31.0	31.2	27.8	29.5	400	8,768	23.3%	7.8	125
1990	29.7	27.3	29.5	29.9	34.3	33.0	39.3	43.4	32.5	32.0	28.8	29.7	390	8,751	19.7%	6.4	122
1991	29.4	26.9	29.6	28.6	29.8	32.1	39.9	46.2	30.2	29.5	29.0	31.2	383	8,735	14.0%	4.5	120
1992	28.6	27.1	29.3	28.0	33.4	31.6	31.0	33.0	30.6	30.6	26.7	27.3	357	8,718	15.0%	4.5	112
1993	28.9	26.1	29.8	29.6	32.2	31.0	30.4	36.1	34.2	31.9	31.3	30.7	372	8,702	19.4%	6.0	117
1994	30.9	27.8	31.6	30.3	33.3	40.8	33.7	36.3	33.9	32.3	29.2	29.2	389	8,685	22.9%	7.4	123
1995	30.1	27.1	30.1	31.2	31.4	40.3	33.7	43.1	34.5	32.1	30.6	30.1	394	8,669	22.7%	7.5	125
1996	29.6	33.2	30.9	30.7	33.0	38.8	43.5	40.9	36.1	32.7	29.7	29.9	409	8,652	22.8%	7.8	130
1997	31.9	28.4	30.1	32.8	33.6	40.8	35.9	38.7	37.6	35.3	31.1	31.4	408	8,636	22.8%	7.7	129
1998	27.9	28.2	30.0	31.8	34.8	36.9	42.2	41.5	39.0	33.7	30.6	29.2	406	8,619	11.7%	4.0	129
1999	28.8	26.5	28.1	29.7	32.8	33.9	35.5	35.8	31.0	29.6	31.1	31.3	374	8,603	13.6%	4.2	119
2000	29.6	28.4	29.8	29.6	34.3	32.9	35.7	43.7	34.6	31.7	29.5	27.2	387	8,586	12.2%	3.9	123
2001	27.8	24.9	28.7	27.6	30.0	30.5	38.8	43.7	34.2	31.3	28.2	28.0	374	8,570	11.3%	3.5	119
Average	29.5	27.6	29.8	30.1	33.1	36.2	38.0	40.0	33.8	31.7	29.4	29.6	389		17.9%		122.8

[1] Water loss data was not available for 2000 and 1996 so water loss % were simmulated for those years

Per Capita Water Use Analysis (Monthly water diversion*without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	22.5	21.4	23.0	25.2	29.3	41.7	35.9	28.8	27.3	23.9	21.3	22.8	323	8,784	101	41.7	158
1989	22.8	19.4	21.8	22.6	26.9	28.5	42.3	33.8	23.3	23.4	20.0	21.7	307	8,768	96	42.3	161
1990	23.3	20.9	23.1	23.5	27.9	26.6	32.9	37.0	26.1	25.6	22.4	23.3	313	8,751	98	37.0	141
1991	25.0	22.5	25.2	24.2	25.3	27.7	35.4	41.7	25.8	25.1	24.5	26.8	329	8,735	103	41.7	159
1992	24.2	22.6	24.9	23.5	28.9	27.2	26.5	28.5	26.1	26.1	22.2	22.8	303	8,718	95	28.9	111
1993	22.9	20.0	23.8	23.6	26.2	25.0	24.3	30.1	28.1	25.9	25.2	24.6	300	8,702	94	30.1	115
1994	23.4	20.4	24.1	22.9	25.9	33.4	26.2	28.8	26.5	24.9	21.8	21.8	300	8,685	95	33.4	128
1995	22.6	19.6	22.6	23.7	23.9	32.9	26.3	35.6	27.1	24.6	23.1	22.6	305	8,669	96	35.6	137
1996	21.9	25.4	23.1	23.0	25.2	31.0	35.8	33.1	28.3	24.9	21.9	22.1	316	8,652	100	35.8	138
1997	24.1	20.7	22.4	25.0	25.8	33.0	28.1	31.0	29.9	27.6	23.4	23.6	315	8,636	100	33.0	127
1998	23.9	24.3	26.0	27.8	30.8	32.9	38.2	37.6	35.1	29.7	26.6	25.2	358	8,619	114	38.2	148
1999	24.5	22.3	23.9	25.5	28.6	29.7	31.3	31.5	26.7	25.4	26.9	27.1	323	8,603	103	31.5	122
2000	25.7	24.4	25.8	25.7	30.4	29.0	31.8	39.8	30.7	27.7	25.5	23.3	340	8,586	108	39.8	154
2001	24.3	21.4	25.2	24.1	26.5	27.0	35.3	40.2	30.7	27.8	24.7	24.5	332	8,570	106	40.2	156
Average	23.7	21.8	23.9	24.3	27.3	30.4	32.2	34.1	28.0	25.9	23.5	23.7	319		100.7	36.4	139.7
% Distrib.	7.4%	6.8%	7.5%	7.6%	8.6%	9.5%	10.1%	10.7%	8.8%	8.1%	7.4%	7.4%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	2,030,000	215,285	1,814,715	207	2.05
1989	2,000,000	255,627	1,744,373	199	1.98
1990	1,785,000	210,534	1,574,466	180	1.79
1991	1,620,000	146,888	1,473,112	169	1.68
1992	1,625,000	147,110	1,477,890	170	1.68
1993	1,546,000	198,082	1,347,918	155	1.54
1994	1,674,000	244,236	1,429,764	165	1.64
1995	1,815,000	245,455	1,569,545	181	1.80
1996	N/A	N/A	N/A	N/A	N/A
1997	1,992,000	254,773	1,737,227	201	2.00
1998	1,680,000	130,348	1,549,652	180	1.79
1999	1,430,000	139,107	1,290,893	150	1.49
2000	N/A	N/A	N/A	N/A	N/A
2001	1,749,000	115,408	1,633,592	191	1.89
Average	1,745,500	191,904	1,553,596	179	1.78

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	206.6
W. Conservation Reduction =	9.6
Subtotal =	197.0
Peak Daily Demand with WC and	
Water Losses =	240.1
Peak Daily Demand Factor with WC	
and Water Losses =	2.15

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	83	87	84	96	107	158	132	106	104	88	81	84	8,784	100.8
1989	84	79	80	86	99	109	156	124	88	86	76	80	8,768	95.8
1990	86	85	85	90	103	101	121	136	99	94	85	86	8,751	97.9
1991	92	92	93	92	93	106	131	154	98	93	93	99	8,735	103.2
1992	89	93	92	90	107	104	98	106	100	97	85	84	8,718	95.4
1993	85	82	88	90	97	96	90	112	108	96	97	91	8,702	94.4
1994	87	84	90	88	96	128	97	107	102	93	84	81	8,685	94.6
1995	84	81	84	91	89	126	98	133	104	92	89	84	8,669	96.3
1996	81	105	86	88	94	119	133	123	109	93	85	83	8,652	100.0
1997	90	85	84	97	96	127	105	116	115	103	90	88	8,636	99.8
1998	89	101	97	108	115	127	143	141	136	111	103	94	8,619	113.8
1999	92	93	90	99	107	115	117	118	104	95	104	102	8,603	103.0
2000	97	102	97	100	114	112	120	149	119	104	99	87	8,586	108.4
2001	91	89	95	94	100	105	133	151	120	105	96	92	8,570	106.0
Average	88	90	89	93	101	117	120	127	107	96	90	88		100.7

Maximum historic water use month = 158 gpc/d

Wahpeton Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = **Summer =**

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpcd)	Summer Per Capita Use (gpcd)
1988	83	87	84	96	107	158	132	106	104	88	81	84	8,784	86	116
1989	84	79	80	86	99	109	156	124	88	86	76	80	8,768	81	110
1990	86	85	85	90	103	101	121	136	99	94	85	86	8,751	86	109
1991	92	92	93	92	93	106	131	154	98	93	93	99	8,735	94	112
1992	89	93	92	90	107	104	98	106	100	97	85	84	8,718	89	102
1993	85	82	88	90	97	96	90	112	108	96	97	91	8,702	89	100
1994	87	84	90	88	96	128	97	107	102	93	84	81	8,685	85	104
1995	84	81	84	91	89	126	98	133	104	92	89	84	8,669	86	107
1996	81	105	86	88	94	119	133	123	109	93	85	83	8,652	88	112
1997	90	85	84	97	96	127	105	116	115	103	90	88	8,636	89	111
1998	89	101	97	108	115	127	143	141	136	111	103	94	8,619	99	129
1999	92	93	90	99	107	115	117	118	104	95	104	102	8,603	96	109
2000	97	102	97	100	114	112	120	149	119	104	99	87	8,586	97	120
2001	91	89	95	94	100	105	133	151	120	105	96	92	8,570	93	119
Average	88	90	89	93	101	117	120	127	107	96	90	88		89.8	111

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	99
Indoor W. Conservation Reduction (gpc/d) =	8.47
Outdoor W. Conservation Reduction (gpc/d) =	0.55
Peak Monthly Demand w/o System Losses (gpc/d) =	158
Estimated Water Losses (%) =	18%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	88	90	89	93	101	117	120	127	107	96	90	88	100.7
Average Monthly Demand w WC (gpc/d)	80	81	80	85	92	107	110	117	98	87	82	80	91.6
Average Monthly Demand w/ WC and Losses (gpc/d)	**97**	**99**	**98**	**103**	**112**	**131**	**134**	**143**	**119**	**106**	**100**	**97**	**111.7**
Max Month Data w/o Losses (gpc/d)	97	105	97	108	115	158	156	154	136	111	104	102	120.2
Max Month Data w/ Losses (gpc/d)	**118**	**128**	**119**	**131**	**141**	**193**	**190**	**188**	**165**	**135**	**127**	**124**	**146.5**
Max Month Data w/ WC (gpc/d)	88	97	89	99	106	149	146	145	126	102	96	93	111.2
Max Month Data w/ WC and Losses (gpc/d)	**107**	**118**	**108**	**121**	**129**	**181**	**178**	**176**	**154**	**124**	**117**	**113**	**135.5**

Water Losses = 17.9%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =	12,140								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w WC and Losses (gpc/d)	111.9	103.4	113.3	115.6	129.2	146.0	154.9	165.1	133.4	122.1	111.7	112.3	1,518.8
Max Month Data w/ Losses (gpc/d)	135.9	133.5	136.9	146.5	162.5	215.6	219.0	216.9	184.7	156.5	141.9	142.9	1,992.8
Max Month Data w/ WC and Losses (gpc/d)	124.0	122.7	125.0	135.0	149.0	202.5	205.6	203.5	171.6	143.0	130.3	131.0	1,843.2

Walsh Rural Water District Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	11.1	11.7	11.5	13.0	11.8	15.3	13.5	15.9	12.1	12.5	9.2	10.9	148	3,160	41.8%	5.2	129
1989	11.6	10.2	12.3	11.1	11.8	13.2	16.2	13.1	10.4	11.4	9.0	9.6	140	3,160	41.8%	4.9	121
1990	8.5	8.4	11.6	10.5	12.5	13.8	15.6	15.5	13.8	11.5	10.1	10.5	142	3,160	41.8%	5.0	123
1991	11.1	8.7	10.6	10.2	12.5	15.1	13.5	13.7	13.3	11.2	10.9	11.1	142	3,160	41.8%	4.9	123
1992	9.4	11.2	12.5	11.3	12.8	14.7	14.0	15.8	12.6	11.7	11.5	10.1	148	3,160	41.8%	5.1	128
1993	10.9	10.9	11.9	11.0	14.1	12.4	13.0	12.7	11.2	12.5	10.6	10.6	142	3,160	41.8%	4.9	123
1994	12.2	11.6	13.1	11.8	14.6	14.5	13.9	15.9	11.9	12.8	11.8	12.2	156	3,160	41.8%	5.4	136
1995	12.0	10.5	14.0	12.6	13.6	15.9	14.8	15.3	13.8	13.3	12.4	12.9	161	3,160	41.8%	5.6	140
1996	13.6	12.4	12.5	11.4	13.0	15.6	14.4	15.8	13.9	13.9	13.4	12.6	163	3,160	41.8%	5.7	141
1997	13.2	12.1	14.0	12.3	12.3	15.4	13.9	14.9	14.5	11.6	12.7	12.7	160	3,160	41.8%	5.6	138
1998	12.1	10.2	11.6	11.6	15.2	13.3	16.8	14.0	13.0	13.8	11.9	12.2	156	3,160	44.1%	5.7	135
1999	12.3	10.2	11.7	13.1	12.0	12.3	15.8	14.3	15.1	11.1	12.3	13.4	154	3,160	40.1%	5.1	133
2000[2]	14.2	13.2	13.4	14.7	14.2	13.3	14.2	13.0	14.1	13.5	13.2	13.6	165	3,160	44.4%	6.1	143
2001[2]	14.2	12.1	14.7	16.5	13.8	14.9	13.8	14.6	12.1	12.4	12.1	12.3	164	3,160	38.7%	5.3	142
Average	11.9	11.0	12.5	12.2	13.2	14.3	14.5	14.6	13.0	12.4	11.5	11.8	153		41.8%		132.4

[1] Water loss data was provided for 1998 - 2001and averaged 41.8% which was used for 1988 - 1997
[2] Walsh purchased 662,000 gallons in 2000 and 7,879,000 gallons in 2001 from Grafton which is added to the above monthly to

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	5.9	6.5	6.3	7.8	6.6	10.2	8.4	10.7	6.9	7.3	4.0	5.7	86	3,160	75	10.7	113
1989	6.7	5.3	7.5	6.2	6.9	8.3	11.3	8.2	5.5	6.5	4.2	4.7	81	3,160	70	11.3	119
1990	3.5	3.4	6.6	5.5	7.5	8.8	10.6	10.6	8.8	6.5	5.2	5.6	83	3,160	72	10.6	112
1991	6.1	3.7	5.6	5.2	7.6	10.1	8.6	8.8	8.4	6.2	6.0	6.2	83	3,160	72	10.1	107
1992	4.2	6.1	7.3	6.2	7.7	9.5	8.8	10.7	7.5	6.6	6.4	5.0	86	3,160	74	10.7	113
1993	5.9	6.0	6.9	6.1	9.2	7.5	8.1	7.8	6.3	7.5	5.7	5.7	83	3,160	72	9.2	97
1994	6.7	6.2	7.7	6.3	9.2	9.1	8.5	10.5	6.4	7.4	6.3	6.8	91	3,160	79	10.5	111
1995	6.4	4.9	8.4	7.0	8.0	10.3	9.2	9.7	8.2	7.7	6.7	7.3	94	3,160	81	10.3	108
1996	7.9	6.7	6.9	5.7	7.4	9.9	8.7	10.2	8.3	8.3	7.7	7.0	95	3,160	82	10.2	107
1997	7.6	6.5	8.4	6.7	6.7	9.8	8.3	9.4	9.0	6.0	7.2	7.1	93	3,160	80	9.8	104
1998	6.4	4.5	5.9	5.8	9.5	7.6	11.1	8.3	7.3	8.1	6.1	6.4	87	3,160	76	11.1	117
1999	7.2	5.1	6.6	8.0	6.9	7.2	10.6	9.1	9.9	6.0	7.1	8.3	92	3,160	80	10.6	112
2000	8.1	7.1	7.3	8.6	8.1	7.2	8.1	6.9	8.0	7.4	7.1	7.5	91	3,160	79	8.6	91
2001	8.9	6.8	9.5	11.2	8.6	9.6	8.6	9.4	6.8	7.1	6.9	7.0	100	3,160	87	11.2	119
Average	6.6	5.6	7.2	6.9	7.8	8.9	9.2	9.3	7.7	7.0	6.2	6.4	89		77.1	10.4	109.2
% Distrib.	7.4%	6.3%	8.1%	7.7%	8.8%	10.0%	10.4%	10.5%	8.6%	7.9%	7.0%	7.2%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998	512,000	187,967	324,033	103	1.33
1999	500,580	168,516	332,064	105	1.36
2000	504,000	200,244	303,756	96	1.25
2001[1]	600,000	173,512	426,488	135	1.75
Average	529,145	182,560	346,585	110	1.42

[1] Information provided by WRWD and includes 72,000 gallons purchased from Grafton to meet peak day demands

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	135.0
W. Conservation Reduction =	9.5
Subtotal =	125.5
Peak Daily Demand with WC and Water Losses =	215.7
Peak Daily Demand Factor with WC and Water Losses =	1.84

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	60	74	64	82	68	107	85	109	73	74	42	58	3,160	74.8
1989	68	60	76	65	71	87	115	84	59	66	44	48	3,160	70.5
1990	36	39	68	58	77	93	109	108	93	67	55	57	3,160	71.8
1991	62	42	57	55	77	107	88	90	88	64	63	63	3,160	71.5
1992	43	69	75	65	78	100	90	109	79	67	67	51	3,160	74.5
1993	60	67	71	64	94	79	82	79	66	77	60	58	3,160	71.6
1994	69	70	78	67	94	96	86	107	68	75	67	69	3,160	78.9
1995	65	55	86	74	82	108	94	99	87	78	71	75	3,160	81.3
1996	81	76	70	60	75	105	89	104	87	84	82	71	3,160	82.0
1997	78	74	86	71	69	104	85	96	94	61	76	73	3,160	80.5
1998	66	51	61	62	97	80	113	84	77	83	65	66	3,160	75.5
1999	73	57	67	84	70	76	109	93	105	61	75	84	3,160	79.8
2000	83	81	75	91	82	76	82	70	84	76	75	77	3,160	79.3
2001	91	77	96	119	87	101	87	96	72	73	72	71	3,160	86.9
Average	67	64	74	73	80	94	94	95	81	72	65	66		77.1

Walsh Rural Water District Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = Summer =

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	60	74	64	82	68	107	85	109	73	74	42	58	3,160	64	86
1989	68	60	76	65	71	87	115	84	59	66	44	48	3,160	60	80
1990	36	39	68	58	77	93	109	108	93	67	55	57	3,160	52	91
1991	62	42	57	55	77	107	88	90	88	64	63	63	3,160	57	86
1992	43	69	75	65	78	100	90	109	79	67	67	51	3,160	62	87
1993	60	67	71	64	94	79	82	79	66	77	60	58	3,160	63	80
1994	69	70	78	67	94	96	86	107	68	75	67	69	3,160	70	88
1995	65	55	86	74	82	108	94	99	87	78	71	75	3,160	71	91
1996	81	76	70	60	75	105	89	104	87	84	82	71	3,160	73	91
1997	78	74	86	71	69	104	85	96	94	61	76	73	3,160	76	85
1998	66	51	61	62	97	80	113	84	77	83	65	66	3,160	62	89
1999	73	57	67	84	70	76	109	93	105	61	75	84	3,160	74	86
2000	83	81	75	91	82	76	82	70	84	76	75	77	3,160	80	79
2001	91	77	96	119	87	101	87	96	72	73	72	71	3,160	88	86
Average	67	64	74	73	80	94	94	95	81	72	65	66		68.0	86

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	88
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	119
Estimated Water Losses (%) =	42%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/ Losses (gpc/d)	67	64	74	73	80	94	94	95	81	72	65	66	77.1
Average Monthly Demand w/ WC (gpc/d)	59	56	65	64	71	85	84	85	71	62	57	58	68.3
Average Monthly Demand w/ WC and Losses (gpc/d)	**101**	**95**	**112**	**111**	**121**	**146**	**145**	**147**	**123**	**107**	**98**	**99**	**117.3**
Max Month Data w/o Losses (gpc/d)	91	81	96	119	97	108	115	109	105	84	82	84	97.7
Max Month Data w/ Losses (gpc/d)	**157**	**138**	**166**	**204**	**166**	**186**	**198**	**188**	**180**	**145**	**140**	**145**	**167.9**
Max Month Data w/ WC (gpc/d)	83	72	88	110	87	99	106	100	95	75	73	76	88.9
Max Month Data w/ WC and Losses (gpc/d)	**143**	**124**	**152**	**190**	**150**	**170**	**182**	**171**	**164**	**129**	**126**	**131**	**152.8**

Water Losses = 41.8%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =		1,129								**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	10.8	9.3	12.1	11.5	13.0	15.1	15.6	15.8	12.8	11.5	10.2	10.6	148
Max Month Data w/ Losses	16.9	13.4	17.8	21.2	17.8	19.4	21.3	20.2	18.7	15.6	14.6	15.6	212
Max Month Data w/ WC and Losses	15.3	12.1	16.3	19.7	16.1	17.7	19.6	18.4	17.0	13.8	13.1	14.1	193

Annual Water Needs Prorated to Include Minto (acre-feet) =			Reclamation 2050 Pop =		1,129								**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	9.0	7.7	10.1	9.6	10.8	12.6	13.0	13.1	10.6	9.6	8.5	8.8	123.4
Max Month Data w/ Losses	14.4	11.5	15.2	18.1	15.2	16.5	18.2	17.2	16.0	13.3	12.4	13.3	181.3
Max Month Data w/ WC and Losses	13.1	10.3	13.9	16.8	13.7	15.1	16.7	15.7	14.5	11.8	11.2	12.0	164.9

Annual Water Needs (acre-feet) =			Water User 2050 Pop =		3,160								**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	25.3	21.6	28.1	26.8	30.3	35.3	36.3	36.7	29.7	26.8	23.8	24.8	345.5
Max Month Data w/ Losses	40.2	32.1	42.5	50.6	42.6	46.2	50.9	48.1	44.7	37.2	34.8	37.2	507.3
Max Month Data w/ WC and Losses	36.7	28.8	39.0	47.1	38.4	42.2	46.7	44.0	40.7	33.0	31.4	33.6	461.6

West Fargo Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Historic Monthly Raw Water Diversion (Millions of Gallons)													Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	29.8	27.2	28.8	36.3	48.2	65.0	75.9	55.6	45.8	32.9	28.2	29.3	503	12,145	0.0%	0.0	113
1989	28.9	26.5	29.6	30.2	42.9	46.9	80.8	56.3	34.7	37.9	33.2	32.3	480	12,216	0.0%	0.0	108
1990	32.2	27.3	31.0	33.6	39.9	34.9	53.0	60.3	41.0	40.2	32.6	33.1	459	12,287	0.0%	0.0	102
1991	32.8	30.6	33.1	34.8	41.7	39.9	41.6	56.9	38.3	37.2	32.0	31.8	451	12,358	0.0%	0.0	100
1992	32.4	29.5	32.3	32.4	43.2	40.5	36.7	43.5	32.0	34.7	29.5	30.7	417	12,429	0.0%	0.0	92
1993	32.1	27.9	31.1	32.1	40.2	35.3	32.5	42.1	38.1	35.2	30.6	31.1	408	12,500	0.0%	0.0	89
1994	32.0	29.6	32.5	33.9	45.2	54.1	38.4	45.2	35.5	34.6	33.2	33.0	447	12,850	0.0%	0.0	95
1995	33.8	28.6	32.6	33.5	38.4	59.4	40.2	59.8	40.5	34.5	32.7	33.1	467	13,200	0.0%	0.0	97
1996	34.9	31.0	34.2	33.3	41.6	53.9	67.8	61.7	42.9	40.0	35.1	35.0	511	13,475	0.0%	0.0	104
1997	35.9	32.3	36.3	34.6	41.4	49.1	47.5	47.8	39.1	39.5	35.3	35.1	474	13,800	0.0%	0.0	94
1998	34.8	30.7	33.9	40.1	48.3	41.7	54.2	73.6	50.3	39.6	50.0	36.7	534	14,500	0.0%	0.0	101
1999	36.2	32.9	39.7	41.6	47.8	56.0	63.3	58.1	42.4	41.8	38.8	39.4	538	14,910	0.0%	0.0	99
2000	39.3	36.7	40.9	39.8	52.9	46.3	55.4	72.1	42.6	42.7	37.6	37.5	544	14,940	0.0%	0.0	100
2001	37.1	32.8	36.9	37.8	47.0	47.9	71.5	62.7	47.9	47.9	39.2	36.1	545	15,693	0.0%	0.0	95
2002	37.7	33.9	37.5	38.3	51.8	61.1	59.7	61.1	49.8	44.9	39.5	38.8	554	16,670	0.0%	0.0	91
Average	32.0	28.7	32.1	33.1	41.5	44.5	49.5	53.4	38.3	36.7	33.3	32.3	455		0.0%		91.2

[1] Unaccounted for losses data was conflicting and relatively near zero so 0% losses were assumed in analysis

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Historic Monthly Metered Water Usage (Millions of Gallons)													Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total				
1988	29.8	27.2	28.8	36.3	48.2	65.0	75.9	55.6	45.8	32.9	28.2	29.3	503	12,145	113	75.9	208
1989	28.9	26.5	29.6	30.2	42.9	46.9	80.8	56.3	34.7	37.9	33.2	32.3	480	12,216	108	80.8	221
1990	32.2	27.3	31.0	33.6	39.9	34.9	53.0	60.3	41.0	40.2	32.6	33.1	459	12,287	102	60.3	163
1991	32.8	30.6	33.1	34.8	41.7	39.9	41.6	56.9	38.3	37.2	32.0	31.8	451	12,358	100	56.9	153
1992	32.4	29.5	32.3	32.4	43.2	40.5	36.7	43.5	32.0	34.7	29.5	30.7	417	12,429	92	43.5	117
1993	32.1	27.9	31.1	32.1	40.2	35.3	32.5	42.1	38.1	35.2	30.6	31.1	408	12,500	89	42.1	112
1994	32.0	29.6	32.5	33.9	45.2	54.1	38.4	45.2	35.5	34.6	33.2	33.0	447	12,850	95	54.1	140
1995	33.8	28.6	32.6	33.5	38.4	59.4	40.2	59.8	40.5	34.5	32.7	33.1	467	13,200	97	59.8	151
1996	34.9	31.0	34.2	33.3	41.6	53.9	67.8	61.7	42.9	40.0	35.1	35.0	511	13,475	104	67.8	168
1997	35.9	32.3	36.3	34.6	41.4	49.1	47.5	47.8	39.1	39.5	35.3	35.1	474	13,800	94	49.1	119
1998	34.8	30.7	33.9	40.1	48.3	41.7	54.2	73.6	50.3	39.6	50.0	36.7	534	14,500	101	73.6	169
1999	36.2	32.9	39.7	41.6	47.8	56.0	63.3	58.1	42.4	41.8	38.8	39.4	538	14,910	99	63.3	141
2000	39.3	36.7	40.9	39.8	52.9	46.3	55.4	72.1	42.6	42.7	37.6	37.5	544	14,940	100	72.1	161
2001	37.1	32.8	36.9	37.8	47.0	47.9	71.5	62.7	47.9	47.9	39.2	36.1	545	15,693	95	71.5	152
2002	37.7	33.9	37.5	38.3	51.8	61.1	59.7	61.1	49.8	44.9	39.5	38.8	554	16,670	91	61.1	122
Average	32.0	28.7	32.1	33.1	41.5	44.5	49.5	53.4	38.3	36.7	33.3	32.3	455		91.2	57.1	139.3
% Distrib.	7.0%	6.3%	7.1%	7.3%	9.1%	9.8%	10.9%	11.7%	8.4%	8.1%	7.3%	7.1%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988	3,132,500	0	3,132,500	258	2.83
1989	3,452,100	0	3,452,100	283	3.10
1990	3,041,800	0	3,041,800	248	2.72
1991	2,918,800	0	2,918,800	236	2.59
1992	2,283,700	0	2,283,700	184	2.02
1993	2,178,300	0	2,178,300	174	1.91
1994	2,602,000	0	2,602,000	202	2.22
1995	3,091,900	0	3,091,900	234	2.57
1996	3,755,000	0	3,755,000	279	3.06
1997	2,729,800	0	2,729,800	198	2.17
1998	3,453,000	0	3,453,000	238	2.61
1999	3,012,100	0	3,012,100	202	2.22
2000	3,837,400	0	3,837,400	257	2.82
2001	3,580,000	0	3,580,000	228	2.50
2002	N/A				
Average	3,076,314	0	3,076,314	230	2.52

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	282.6
W. Conservation Reduction =	7.2
Subtotal =	275.4
Peak Daily Demand with WC and Water Losses =	275.4
Peak Daily Demand Factor with WC and Water Losses =	3.00

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Historic Monthly Metered Water Usage (gallons per capita/day)												Population	Average Per Capita Use (gpc/d)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1988	77	78	79	83	114	129	215	150	95	101	91	86	12,145	113.5
1989	76	77	78	82	113	128	213	149	95	100	90	85	12,216	107.7
1990	85	79	81	91	105	95	139	158	111	106	88	87	12,287	102.4
1991	86	88	86	94	109	108	109	148	103	97	86	83	12,358	99.9
1992	84	85	84	87	112	109	95	113	86	90	79	80	12,429	92.0
1993	83	80	80	86	104	94	84	109	102	91	82	80	12,500	89.5
1994	80	82	82	88	113	140	96	113	92	87	86	83	12,850	95.3
1995	83	77	80	85	94	150	98	146	102	84	82	81	13,200	97.0
1996	84	82	82	82	100	133	162	148	106	96	87	84	13,475	104.0
1997	84	84	85	84	97	119	111	112	94	92	85	82	13,800	94.1
1998	77	76	75	92	107	96	121	164	116	88	115	82	14,500	100.9
1999	78	79	86	93	103	125	137	126	95	91	87	85	14,910	98.9
2000	85	88	88	89	114	103	120	156	95	92	84	81	14,940	99.7
2001	76	75	76	80	97	102	147	129	102	99	83	74	15,693	95.1
2002	73	73	73	77	100	122	116	118	99	87	79	75	16,670	91.1
Average	81	80	81	86	105	117	131	136	100	93	87	82		91.2

Maximum historic water use month = 215 gpc/d

West Fargo Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses)

Winter = Summer =

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)														
1988	77	78	79	83	114	129	215	150	95	101	91	86	12,145	82	134
1989	76	77	78	82	113	128	213	149	95	100	90	85	12,216	82	133
1990	85	79	81	91	105	95	139	158	111	106	88	87	12,287	85	119
1991	86	88	86	94	109	108	109	148	103	97	86	83	12,358	87	112
1992	84	85	84	87	112	109	95	113	86	90	79	80	12,429	83	101
1993	83	80	80	86	104	94	84	109	102	91	82	80	12,500	82	97
1994	80	82	82	88	113	140	96	113	92	87	86	83	12,850	83	107
1995	83	77	80	85	94	150	98	146	102	84	82	81	13,200	81	112
1996	84	82	82	82	100	133	162	148	106	96	87	84	13,475	83	124
1997	84	84	85	84	97	119	111	112	94	92	85	82	13,800	84	104
1998	77	76	75	92	107	96	121	164	116	88	115	82	14,500	86	115
1999	78	79	86	93	103	125	137	126	95	91	87	85	14,910	85	113
2000	85	88	88	89	114	103	120	156	95	92	84	81	14,940	86	113
2001	76	75	76	80	97	102	147	129	102	99	83	74	15,693	77	112
2002	73	73	73	77	100	122	116	118	99	87	79	75	16,670	75	107
Average	81	80	81	86	105	117	131	136	100	93	87	82		82.8	114

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	82
Indoor W. Conservation Reduction (gpc/d) =	5.89
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	215
Estimated Water Losses (%) =	0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	81	80	81	86	105	117	131	136	100	93	87	82	98.4
Average Monthly Demand w/ WC (gpc/d)	75	74	75	80	98	110	124	129	92	86	81	76	91.8
Average Monthly Demand w/ WC and Losses (gpc/d)	**75**	**74**	**75**	**80**	**98**	**110**	**124**	**129**	**92**	**86**	**81**	**76**	**91.8**
Max Month Data w/o Losses (gpc/d)	86	88	88	94	114	150	215	164	116	106	115	87	118.7
Max Month Data w/ Losses (gpc/d)	**86**	**88**	**88**	**94**	**114**	**150**	**215**	**164**	**116**	**106**	**115**	**87**	**118.7**
Max Month Data w/ WC (gpc/d)	80	82	82	88	107	143	208	157	109	98	109	81	112.2
Max Month Data w/ WC and Losses (gpc/d)	**80**	**82**	**82**	**88**	**107**	**143**	**208**	**157**	**109**	**98**	**109**	**81**	**112.2**

Water Losses = 0.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			Reclamation 2050 Pop =	33,900								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	241.3	216.3	242.2	250.4	317.1	342.2	398.8	415.0	288.4	277.8	253.2	245.1	3,487.7
Max Month Data w/ Losses	276.0	257.4	284.6	293.0	368.3	468.1	692.5	528.3	361.1	340.8	359.0	280.1	4,509.2
Max Month Data w/ WC and Losses	257.0	240.2	265.6	274.6	345.1	445.7	669.3	505.1	338.7	317.6	340.6	261.1	4,260.7

Annual Water Needs (acre-feet) =			Water User 2050 Pop =	34,705								Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses (gpc/d)	247.0	221.4	247.9	256.4	324.6	350.3	408.2	424.8	295.3	284.4	259.3	250.9	3,570.5
Max Month Data w/ Losses (gpc/d)	282.6	263.5	291.4	299.9	377.0	479.2	709.0	540.8	369.7	348.9	367.5	286.8	4,616.3
Max Month Data w/ WC and Losses (gpc/d)	263.1	245.9	271.9	281.1	353.3	456.2	685.2	517.1	346.7	325.2	348.7	267.3	4,361.8

Wyndmere Water Demand Calculations
Maximum Month Method

Historic Monthly Raw Water Diversions (Millions of Gallons)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Percent Unaccounted for Losses (%)[1]	Estimated Monthly Water Losses (10^6-gals)	Annual Per Capita Use (gpc/d)
	Historic Monthly Raw Water Diversion (Millions of Gallons)[2]																
1988	1.0	1.0	1.0	1.0	1.1	1.3	1.2	1.3	1.1	1.1	1.0	1.0	13	495	0.0%	0.0	72.2
1989	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.1	1.8	1.7	1.7	1.7	21	498	0.0%	0.0	117.6
1990	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.1	1.8	1.8	1.7	1.7	22	501	0.0%	0.0	119.2
1991	1.5	1.5	1.4	1.6	1.7	1.9	1.8	1.9	1.6	1.6	1.5	1.5	20	504	0.0%	0.0	107.5
1992	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.2	1.8	1.8	1.7	1.7	22	507	0.0%	0.0	118.1
1993	1.6	1.5	1.5	1.6	1.7	1.9	1.9	2.0	1.7	1.6	1.6	1.6	20	511	0.0%	0.0	107.2
1994	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.1	1.8	1.7	1.7	1.7	21	514	0.0%	0.0	114.0
1995	1.7	1.7	1.6	1.7	1.9	2.1	2.1	2.2	1.8	1.8	1.7	1.7	22	517	0.0%	0.0	117.1
1996	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.1	1.8	1.8	1.7	1.7	22	520	0.0%	0.0	114.6
1997	1.8	1.7	1.7	1.8	2.0	2.2	2.1	2.2	1.9	1.8	1.8	1.8	23	523	0.0%	0.0	118.5
1998	2.2	2.1	2.1	2.2	2.5	2.7	2.6	2.8	2.3	2.3	2.2	2.2	28	527	0.0%	0.0	146.6
1999	1.6	1.5	1.5	1.6	1.8	2.0	1.9	2.0	1.7	1.6	1.6	1.6	20	530	0.0%	0.0	105.1
2000	1.6	1.5	1.5	1.6	1.8	2.0	1.9	2.0	1.7	1.6	1.6	1.6	20	533	0.0%	0.0	104.3
2001	1.3	1.3	1.2	1.3	1.5	1.6	1.6	1.6	1.4	1.4	1.3	1.3	17	536	0.0%	0.0	85.6
Average	1.6	1.6	1.5	1.6	1.8	2.0	1.9	2.0	1.7	1.7	1.6	1.6	21		0.0%		110.5

1 Water loss data was not available so zero% was assumed in analysis

2 Use monthly distribution percentages from Lisbon to calculate monthly raw water diversions

Per Capita Water Use Analysis (Monthly water diversion *without* system losses)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Population	Annual Per Capita Use (gpc/d)	High Monthly Water Use (10^6-gals)	Monthly High Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (Millions of Gallons)																
1988	1.0	1.0	1.0	1.0	1.1	1.3	1.2	1.3	1.1	1.1	1.0	1.0	13	495	72	1.3	86
1989	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.1	1.8	1.7	1.7	1.7	21	498	118	2.1	141
1990	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.1	1.8	1.8	1.7	1.7	22	501	119	2.1	143
1991	1.5	1.5	1.4	1.6	1.7	1.9	1.8	1.9	1.6	1.6	1.5	1.5	20	504	107	1.9	129
1992	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.2	1.8	1.8	1.7	1.7	22	507	118	2.2	141
1993	1.6	1.5	1.5	1.6	1.7	1.9	1.9	2.0	1.7	1.6	1.6	1.6	20	511	107	2.0	128
1994	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.1	1.8	1.7	1.7	1.7	21	514	114	2.1	136
1995	1.7	1.7	1.6	1.7	1.9	2.1	2.1	2.2	1.8	1.8	1.7	1.7	22	517	117	2.2	140
1996	1.7	1.6	1.6	1.7	1.9	2.1	2.0	2.1	1.8	1.8	1.7	1.7	22	520	115	2.1	137
1997	1.8	1.7	1.7	1.8	2.0	2.2	2.1	2.2	1.9	1.8	1.8	1.8	23	523	119	2.2	142
1998	2.2	2.1	2.1	2.2	2.5	2.7	2.6	2.8	2.3	2.3	2.2	2.2	28	527	147	2.8	176
1999	1.6	1.5	1.5	1.6	1.8	2.0	1.9	2.0	1.7	1.6	1.6	1.6	20	530	105	2.0	126
2000	1.6	1.5	1.5	1.6	1.8	2.0	1.9	2.0	1.7	1.6	1.6	1.6	20	533	104	2.0	125
2001	1.3	1.3	1.2	1.3	1.5	1.6	1.6	1.6	1.4	1.4	1.3	1.3	17	536	86	1.6	102
Average	1.6	1.6	1.5	1.6	1.8	2.0	1.9	2.0	1.7	1.7	1.6	1.6	21		110.5	2.0	132.3
% Distrib.	7.8%	7.5%	7.3%	7.9%	8.7%	9.7%	9.3%	9.8%	8.3%	8.1%	7.8%	7.8%	100.0%				

Daily Peak Demand Analysis

Year	Peak Daily Water Use w/ Losses (gallons)	Estimated Daily Water Losses (gallons)	Peak Daily Water Use w/o Losses (gallons)	Peak Daily Per Capita Use w/o Losses (gpc/d)	Daily Peaking Factor
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
Average	0	0	0	0	0.00

Peak Daily Demand Estimate (with WC and Losses) =	(gpc/d)
Max Daily Water Use (w/o water losses) =	
W. Conservation Reduction =	
Subtotal =	
Peak Daily Demand with WC and	
Water Losses =	
Peak Daily Demand Factor with WC	
and Water Losses =	

WC = Water Conservation

Historic Monthly Per Capita Water Use Data (without system losses)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Average Per Capita Use (gpc/d)
	Historic Monthly Metered Water Usage (gallons per capita/day)													
1988	66	71	62	69	74	85	79	84	73	69	68	66	495	72.2
1989	108	115	101	113	121	139	129	136	119	112	111	108	498	117.6
1990	109	117	102	114	122	141	131	138	120	113	113	110	501	119.2
1991	98	105	92	103	110	127	118	125	108	102	102	99	504	107.5
1992	108	116	101	113	121	139	129	137	119	112	112	109	507	118.1
1993	98	105	92	103	110	127	118	124	108	102	102	99	511	107.2
1994	104	112	98	109	117	135	125	132	115	108	108	105	514	114.0
1995	107	115	101	112	120	138	128	136	118	111	111	108	517	117.1
1996	105	112	98	110	118	135	126	133	116	109	109	105	520	114.6
1997	108	116	102	114	122	140	130	137	120	113	112	109	523	118.5
1998	134	144	126	141	151	173	161	170	148	139	139	135	527	146.6
1999	96	103	90	101	108	124	115	122	106	100	100	97	530	105.1
2000	95	102	90	100	107	123	114	121	105	99	99	96	533	104.3
2001	78	84	74	82	88	101	94	99	86	81	81	79	536	85.6
Average	101	108	95	106	113	130	121	128	111	105	105	102		110.5

Wyndmere Water Demand Calculations
Maximum Month Method

Winter and Summer Use - Historic Monthly Per Capita Water Use Data (w/o system losses) **Winter =** **Summer =**

Year	Historic Monthly Metered Water Usage (gallons per capita/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Population	Winter Per Capita Use (gpc/d)	Summer Per Capita Use (gpc/d)
1988	66	71	62	69	74	85	79	84	73	69	68	66	495	67	77
1989	108	115	101	113	121	139	129	136	119	112	111	108	498	109	126
1990	109	117	102	114	122	141	131	138	120	113	113	110	501	111	128
1991	98	105	92	103	110	127	118	125	108	102	102	99	504	100	115
1992	108	116	101	113	121	139	129	137	119	112	112	109	507	110	126
1993	98	105	92	103	110	127	118	124	108	102	102	99	511	100	115
1994	104	112	98	109	117	135	125	132	115	108	108	105	514	106	122
1995	107	115	101	112	120	138	128	136	118	111	111	108	517	109	125
1996	105	112	98	110	118	135	126	133	116	109	109	105	520	107	123
1997	108	116	102	114	122	140	130	137	120	113	112	109	523	110	127
1998	134	144	126	141	151	173	161	170	148	139	139	135	527	136	157
1999	96	103	90	101	108	124	115	122	106	100	100	97	530	98	113
2000	95	102	90	100	107	123	114	121	105	99	99	96	533	97	112
2001	78	84	74	82	88	101	94	99	86	81	81	79	536	80	92
Average	101	108	95	106	113	130	121	128	111	105	105	102		102.8	118

Per Capita Water Use Analysis (Max Month Method)

Maximum Month Water Demand with Water Conservation (gpc/d) =

Winter Demand without Losses (gpc/d) =	136
Indoor W. Conservation Reduction (gpc/d) =	8.15
Outdoor W. Conservation Reduction (gpc/d) =	0.65
Peak Monthly Demand w/o System Losses (gpc/d) =	173
Estimated Water Losses (%) =	0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Per Capita (gpc/d)
Average Monthly Demand w/o Losses (gpc/d)	101	108	95	106	113	130	121	128	111	105	105	102	110.5
Average Monthly Demand w/ WC (gpc/d)	93	100	87	98	104	121	112	119	102	96	97	94	101.7
Average Monthly Demand w/ WC and Losses (gpc/d)	**93**	**100**	**87**	**98**	**104**	**121**	**112**	**119**	**102**	**96**	**97**	**94**	**101.7**
Max Month Data w/o Losses (gpc/d)	134	144	126	141	151	173	161	170	148	139	139	135	146.6
Max Month Data w/ Losses (gpc/d)	**134**	**144**	**126**	**141**	**151**	**173**	**161**	**170**	**148**	**139**	**139**	**135**	**146.6**
Max Month Data w/ WC (gpc/d)	126	136	118	133	141	164	151	160	138	130	131	127	137.8
Max Month Data w/ WC and Losses (gpc/d)	**126**	**136**	**118**	**133**	**141**	**164**	**151**	**160**	**138**	**130**	**131**	**127**	**137.8**

Water Losses = 0.0%
WC = Water Conservation

Annual Water Needs (acre-feet) =			2050 Population =		530							**Total**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(Ac-Ft)
Average Monthly Demand w/ WC and Losses	4.7	4.6	4.4	4.8	5.2	5.9	5.6	6.0	5.0	4.8	4.7	4.7	60
Max Month Data w/ Losses	6.8	6.5	6.4	6.9	7.6	8.4	8.1	8.6	7.2	7.0	6.8	6.8	87
Max Month Data w/ WC and Losses	6.3	6.2	5.9	6.5	7.1	8.0	7.6	8.1	6.8	6.5	6.4	6.4	82

Appendix A – Attachment 5

Data Sheets for Peak Day Analysis of Municipal and Rural Water Systems

Peak Day Water Demand Analysis
Red River Valley Water Supply Project

	Method of Meeting Peak Day Demand					
	Scenario One			Scenario Two		
Water Systems	Well Capacity (cfs)	Storage Capacity (millions of gallons)	Added Pipeline Capacity [1] (cfs)	Well Capacity (cfs)	Storage Capacity (millions of gallons)	Added Pipeline Capacity [1] (cfs)
Cass Rural Water Users	0.56	2.78	0.56	0.85	4.27	0.85
Drayton	NA	1.86	0.45	NA	1.86	0.45
East Grand Forks	NA	7.90	3.79	NA	10.41	5.27
Fargo	39.26	125.30	39.26	46.72	147.69	46.72
Grafton	NA	2.69	0.52	NA	3.81	0.79
Grand Forks	27.05	65.37	27.05	28.67	69.50	28.67
Grand Forks Traill Water District	1.29	4.12	1.29	1.86	5.85	1.86
Langdon (City and RWS)	NA	2.45	0.92	NA	2.75	1.08
Moorhead	5.12	24.01	5.12	6.42	30.04	6.42
Valley City	1.53	3.36	1.53	1.97	4.26	1.97
West Fargo	3.56	15.99	3.56	3.64	16.18	3.64
Totals	78.37	255.83	84.05	90.13	296.63	97.71

[1] Only some of the alternatives have pipeline conveyance features which can be increased in capacity to meet peak day demands
NA - This method of meeting peak day demand is not available

West Fargo - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	29.33 ac-ft	14.8 cfs	9.6 mgd	6636.5 gpm
Max Month 2050 Water Demand =	685.2 ac-ft	11.1 cfs	7.2 mgd	5001.3 gpm
Max Month Project Flows =	685.2 ac-ft	11.1 cfs	7.2 mgd	

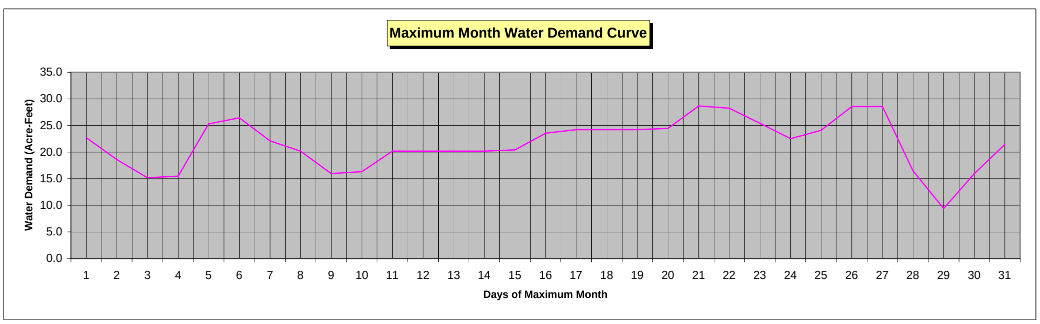
Starting Storage = 8.0 million gallons
Required Storage + 16.2 million gallons or 50 ac-ft
Storage estimated cost = $8,092,000 (assumes $0.50 per gallon cost)

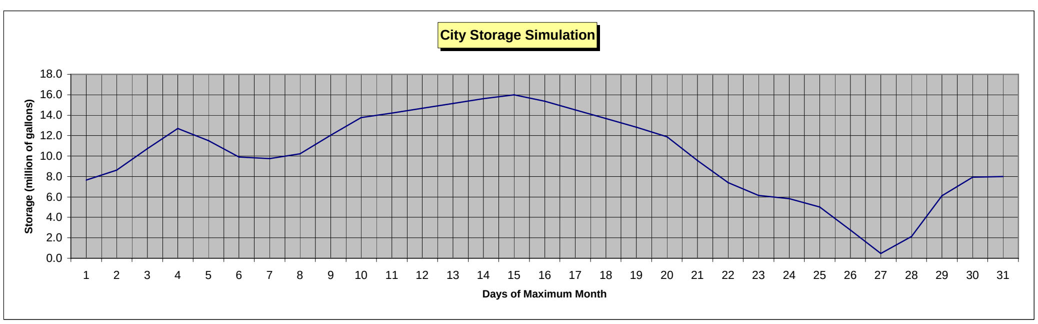
Monthly shortage in storage (31 days) =	19.3 mg	59.2 ac-ft		
Peak day shortage in storage =	2.4 mg	7.2 ac-ft	3.6 cfs	1634.4 gpm

Groundwater Analysis:

West Fargo aquifer storage and recovery system is designed to withdraw 5,000 gpm to meet the maximum month withdrawal rate. However, the West Fargo North Aquifer daily withdrawal rate could be increased to incorporate daily peaking requirements which are estimated to be 1,635 gpm.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.39%	11.7	23.2	22.1	23.2	22.1	-1.1	-0.4	7.6
2	2.78%	9.6	19.0	22.1	42.3	44.2	3.1	1.0	8.6
3	2.26%	7.8	15.5	22.1	57.8	66.3	6.6	2.1	10.8
4	2.31%	8.0	15.8	22.1	73.6	88.4	6.3	2.0	12.8
5	3.78%	13.1	25.9	22.1	99.5	110.5	-3.8	-1.2	11.6
6	3.95%	13.7	27.1	22.1	126.6	132.6	-5.0	-1.6	10.0
7	3.30%	11.4	22.6	22.1	149.2	154.7	-0.5	-0.2	9.8
8	3.01%	10.4	20.7	22.1	169.9	176.8	1.5	0.5	10.3
9	2.39%	8.3	16.4	22.1	186.3	198.9	5.7	1.9	12.1
10	2.44%	8.4	16.7	22.1	202.9	221.0	5.4	1.8	13.9
11	3.01%	10.4	20.7	22.1	223.6	243.1	1.5	0.5	14.4
12	3.01%	10.4	20.7	22.1	244.2	265.2	1.5	0.5	14.8
13	3.01%	10.4	20.7	22.1	264.9	287.3	1.5	0.5	15.3
14	3.01%	10.4	20.7	22.1	285.6	309.4	1.5	0.5	15.8
15	3.05%	10.5	20.9	22.1	306.4	331.5	1.2	0.4	16.2
16	3.52%	12.2	24.1	22.1	330.6	353.7	-2.0	-0.7	15.5
17	3.61%	12.5	24.8	22.1	355.3	375.8	-2.7	-0.9	14.7
18	3.61%	12.5	24.8	22.1	380.1	397.9	-2.7	-0.9	13.8
19	3.61%	12.5	24.8	22.1	404.8	420.0	-2.7	-0.9	12.9
20	3.66%	12.6	25.1	22.1	429.9	442.1	-3.0	-1.0	12.0
21	4.28%	14.8	29.3	22.1	459.2	464.2	-7.2	-2.4	9.6
22	4.23%	14.6	29.0	22.1	488.2	486.3	-6.9	-2.2	7.4
23	3.80%	13.1	26.0	22.1	514.2	508.4	-3.9	-1.3	6.1
24	3.37%	11.6	23.1	22.1	537.3	530.5	-1.0	-0.3	5.8
25	3.60%	12.4	24.7	22.1	561.9	552.6	-2.6	-0.8	5.0
26	4.27%	14.8	29.3	22.1	591.2	574.7	-7.2	-2.3	2.6
27	4.27%	14.7	29.2	22.1	620.4	596.8	-7.1	-2.3	0.3
28	2.47%	8.5	16.9	22.1	637.3	618.9	5.2	1.7	2.0
29	1.40%	4.9	9.6	22.1	647.0	641.0	12.5	4.1	6.1
30	2.38%	8.2	16.3	22.1	663.3	663.1	5.8	1.9	7.9
31	3.20%	11.1	21.9	22.1	685.2	685.2	0.2	0.1	8.0
Totals			685.2	685.2					





West Fargo - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

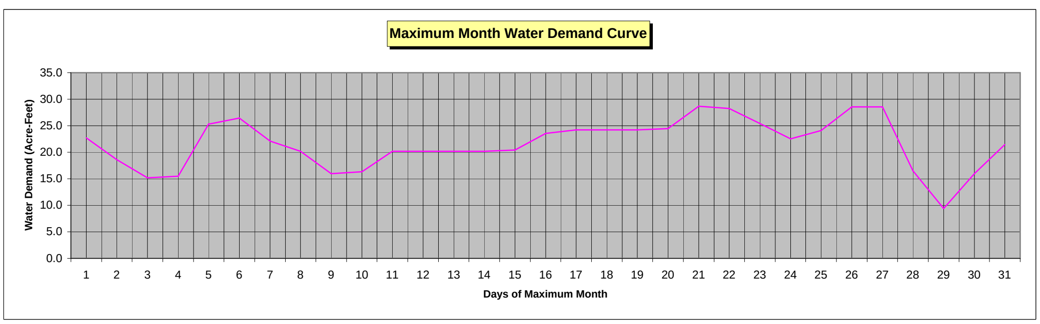
Basic Design Data:

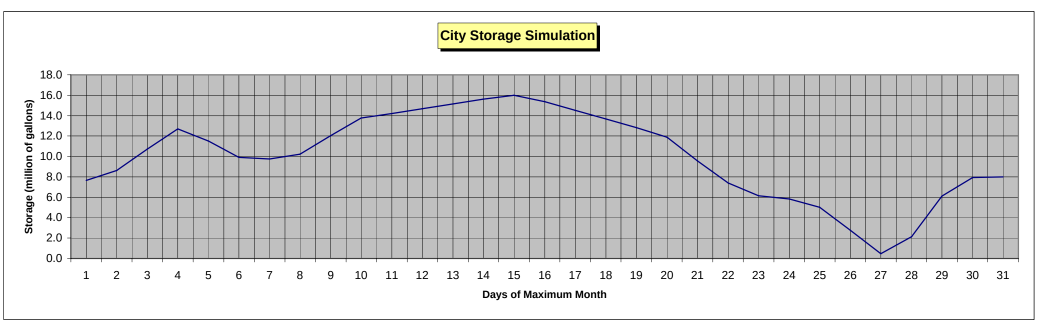
Peak Day 2050 Water Demand =	28.65 ac-ft	14.4 cfs	9.3 mgd	6482.6 gpm
Max Month 2050 Water Demand =	669.3 ac-ft	10.9 cfs	7.0 mgd	4885.2 gpm
Max Month Project Flows =	669.3 ac-ft	10.9 cfs	7.0 mgd	
Starting Storage =	8.0 million gallons			
Required Storage +	16.0 million gallons	or	49 ac-ft	
Storage estimated cost =	$7,997,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	18.8 mg	57.8 ac-ft		
Peak day shortage in storage =	2.3 mg	7.1 ac-ft	3.6 cfs	1596.5 gpm

Groundwater Analysis:

West Fargo aquifer storage and recovery system is designed to withdraw 4,900 gpm to meet the maximum month withdrawal rate. However, the West Fargo North Aquifer daily withdrawal rate could be increased to incorporate daily peaking requirements which are estimated to be 1,597 gpm.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.39%	11.4	22.7	21.6	22.7	21.6	-1.1	-0.4	7.6
2	2.78%	9.4	18.6	21.6	41.3	43.2	3.0	1.0	8.6
3	2.26%	7.6	15.2	21.6	56.4	64.8	6.4	2.1	10.7
4	2.31%	7.8	15.5	21.6	71.9	86.4	6.1	2.0	12.7
5	3.78%	12.8	25.3	21.6	97.2	108.0	-3.7	-1.2	11.5
6	3.95%	13.3	26.4	21.6	123.7	129.5	-4.9	-1.6	9.9
7	3.30%	11.1	22.1	21.6	145.8	151.1	-0.5	-0.2	9.7
8	3.01%	10.2	20.2	21.6	165.9	172.7	1.4	0.5	10.2
9	2.39%	8.1	16.0	21.6	181.9	194.3	5.6	1.8	12.0
10	2.44%	8.2	16.3	21.6	198.2	215.9	5.3	1.7	13.8
11	3.01%	10.2	20.2	21.6	218.4	237.5	1.4	0.5	14.2
12	3.01%	10.2	20.2	21.6	238.6	259.1	1.4	0.5	14.7
13	3.01%	10.2	20.2	21.6	258.8	280.7	1.4	0.5	15.1
14	3.01%	10.2	20.2	21.6	278.9	302.3	1.4	0.5	15.6
15	3.05%	10.3	20.4	21.6	299.3	323.9	1.2	0.4	16.0
16	3.52%	11.9	23.6	21.6	322.9	345.4	-2.0	-0.6	15.4
17	3.61%	12.2	24.2	21.6	347.1	367.0	-2.6	-0.8	14.5
18	3.61%	12.2	24.2	21.6	371.3	388.6	-2.6	-0.8	13.7
19	3.61%	12.2	24.2	21.6	395.5	410.2	-2.6	-0.8	12.8
20	3.66%	12.3	24.5	21.6	419.9	431.8	-2.9	-0.9	11.9
21	4.28%	14.4	28.6	21.6	448.6	453.4	-7.1	-2.3	9.6
22	4.23%	14.3	28.3	21.6	476.9	475.0	-6.7	-2.2	7.4
23	3.80%	12.8	25.4	21.6	502.3	496.6	-3.8	-1.2	6.1
24	3.37%	11.4	22.5	21.6	524.8	518.2	-0.9	-0.3	5.8
25	3.60%	12.1	24.1	21.6	548.9	539.8	-2.5	-0.8	5.0
26	4.27%	14.4	28.6	21.6	577.5	561.3	-7.0	-2.3	2.8
27	4.27%	14.4	28.6	21.6	606.0	582.9	-7.0	-2.3	0.5
28	2.47%	8.3	16.5	21.6	622.5	604.5	5.1	1.7	2.1
29	1.40%	4.7	9.4	21.6	631.9	626.1	12.2	4.0	6.1
30	2.38%	8.0	15.9	21.6	647.9	647.7	5.7	1.8	7.9
31	3.20%	10.8	21.4	21.6	669.3	669.3	0.2	0.1	8.0
Totals			669.3	669.3					





Valley City - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	8.90 ac-ft	4.5 cfs	2.9 mgd	2013.8 gpm
Max Month 2050 Water Demand =	154.6 ac-ft	2.5 cfs	1.6 mgd	1128.4 gpm
Max Month Project Flows =	154.6 ac-ft	2.5 cfs	1.6 mgd	

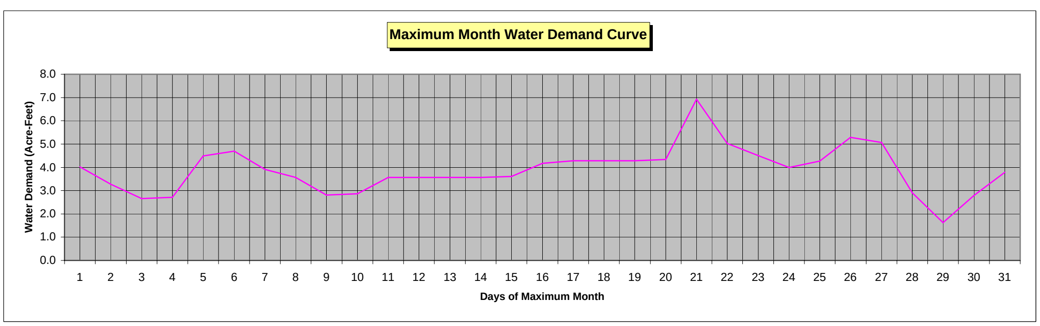
Starting Storage =	2.0 million gallons			
Required Storage +	4.3 million gallons	or	13 ac-ft	
Storage estimated cost =	$2,131,000 (assumes $0.50 per gallon cost)			

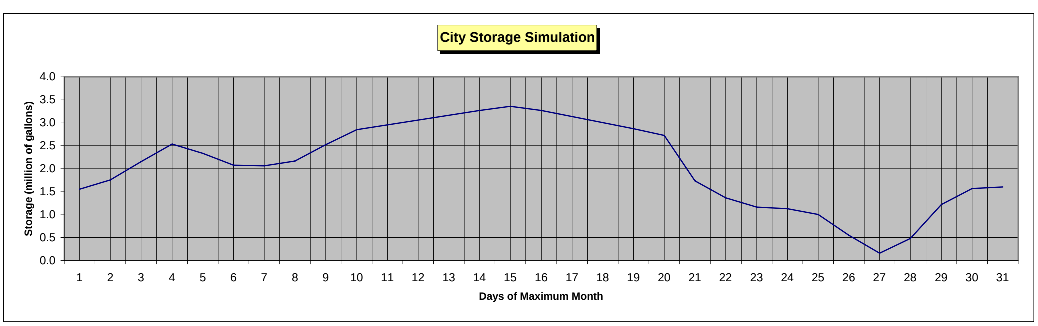
Monthly shortage in storage (31 days) =	4.8 mg	14.6 ac-ft		
Peak day shortage in storage =	1.3 mg	3.9 ac-ft	2.0 cfs	882.7 gpm

Groundwater Analysis:

Valley City has a permitted withdrawal rate of 800 gpm from their groundwater source in addition their 13,464 gpm surface water source. The 800 gpm well capacity is just short of the peak day storage of requirement of 854.2 gpm. However, since Valley City's groundwater source is directly recharged by the Sheyenne River, expansion of the existing permit to cover higher withdrawal rates is highly likely.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.33%	2.6	5.2	5.0	5.2	5.0	-0.2	-0.1	1.9
2	2.72%	2.1	4.2	5.0	9.4	10.0	0.8	0.3	2.2
3	2.21%	1.7	3.4	5.0	12.8	15.0	1.6	0.5	2.7
4	2.26%	1.8	3.5	5.0	16.3	19.9	1.5	0.5	3.2
5	3.72%	2.9	5.8	5.0	22.0	24.9	-0.8	-0.3	2.9
6	3.90%	3.0	6.0	5.0	28.1	29.9	-1.0	-0.3	2.6
7	3.25%	2.5	5.0	5.0	33.1	34.9	0.0	0.0	2.6
8	2.96%	2.3	4.6	5.0	37.7	39.9	0.4	0.1	2.7
9	2.33%	1.8	3.6	5.0	41.3	44.9	1.4	0.4	3.2
10	2.38%	1.9	3.7	5.0	44.9	49.9	1.3	0.4	3.6
11	2.96%	2.3	4.6	5.0	49.5	54.9	0.4	0.1	3.7
12	2.96%	2.3	4.6	5.0	54.1	59.8	0.4	0.1	3.9
13	2.96%	2.3	4.6	5.0	58.7	64.8	0.4	0.1	4.0
14	2.96%	2.3	4.6	5.0	63.2	69.8	0.4	0.1	4.1
15	2.99%	2.3	4.6	5.0	67.9	74.8	0.4	0.1	4.3
16	3.47%	2.7	5.4	5.0	73.2	79.8	-0.4	-0.1	4.1
17	3.56%	2.8	5.5	5.0	78.7	84.8	-0.5	-0.2	4.0
18	3.56%	2.8	5.5	5.0	84.2	89.8	-0.5	-0.2	3.8
19	3.56%	2.8	5.5	5.0	89.7	94.8	-0.5	-0.2	3.6
20	3.60%	2.8	5.6	5.0	95.3	99.7	-0.6	-0.2	3.4
21	5.75%	4.5	8.9	5.0	104.2	104.7	-3.9	-1.3	2.2
22	4.17%	3.3	6.4	5.0	110.6	109.7	-1.5	-0.5	1.7
23	3.74%	2.9	5.8	5.0	116.4	114.7	-0.8	-0.3	1.4
24	3.31%	2.6	5.1	5.0	121.5	119.7	-0.1	0.0	1.4
25	3.55%	2.8	5.5	5.0	127.0	124.7	-0.5	-0.2	1.2
26	4.39%	3.4	6.8	5.0	133.8	129.7	-1.8	-0.6	0.7
27	4.21%	3.3	6.5	5.0	140.3	134.7	-1.5	-0.5	0.2
28	2.41%	1.9	3.7	5.0	144.0	139.6	1.3	0.4	0.6
29	1.35%	1.1	2.1	5.0	146.1	144.6	2.9	0.9	1.5
30	2.33%	1.8	3.6	5.0	149.7	149.6	1.4	0.5	2.0
31	3.15%	2.5	4.9	5.0	154.6	154.6	0.1	0.0	2.0
Totals			154.6	154.6					





Valley City - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

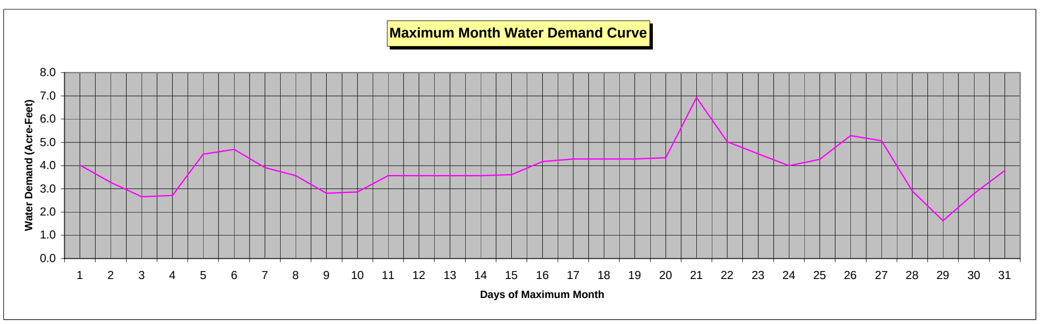
Peak Day 2050 Water Demand =	6.90 ac-ft	3.5 cfs	2.2 mgd	1561.3 gpm
Max Month 2050 Water Demand =	120.4 ac-ft	2.0 cfs	1.3 mgd	878.8 gpm
Max Month Project Flows =	120.4 ac-ft	2.0 cfs	1.3 mgd	

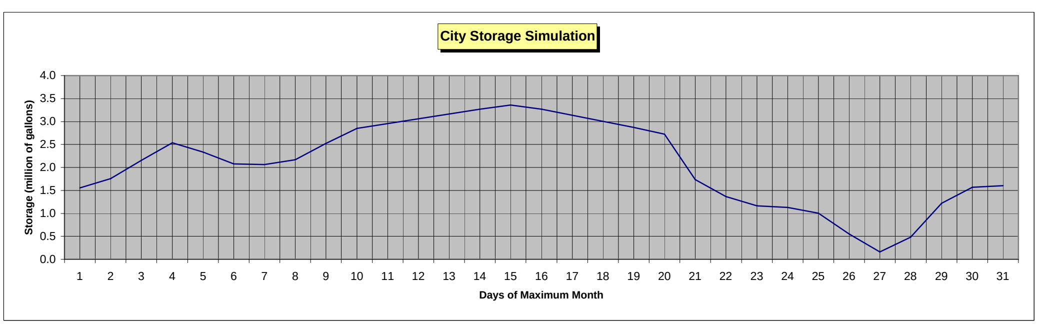
Starting Storage =	1.6 million gallons			
Required Storage +	3.4 million gallons	or	10 ac-ft	
Storage estimated cost =	$1,680,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	3.7 mg	11.4 ac-ft		
Peak day shortage in storage =	1.0 mg	3.0 ac-ft	1.5 cfs	687.5 gpm

Groundwater Analysis:

Valley City has a permitted withdrawal rate of 800 gpm from their groundwater source in addition their 13,464 gpm surface water source. The 800 gpm well capacity is adequate to cover their peak day storage of 665.2 gpm.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.33%	2.0	4.0	3.9	4.0	3.9	-0.1	0.0	1.6
2	2.72%	1.7	3.3	3.9	7.3	7.8	0.6	0.2	1.8
3	2.21%	1.3	2.7	3.9	10.0	11.7	1.2	0.4	2.2
4	2.26%	1.4	2.7	3.9	12.7	15.5	1.2	0.4	2.5
5	3.72%	2.3	4.5	3.9	17.2	19.4	-0.6	-0.2	2.3
6	3.90%	2.4	4.7	3.9	21.8	23.3	-0.8	-0.3	2.1
7	3.25%	2.0	3.9	3.9	25.8	27.2	0.0	0.0	2.1
8	2.96%	1.8	3.6	3.9	29.3	31.1	0.3	0.1	2.2
9	2.33%	1.4	2.8	3.9	32.1	35.0	1.1	0.3	2.5
10	2.38%	1.4	2.9	3.9	35.0	38.8	1.0	0.3	2.9
11	2.96%	1.8	3.6	3.9	38.6	42.7	0.3	0.1	3.0
12	2.96%	1.8	3.6	3.9	42.1	46.6	0.3	0.1	3.1
13	2.96%	1.8	3.6	3.9	45.7	50.5	0.3	0.1	3.2
14	2.96%	1.8	3.6	3.9	49.3	54.4	0.3	0.1	3.3
15	2.99%	1.8	3.6	3.9	52.9	58.3	0.3	0.1	3.4
16	3.47%	2.1	4.2	3.9	57.0	62.1	-0.3	-0.1	3.3
17	3.56%	2.2	4.3	3.9	61.3	66.0	-0.4	-0.1	3.1
18	3.56%	2.2	4.3	3.9	65.6	69.9	-0.4	-0.1	3.0
19	3.56%	2.2	4.3	3.9	69.9	73.8	-0.4	-0.1	2.9
20	3.60%	2.2	4.3	3.9	74.2	77.7	-0.5	-0.1	2.7
21	5.75%	3.5	6.9	3.9	81.1	81.6	-3.0	-1.0	1.7
22	4.17%	2.5	5.0	3.9	86.2	85.4	-1.1	-0.4	1.4
23	3.74%	2.3	4.5	3.9	90.7	89.3	-0.6	-0.2	1.2
24	3.31%	2.0	4.0	3.9	94.7	93.2	-0.1	0.0	1.1
25	3.55%	2.2	4.3	3.9	98.9	97.1	-0.4	-0.1	1.0
26	4.39%	2.7	5.3	3.9	104.2	101.0	-1.4	-0.5	0.5
27	4.21%	2.6	5.1	3.9	109.3	104.9	-1.2	-0.4	0.2
28	2.41%	1.5	2.9	3.9	112.2	108.7	1.0	0.3	0.5
29	1.35%	0.8	1.6	3.9	113.8	112.6	2.3	0.7	1.2
30	2.33%	1.4	2.8	3.9	116.6	116.5	1.1	0.4	1.6
31	3.15%	1.9	3.8	3.9	120.4	120.4	0.1	0.0	1.6
Totals			120.4	120.4					





Moorhead - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

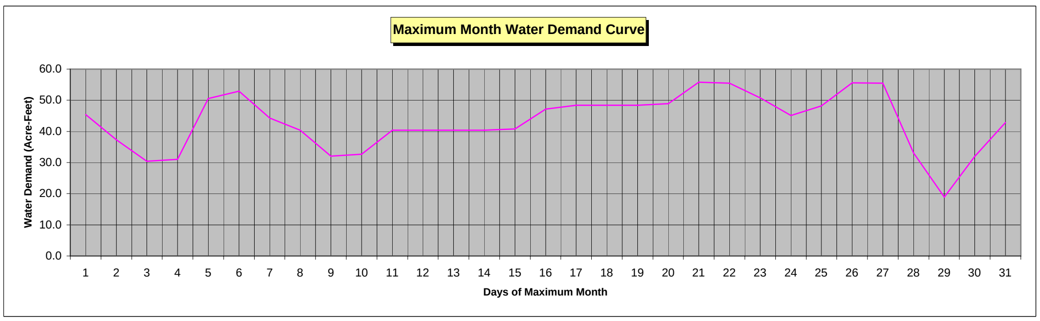
Basic Design Data:

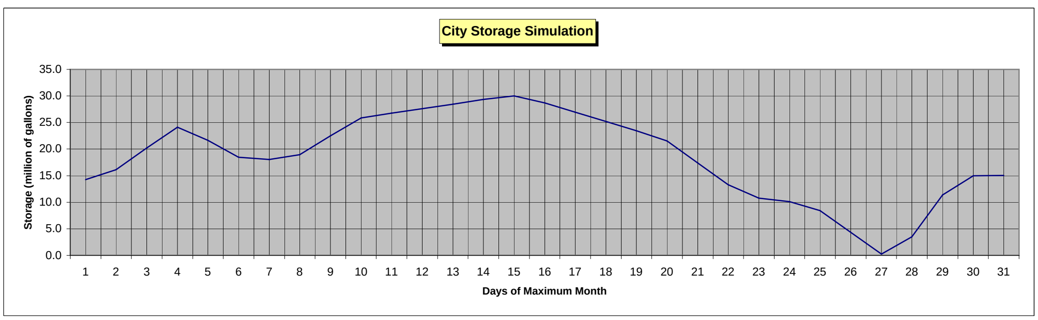
Peak Day 2050 Water Demand =	57.18 ac-ft	28.8 cfs	18.6 mgd	12938.1 gpm
Max Month 2050 Water Demand =	1333.8 ac-ft	21.7 cfs	14.0 mgd	9735.4 gpm
Max Month Project Flows =	1333.8 ac-ft	21.7 cfs	14.0 mgd	
Starting Storage =	15.0 million gallons			
Required Storage +	30.0 million gallons	or	92 ac-ft	
Storage estimated cost =	$15,018,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	36.6 mg	112.4 ac-ft		
Peak day shortage in storage =	4.1 mg	12.7 ac-ft	6.4 cfs	2879.7 gpm

Groundwater Analysis:

Moorhead has a permitted withdrawal rate of 4,150 gpm from their groundwater sources which is already allocated for day-to-day use. However, it is generally understood that Moorhead has significantly more groundwater capacity available in the Buffalo Aquifer (10 miles south of Moorhead) if needed. To meet Moorhead's peak day requirements, additional well capacity of 2880 gpm will be developed to meet daily peaking.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.40%	22.9	45.4	43.0	45.4	43.0	-2.4	-0.8	14.2
2	2.79%	18.8	37.3	43.0	82.6	86.1	5.8	1.9	16.1
3	2.28%	15.3	30.4	43.0	113.0	129.1	12.6	4.1	20.2
4	2.32%	15.6	31.0	43.0	144.0	172.1	12.0	3.9	24.1
5	3.79%	25.5	50.6	43.0	194.6	215.1	-7.6	-2.5	21.7
6	3.97%	26.7	52.9	43.0	247.5	258.2	-9.9	-3.2	18.5
7	3.32%	22.3	44.2	43.0	291.8	301.2	-1.2	-0.4	18.1
8	3.03%	20.4	40.4	43.0	332.2	344.2	2.6	0.9	18.9
9	2.40%	16.2	32.0	43.0	364.2	387.2	11.0	3.6	22.5
10	2.45%	16.5	32.7	43.0	396.9	430.3	10.4	3.4	25.9
11	3.03%	20.4	40.4	43.0	437.3	473.3	2.6	0.9	26.7
12	3.03%	20.4	40.4	43.0	477.6	516.3	2.6	0.9	27.6
13	3.03%	20.4	40.4	43.0	518.0	559.3	2.6	0.9	28.5
14	3.03%	20.4	40.4	43.0	558.4	602.4	2.6	0.9	29.3
15	3.06%	20.6	40.8	43.0	599.2	645.4	2.2	0.7	30.0
16	3.53%	23.8	47.1	43.0	646.4	688.4	-4.1	-1.3	28.7
17	3.63%	24.4	48.4	43.0	694.8	731.4	-5.4	-1.7	26.9
18	3.63%	24.4	48.4	43.0	743.2	774.5	-5.4	-1.7	25.2
19	3.63%	24.4	48.4	43.0	791.5	817.5	-5.4	-1.7	23.5
20	3.67%	24.7	49.0	43.0	840.5	860.5	-5.9	-1.9	21.5
21	4.18%	28.1	55.8	43.0	896.2	903.5	-12.7	-4.1	17.4
22	4.16%	28.0	55.5	43.0	951.7	946.6	-12.5	-4.1	13.3
23	3.81%	25.6	50.8	43.0	1,002.5	989.6	-7.8	-2.5	10.8
24	3.38%	22.7	45.1	43.0	1,047.6	1,032.6	-2.1	-0.7	10.1
25	3.61%	24.3	48.2	43.0	1,095.8	1,075.6	-5.2	-1.7	8.4
26	4.17%	28.0	55.6	43.0	1,151.4	1,118.7	-12.6	-4.1	4.3
27	4.16%	28.0	55.5	43.0	1,206.9	1,161.7	-12.5	-4.1	0.3
28	2.48%	16.7	33.1	43.0	1,240.0	1,204.7	9.9	3.2	3.5
29	1.42%	9.5	18.9	43.0	1,258.9	1,247.7	24.1	7.9	11.4
30	2.40%	16.1	31.9	43.0	1,290.9	1,290.8	11.1	3.6	15.0
31	3.22%	21.6	42.9	43.0	1,333.8	1,333.8	0.1	0.0	15.0
Totals			1,333.8	1,333.8					





Moorhead - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	44.56 ac-ft	22.5 cfs	14.5 mgd	10082.6 gpm
Max Month 2050 Water Demand =	1065.3 ac-ft	17.3 cfs	11.2 mgd	7775.7 gpm
Max Month Project Flows =	1065.3 ac-ft	17.3 cfs	11.2 mgd	

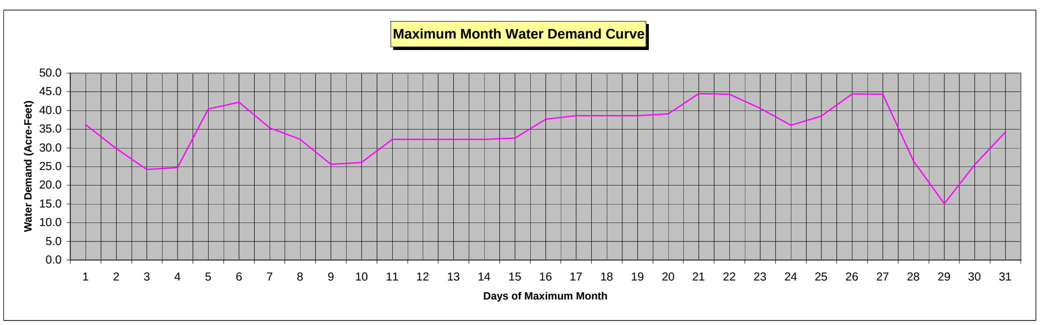
Starting Storage =	12.0 million gallons		
Required Storage +	24.0 million gallons	or	74 ac-ft
Storage estimated cost =	$12,005,000 (assumes $0.50 per gallon cost)		

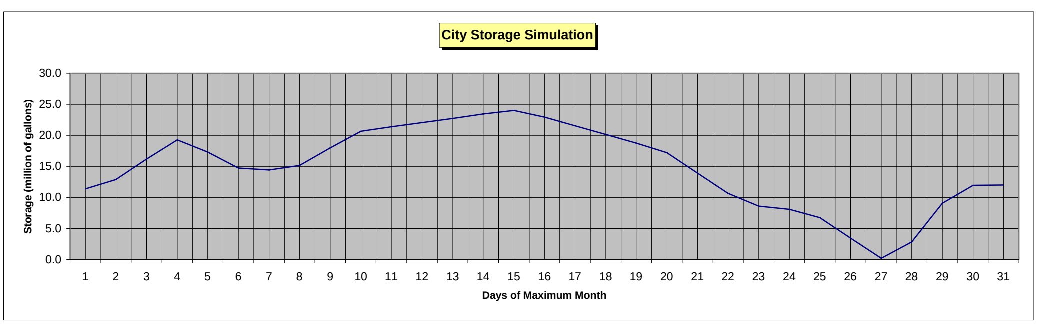
Monthly shortage in storage (31 days) =	29.2 mg	89.8 ac-ft		
Peak day shortage in storage =	3.3 mg	10.2 ac-ft	5.1 cfs	2300.0 gpm

Groundwater Analysis:

Moorhead has a permitted withdrawal rate of 4,150 gpm from their groundwater sources which is already allocated for day-to-day use. However, it is generally understood that Moorhead has significantly more groundwater capacity available in the Buffalo Aquifer (10 miles south of Moorhead) if needed. To meet Moorhead's peak day requirements, additional well capacity of 2300 gpm will be developed to meet daily peaking.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.40%	18.3	36.3	34.4	36.3	34.4	-1.9	-0.6	11.4
2	2.79%	15.0	29.8	34.4	66.0	68.7	4.6	1.5	12.9
3	2.28%	12.2	24.3	34.4	90.3	103.1	10.1	3.3	16.2
4	2.32%	12.5	24.8	34.4	115.0	137.5	9.6	3.1	19.3
5	3.79%	20.4	40.4	34.4	155.5	171.8	-6.0	-2.0	17.3
6	3.97%	21.3	42.2	34.4	197.7	206.2	-7.9	-2.6	14.8
7	3.32%	17.8	35.3	34.4	233.0	240.6	-1.0	-0.3	14.5
8	3.03%	16.3	32.3	34.4	265.3	274.9	2.1	0.7	15.1
9	2.40%	12.9	25.6	34.4	290.9	309.3	8.8	2.9	18.0
10	2.45%	13.2	26.1	34.4	317.0	343.6	8.3	2.7	20.7
11	3.03%	16.3	32.3	34.4	349.2	378.0	2.1	0.7	21.4
12	3.03%	16.3	32.3	34.4	381.5	412.4	2.1	0.7	22.1
13	3.03%	16.3	32.3	34.4	413.7	446.7	2.1	0.7	22.7
14	3.03%	16.3	32.3	34.4	446.0	481.1	2.1	0.7	23.4
15	3.06%	16.4	32.6	34.4	478.6	515.5	1.8	0.6	24.0
16	3.53%	19.0	37.6	34.4	516.3	549.8	-3.3	-1.1	22.9
17	3.63%	19.5	38.6	34.4	554.9	584.2	-4.3	-1.4	21.5
18	3.63%	19.5	38.6	34.4	593.6	618.6	-4.3	-1.4	20.1
19	3.63%	19.5	38.6	34.4	632.2	652.9	-4.3	-1.4	18.8
20	3.67%	19.7	39.1	34.4	671.3	687.3	-4.7	-1.5	17.2
21	4.18%	22.5	44.5	34.4	715.8	721.7	-10.2	-3.3	13.9
22	4.16%	22.3	44.3	34.4	760.1	756.0	-10.0	-3.2	10.7
23	3.81%	20.5	40.6	34.4	800.7	790.4	-6.2	-2.0	8.6
24	3.38%	18.2	36.0	34.4	836.7	824.7	-1.6	-0.5	8.1
25	3.61%	19.4	38.5	34.4	875.2	859.1	-4.1	-1.3	6.8
26	4.17%	22.4	44.4	34.4	919.6	893.5	-10.1	-3.3	3.5
27	4.16%	22.3	44.3	34.4	964.0	927.8	-10.0	-3.2	0.2
28	2.48%	13.3	26.4	34.4	990.4	962.2	7.9	2.6	2.8
29	1.42%	7.6	15.1	34.4	1,005.5	996.6	19.3	6.3	9.1
30	2.40%	12.9	25.5	34.4	1,031.0	1,030.9	8.8	2.9	12.0
31	3.22%	17.3	34.3	34.4	1,065.3	1,065.3	0.1	0.0	12.0
Totals			1,065.3	1,065.3					



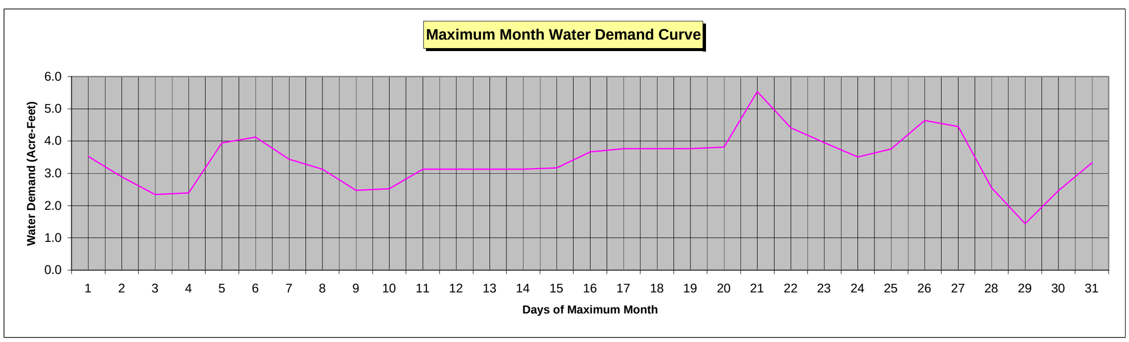


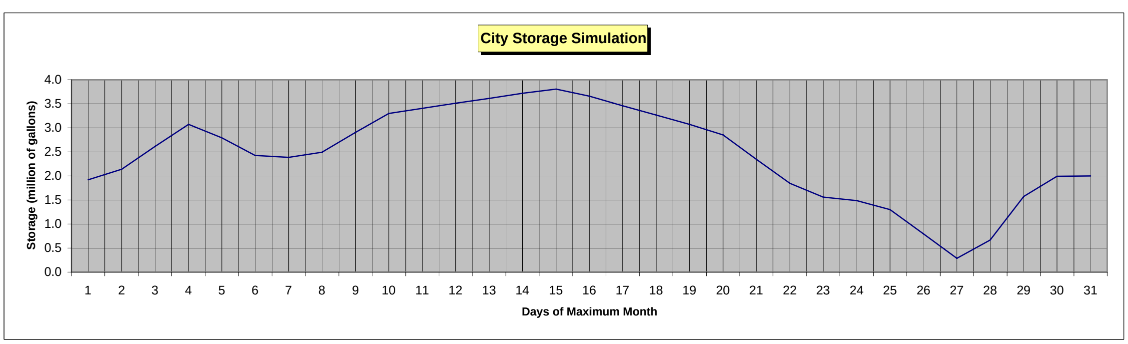
Langdon (City and RWS) - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	5.40 ac-ft	2.7 cfs	1.8 mgd
Max Month 2050 Water Demand =	105.3 ac-ft	1.7 cfs	1.1 mgd
Max Month Project Flows =	105.3 ac-ft	1.7 cfs	1.1 mgd
Starting Storage =	1.3 million gallons		
Required Storage +	2.8 million gallons	or	8 ac-ft
Storage estimated cost =	$1,377,000 (assumes $0.50 per gallon cost)		
Monthly shortage in storage (31 days) =	3.2 mg	9.7 ac-ft	
Peak day shortage in storage =	0.7 mg	2.1 ac-ft	1.08 cfs

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.35%	1.8	3.5	3.4	3.5	3.4	-0.1	0.0	1.3
2	2.74%	1.5	2.9	3.4	6.4	6.8	0.5	0.2	1.4
3	2.23%	1.2	2.3	3.4	8.8	10.2	1.1	0.3	1.8
4	2.27%	1.2	2.4	3.4	11.2	13.6	1.0	0.3	2.1
5	3.74%	2.0	3.9	3.4	15.1	17.0	-0.5	-0.2	1.9
6	3.91%	2.1	4.1	3.4	19.2	20.4	-0.7	-0.2	1.7
7	3.26%	1.7	3.4	3.4	22.7	23.8	0.0	0.0	1.7
8	2.98%	1.6	3.1	3.4	25.8	27.2	0.3	0.1	1.8
9	2.35%	1.2	2.5	3.4	28.3	30.6	0.9	0.3	2.1
10	2.40%	1.3	2.5	3.4	30.8	34.0	0.9	0.3	2.3
11	2.98%	1.6	3.1	3.4	33.9	37.4	0.3	0.1	2.4
12	2.98%	1.6	3.1	3.4	37.1	40.8	0.3	0.1	2.5
13	2.98%	1.6	3.1	3.4	40.2	44.2	0.3	0.1	2.6
14	2.98%	1.6	3.1	3.4	43.3	47.6	0.3	0.1	2.7
15	3.01%	1.6	3.2	3.4	46.5	51.0	0.2	0.1	2.8
16	3.48%	1.8	3.7	3.4	50.2	54.3	-0.3	-0.1	2.7
17	3.58%	1.9	3.8	3.4	53.9	57.7	-0.4	-0.1	2.5
18	3.58%	1.9	3.8	3.4	57.7	61.1	-0.4	-0.1	2.4
19	3.58%	1.9	3.8	3.4	61.4	64.5	-0.4	-0.1	2.3
20	3.62%	1.9	3.8	3.4	65.3	67.9	-0.4	-0.1	2.2
21	5.25%	2.8	5.5	3.4	70.8	71.3	-2.1	-0.7	1.5
22	4.19%	2.2	4.4	3.4	75.2	74.7	-1.0	-0.3	1.1
23	3.76%	2.0	4.0	3.4	79.2	78.1	-0.6	-0.2	1.0
24	3.33%	1.8	3.5	3.4	82.7	81.5	-0.1	0.0	0.9
25	3.56%	1.9	3.8	3.4	86.4	84.9	-0.4	-0.1	0.8
26	4.41%	2.3	4.6	3.4	91.1	88.3	-1.2	-0.4	0.4
27	4.23%	2.2	4.5	3.4	95.5	91.7	-1.1	-0.3	0.1
28	2.43%	1.3	2.6	3.4	98.1	95.1	0.8	0.3	0.3
29	1.37%	0.7	1.4	3.4	99.5	98.5	2.0	0.6	1.0
30	2.34%	1.2	2.5	3.4	102.0	101.9	0.9	0.3	1.3
31	3.16%	1.7	3.3	3.4	105.3	105.3	0.1	0.0	1.3
Totals			105.3	105.3					





Langdon (City and RWS) - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

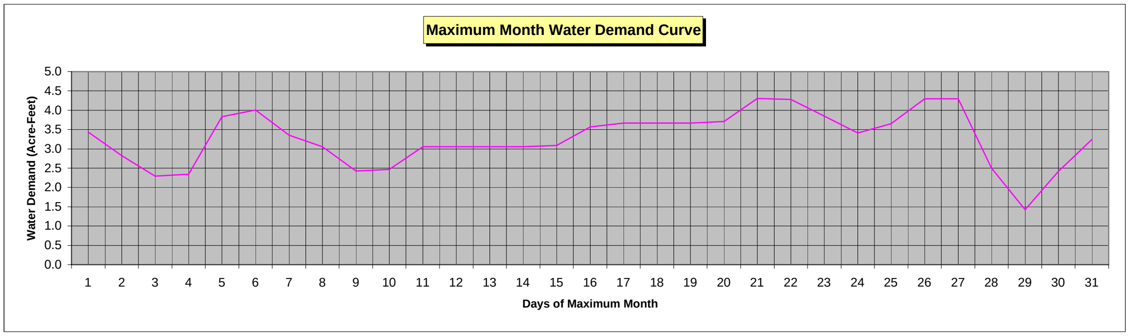
Basic Design Data:

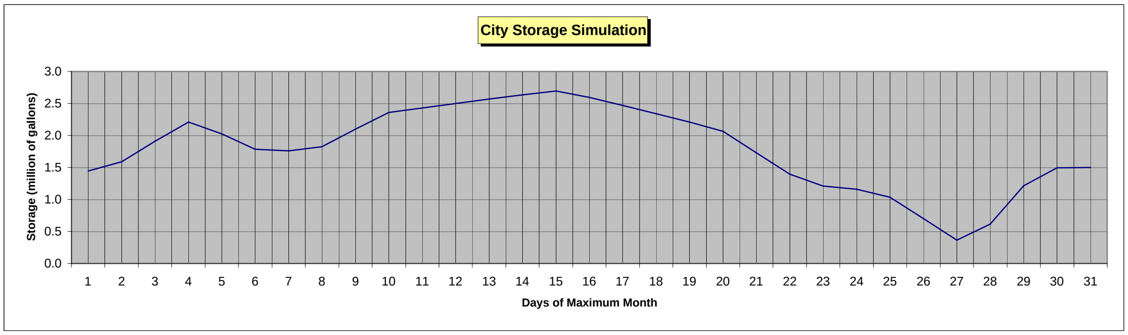
Peak Day 2050 Water Demand =	4.60 ac-ft	2.3 cfs	1.5 mgd
Max Month 2050 Water Demand =	90.4 ac-ft	1.5 cfs	1.0 mgd
Max Month Project Flows =	90.4 ac-ft	1.5 cfs	1.0 mgd

Starting Storage =	1.2 million gallons		
Required Storage +	2.4 million gallons	or	8 ac-ft
Storage estimated cost =	$1,224,000 (assumes $0.50 per gallon cost)		

Monthly shortage in storage (31 days) =	2.7 mg	8.3 ac-ft	
Peak day shortage in storage =	0.6 mg	1.8 ac-ft	0.92 cfs

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.35%	1.5	3.0	2.9	3.0	2.9	-0.1	0.0	1.2
2	2.74%	1.2	2.5	2.9	5.5	5.8	0.4	0.1	1.3
3	2.23%	1.0	2.0	2.9	7.5	8.7	0.9	0.3	1.6
4	2.27%	1.0	2.1	2.9	9.6	11.7	0.9	0.3	1.9
5	3.74%	1.7	3.4	2.9	13.0	14.6	-0.5	-0.2	1.7
6	3.91%	1.8	3.5	2.9	16.5	17.5	-0.6	-0.2	1.5
7	3.26%	1.5	3.0	2.9	19.4	20.4	0.0	0.0	1.5
8	2.98%	1.4	2.7	2.9	22.1	23.3	0.2	0.1	1.6
9	2.35%	1.1	2.1	2.9	24.3	26.2	0.8	0.3	1.8
10	2.40%	1.1	2.2	2.9	26.4	29.2	0.7	0.2	2.1
11	2.98%	1.4	2.7	2.9	29.1	32.1	0.2	0.1	2.2
12	2.98%	1.4	2.7	2.9	31.8	35.0	0.2	0.1	2.2
13	2.98%	1.4	2.7	2.9	34.5	37.9	0.2	0.1	2.3
14	2.98%	1.4	2.7	2.9	37.2	40.8	0.2	0.1	2.4
15	3.01%	1.4	2.7	2.9	39.9	43.7	0.2	0.1	2.4
16	3.48%	1.6	3.1	2.9	43.1	46.7	-0.2	-0.1	2.4
17	3.58%	1.6	3.2	2.9	46.3	49.6	-0.3	-0.1	2.3
18	3.58%	1.6	3.2	2.9	49.5	52.5	-0.3	-0.1	2.2
19	3.58%	1.6	3.2	2.9	52.8	55.4	-0.3	-0.1	2.1
20	3.62%	1.6	3.3	2.9	56.0	58.3	-0.4	-0.1	1.9
21	5.25%	2.4	4.7	2.9	60.8	61.2	-1.8	-0.6	1.4
22	4.19%	1.9	3.8	2.9	64.6	64.2	-0.9	-0.3	1.1
23	3.76%	1.7	3.4	2.9	68.0	67.1	-0.5	-0.2	0.9
24	3.33%	1.5	3.0	2.9	71.0	70.0	-0.1	0.0	0.9
25	3.56%	1.6	3.2	2.9	74.2	72.9	-0.3	-0.1	0.8
26	4.41%	2.0	4.0	2.9	78.2	75.8	-1.1	-0.3	0.4
27	4.23%	1.9	3.8	2.9	82.0	78.7	-0.9	-0.3	0.1
28	2.43%	1.1	2.2	2.9	84.2	81.7	0.7	0.2	0.4
29	1.37%	0.6	1.2	2.9	85.4	84.6	1.7	0.5	0.9
30	2.34%	1.1	2.1	2.9	87.5	87.5	0.8	0.3	1.2
31	3.16%	1.4	2.9	2.9	90.4	90.4	0.1	0.0	1.2
Totals			90.4	90.4					





Grand Forks-Traill Water District - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

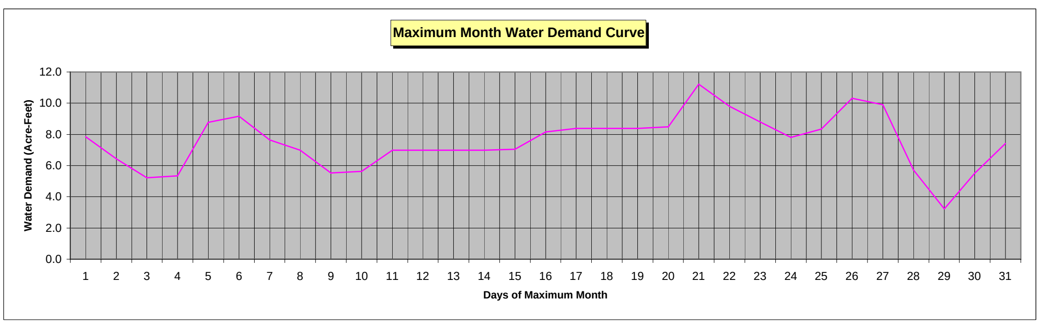
Basic Design Data:

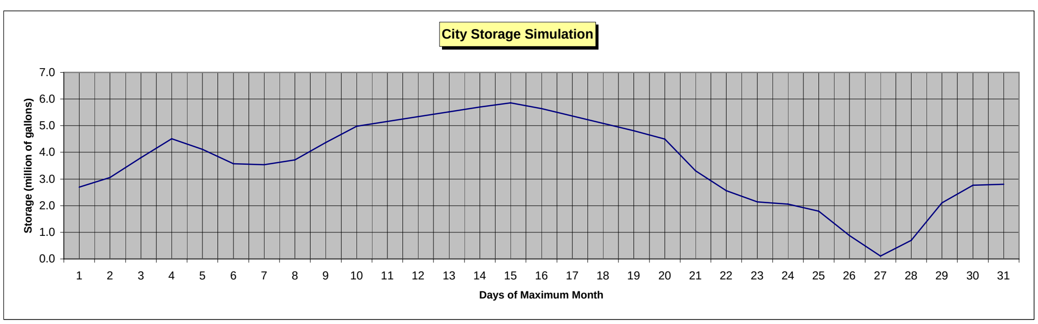
Peak Day 2050 Water Demand =	11.20 ac-ft	5.6 cfs	3.6 mgd	2534.2 gpm
Max Month 2050 Water Demand =	233.3 ac-ft	3.8 cfs	2.5 mgd	1702.9 gpm
Max Month Project Flows =	233.3 ac-ft	3.8 cfs	2.5 mgd	
Starting Storage =	2.8 million gallons			
Required Storage +	5.9 million gallons	or	18 ac-ft	
Storage estimated cost =	$2,926,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	6.8 mg	21.0 ac-ft		
Peak day shortage in storage =	1.2 mg	3.7 ac-ft	1.9 cfs	834.7 gpm

Groundwater Analysis:

Grand Forks-Traill Water District (GFTWD) currently has wells in the Elk Valley Aquifer but their existing permitted capacity is insufficient to meet their future needs so Reclamation proposes that they purchase some of their future water needs from the city of Grand Forks. Since their additional peak day water need is only 807.8 gpm Reclamation proposes that GFTWD contract with a local Elk Valley Aquifer irrigator (only need one irrigation well) to meet the infrequent peaking need.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.37%	4.0	7.9	7.5	7.9	7.5	-0.3	-0.1	2.7
2	2.76%	3.2	6.4	7.5	14.3	15.1	1.1	0.4	3.1
3	2.24%	2.6	5.2	7.5	19.5	22.6	2.3	0.7	3.8
4	2.29%	2.7	5.3	7.5	24.8	30.1	2.2	0.7	4.5
5	3.76%	4.4	8.8	7.5	33.6	37.6	-1.2	-0.4	4.1
6	3.93%	4.6	9.2	7.5	42.8	45.2	-1.6	-0.5	3.6
7	3.28%	3.9	7.7	7.5	50.4	52.7	-0.1	0.0	3.5
8	2.99%	3.5	7.0	7.5	57.4	60.2	0.5	0.2	3.7
9	2.37%	2.8	5.5	7.5	62.9	67.7	2.0	0.7	4.4
10	2.41%	2.8	5.6	7.5	68.6	75.3	1.9	0.6	5.0
11	2.99%	3.5	7.0	7.5	75.5	82.8	0.5	0.2	5.2
12	2.99%	3.5	7.0	7.5	82.5	90.3	0.5	0.2	5.3
13	2.99%	3.5	7.0	7.5	89.5	97.8	0.5	0.2	5.5
14	2.99%	3.5	7.0	7.5	96.5	105.4	0.5	0.2	5.7
15	3.02%	3.6	7.1	7.5	103.5	112.9	0.5	0.2	5.9
16	3.50%	4.1	8.2	7.5	111.7	120.4	-0.6	-0.2	5.6
17	3.59%	4.2	8.4	7.5	120.1	127.9	-0.9	-0.3	5.4
18	3.59%	4.2	8.4	7.5	128.4	135.5	-0.9	-0.3	5.1
19	3.59%	4.2	8.4	7.5	136.8	143.0	-0.9	-0.3	4.8
20	3.63%	4.3	8.5	7.5	145.3	150.5	-1.0	-0.3	4.5
21	4.81%	5.7	11.2	7.5	156.5	158.0	-3.7	-1.2	3.3
22	4.20%	4.9	9.8	7.5	166.3	165.6	-2.3	-0.7	2.6
23	3.77%	4.4	8.8	7.5	175.1	173.1	-1.3	-0.4	2.1
24	3.34%	3.9	7.8	7.5	182.9	180.6	-0.3	-0.1	2.1
25	3.58%	4.2	8.3	7.5	191.2	188.1	-0.8	-0.3	1.8
26	4.42%	5.2	10.3	7.5	201.6	195.7	-2.8	-0.9	0.9
27	4.24%	5.0	9.9	7.5	211.5	203.2	-2.4	-0.8	0.1
28	2.44%	2.9	5.7	7.5	217.2	210.7	1.8	0.6	0.7
29	1.38%	1.6	3.2	7.5	220.4	218.2	4.3	1.4	2.1
30	2.36%	2.8	5.5	7.5	225.9	225.8	2.0	0.7	2.8
31	3.18%	3.7	7.4	7.5	233.3	233.3	0.1	0.0	2.8
Totals			233.3	233.3					





Grand Forks-Traill Water District - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

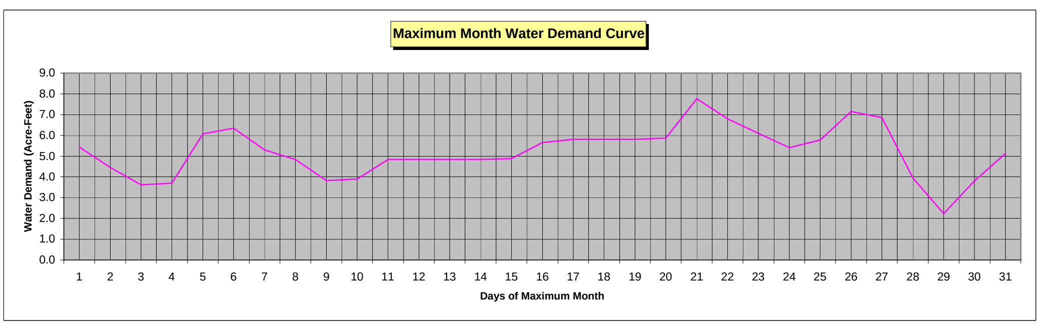
Basic Design Data:

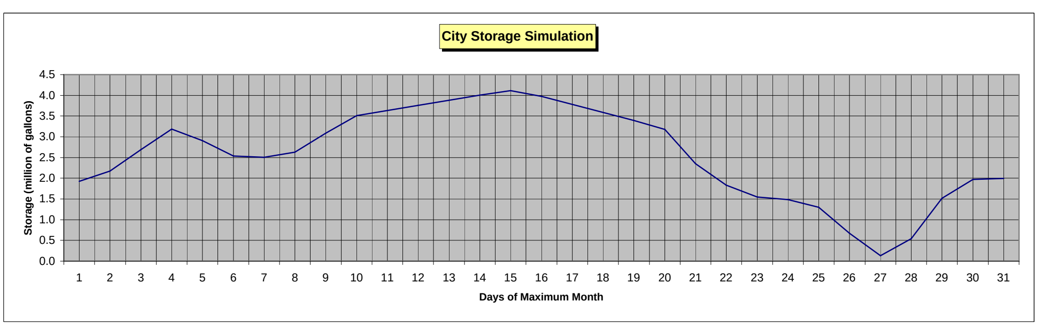
Peak Day 2050 Water Demand =	7.80 ac-ft	3.9 cfs	2.5 mgd	1764.9 gpm
Max Month 2050 Water Demand =	161.7 ac-ft	2.6 cfs	1.7 mgd	1180.3 gpm
Max Month Project Flows =	161.7 ac-ft	2.6 cfs	1.7 mgd	
Starting Storage =	2.0 million gallons			
Required Storage +	4.1 million gallons	or	13 ac-ft	
Storage estimated cost =	$2,058,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	4.7 mg	14.5 ac-ft		
Peak day shortage in storage =	0.8 mg	2.6 ac-ft	1.3 cfs	578.5 gpm

Groundwater Analysis:

Grand Forks-Traill Water District (GFTWD) currently has wells in the Elk Valley Aquifer but their existing permitted capacity is insufficient to meet their future needs so Reclamation proposes that they purchase some of their future water needs from the city of Grand Forks. Since their additional peak day water need is only 556.3 gpm Reclamation proposes that GFTWD contract with a local Elk Valley Aquifer irrigator (only need one irrigation well) to meet the infrequent peaking need.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.37%	2.7	5.4	5.2	5.4	5.2	-0.2	-0.1	1.9
2	2.76%	2.2	4.5	5.2	9.9	10.4	0.8	0.2	2.2
3	2.24%	1.8	3.6	5.2	13.5	15.6	1.6	0.5	2.7
4	2.29%	1.9	3.7	5.2	17.2	20.9	1.5	0.5	3.2
5	3.76%	3.1	6.1	5.2	23.3	26.1	-0.9	-0.3	2.9
6	3.93%	3.2	6.4	5.2	29.6	31.3	-1.1	-0.4	2.5
7	3.28%	2.7	5.3	5.2	35.0	36.5	-0.1	0.0	2.5
8	2.99%	2.4	4.8	5.2	39.8	41.7	0.4	0.1	2.6
9	2.37%	1.9	3.8	5.2	43.6	46.9	1.4	0.5	3.1
10	2.41%	2.0	3.9	5.2	47.5	52.2	1.3	0.4	3.5
11	2.99%	2.4	4.8	5.2	52.4	57.4	0.4	0.1	3.6
12	2.99%	2.4	4.8	5.2	57.2	62.6	0.4	0.1	3.8
13	2.99%	2.4	4.8	5.2	62.0	67.8	0.4	0.1	3.9
14	2.99%	2.4	4.8	5.2	66.9	73.0	0.4	0.1	4.0
15	3.02%	2.5	4.9	5.2	71.7	78.2	0.3	0.1	4.1
16	3.50%	2.9	5.7	5.2	77.4	83.5	-0.4	-0.1	4.0
17	3.59%	2.9	5.8	5.2	83.2	88.7	-0.6	-0.2	3.8
18	3.59%	2.9	5.8	5.2	89.0	93.9	-0.6	-0.2	3.6
19	3.59%	2.9	5.8	5.2	94.8	99.1	-0.6	-0.2	3.4
20	3.63%	3.0	5.9	5.2	100.7	104.3	-0.7	-0.2	3.2
21	4.81%	3.9	7.8	5.2	108.5	109.5	-2.6	-0.8	2.3
22	4.20%	3.4	6.8	5.2	115.3	114.8	-1.6	-0.5	1.8
23	3.77%	3.1	6.1	5.2	121.4	120.0	-0.9	-0.3	1.5
24	3.34%	2.7	5.4	5.2	126.8	125.2	-0.2	-0.1	1.5
25	3.58%	2.9	5.8	5.2	132.6	130.4	-0.6	-0.2	1.3
26	4.42%	3.6	7.1	5.2	139.7	135.6	-1.9	-0.6	0.7
27	4.24%	3.5	6.9	5.2	146.6	140.8	-1.6	-0.5	0.1
28	2.44%	2.0	4.0	5.2	150.5	146.1	1.3	0.4	0.5
29	1.38%	1.1	2.2	5.2	152.8	151.3	3.0	1.0	1.5
30	2.36%	1.9	3.8	5.2	156.6	156.5	1.4	0.5	2.0
31	3.18%	2.6	5.1	5.2	161.7	161.7	0.1	0.0	2.0
Totals			161.7	161.7					





Grand Forks - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	144.77 ac-ft	73.0 cfs	47.2 mgd	32757.1 gpm
Max Month 2050 Water Demand =	2685.8 ac-ft	43.7 cfs	28.2 mgd	19603.7 gpm
Max Month Project Flows =	2685.8 ac-ft	43.7 cfs	28.2 mgd	

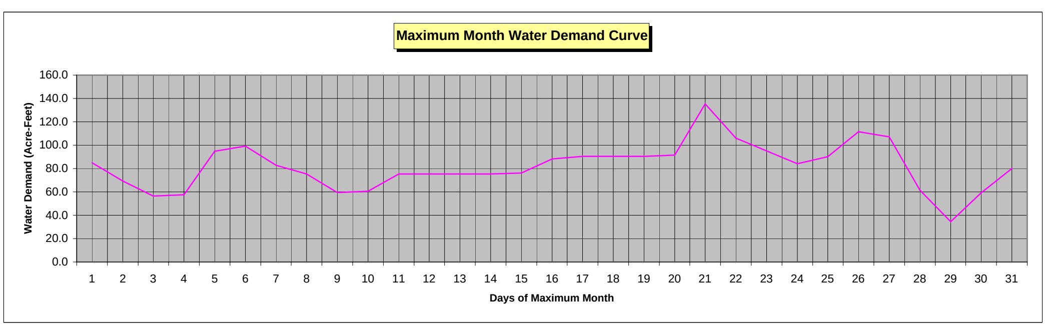
Starting Storage = 32.0 million gallons
Required Storage + 69.5 million gallons or 213 ac-ft
Storage estimated cost = $34,748,000 (assumes $0.50 per gallon cost)

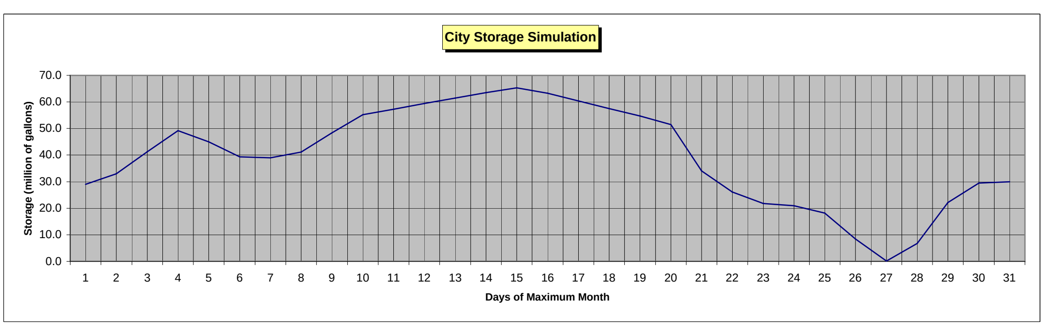
Monthly shortage in storage (31 days) =	81.0 mg	248.5 ac-ft		
Peak day shortage in storage =	18.5 mg	56.9 ac-ft	28.7 cfs	12869.0 gpm

Groundwater Analysis:

Grand Forks currently has no developed groundwater resources to draw on to meet peak day water demands. However, the Elk Valley Aquifer approximately 17 miles west of Grand Forks has some developed irrigation groundwater that could potentially be purchased on a short term basis to meet peak day requirements. To meet Grand Fork's peak day requirements, additional well capacity of 12,900 gpm will need to be developed.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.35%	45.3	89.9	86.6	89.9	86.6	-3.3	-1.1	30.9
2	2.74%	37.1	73.6	86.6	163.5	173.3	13.1	4.3	35.2
3	2.22%	30.1	59.7	86.6	223.2	259.9	26.9	8.8	44.0
4	2.27%	30.7	61.0	86.6	284.1	346.6	25.7	8.4	52.3
5	3.74%	50.6	100.4	86.6	384.5	433.2	-13.8	-4.5	47.9
6	3.91%	52.9	105.0	86.6	489.6	519.8	-18.4	-6.0	41.9
7	3.26%	44.2	87.6	86.6	577.2	606.5	-1.0	-0.3	41.5
8	2.97%	40.3	79.8	86.6	657.0	693.1	6.8	2.2	43.8
9	2.35%	31.8	63.1	86.6	720.1	779.7	23.6	7.7	51.4
10	2.39%	32.4	64.3	86.6	784.4	866.4	22.3	7.3	58.7
11	2.97%	40.3	79.8	86.6	864.2	953.0	6.8	2.2	60.9
12	2.97%	40.3	79.8	86.6	944.1	1,039.7	6.8	2.2	63.1
13	2.97%	40.3	79.8	86.6	1,023.9	1,126.3	6.8	2.2	65.4
14	2.97%	40.3	79.8	86.6	1,103.8	1,212.9	6.8	2.2	67.6
15	3.01%	40.7	80.7	86.6	1,184.5	1,299.6	5.9	1.9	69.5
16	3.48%	47.1	93.4	86.6	1,277.9	1,386.2	-6.8	-2.2	67.3
17	3.57%	48.4	96.0	86.6	1,373.9	1,472.9	-9.3	-3.0	64.2
18	3.57%	48.4	96.0	86.6	1,469.9	1,559.5	-9.3	-3.0	61.2
19	3.57%	48.4	96.0	86.6	1,565.8	1,646.1	-9.3	-3.0	58.2
20	3.62%	49.0	97.1	86.6	1,662.9	1,732.8	-10.5	-3.4	54.8
21	5.34%	72.4	143.5	86.6	1,806.4	1,819.4	-56.9	-18.5	36.2
22	4.18%	56.7	112.4	86.6	1,918.8	1,906.1	-25.7	-8.4	27.8
23	3.75%	50.8	100.8	86.6	2,019.6	1,992.7	-14.2	-4.6	23.2
24	3.32%	45.0	89.3	86.6	2,108.9	2,079.3	-2.7	-0.9	22.4
25	3.56%	48.2	95.6	86.6	2,204.5	2,166.0	-8.9	-2.9	19.4
26	4.40%	59.6	118.2	86.6	2,322.8	2,252.6	-31.6	-10.3	9.1
27	4.23%	57.2	113.5	86.6	2,436.3	2,339.2	-26.9	-8.8	0.4
28	2.43%	32.9	65.2	86.6	2,501.4	2,425.9	21.5	7.0	7.4
29	1.36%	18.5	36.6	86.6	2,538.1	2,512.5	50.0	16.3	23.7
30	2.34%	31.7	62.9	86.6	2,600.9	2,599.2	23.8	7.7	31.4
31	3.16%	42.8	84.9	86.6	2,685.8	2,685.8	1.8	0.6	32.0
Totals			2,685.8	2,685.8					





Grand Forks - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

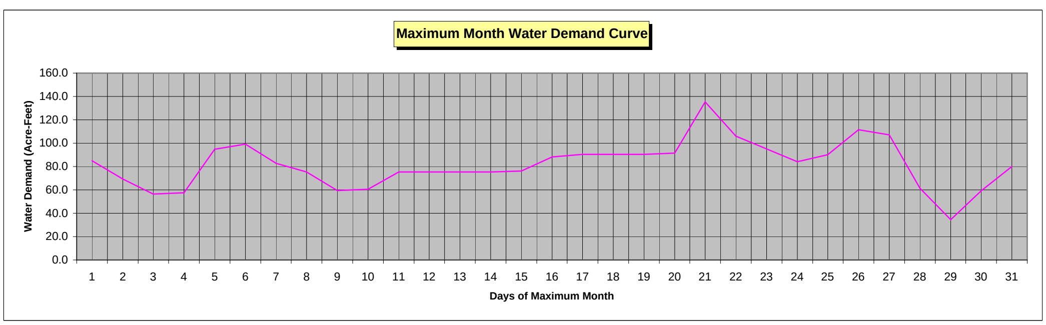
Basic Design Data:

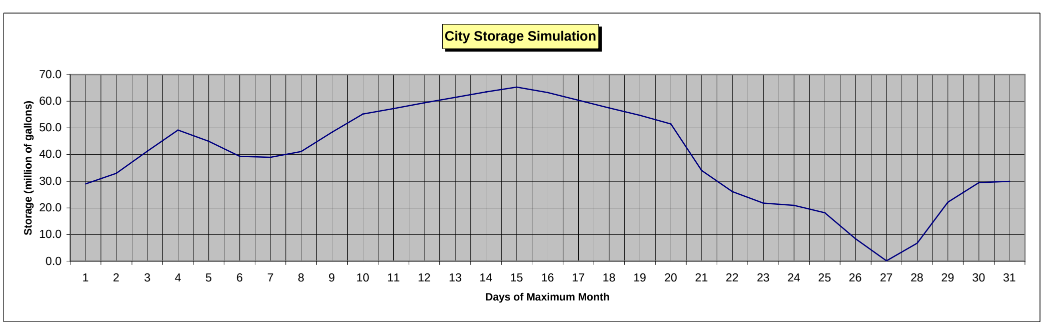
Peak Day 2050 Water Demand =	135.35 ac-ft	68.2 cfs	44.1 mgd	30625.6 gpm
Max Month 2050 Water Demand =	2533.2 ac-ft	41.2 cfs	26.6 mgd	18489.9 gpm
Max Month Project Flows =	2533.2 ac-ft	41.2 cfs	26.6 mgd	
Starting Storage =	30.0 million gallons			
Required Storage +	65.4 million gallons	or	201 ac-ft	
Storage estimated cost =	$32,683,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	76.4 mg	234.4 ac-ft		
Peak day shortage in storage =	17.5 mg	53.6 ac-ft	27.0 cfs	12137.8 gpm

Groundwater Analysis:

Grand Forks currently has no developed groundwater resources to draw on to meet peak day water demands. However, the Elk Valley Aquifer approximately 17 miles west of Grand Forks has some developed irrigation groundwater that could potentially be purchased on a short term basis to meet peak day requirements. To meet Grand Fork's peak day requirements, additional well capacity of 12,200 gpm will need to be developed.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.35%	42.8	84.8	81.7	84.8	81.7	-3.1	-1.0	29.0
2	2.74%	35.0	69.4	81.7	154.2	163.4	12.3	4.0	33.0
3	2.22%	28.4	56.3	81.7	210.5	245.1	25.4	8.3	41.3
4	2.27%	29.0	57.5	81.7	268.0	326.9	24.2	7.9	49.2
5	3.74%	47.7	94.7	81.7	362.7	408.6	-13.0	-4.2	45.0
6	3.91%	49.9	99.1	81.7	461.7	490.3	-17.3	-5.6	39.3
7	3.26%	41.7	82.6	81.7	544.4	572.0	-0.9	-0.3	39.0
8	2.97%	38.0	75.3	81.7	619.7	653.7	6.4	2.1	41.1
9	2.35%	30.0	59.5	81.7	679.2	735.4	22.2	7.2	48.3
10	2.39%	30.6	60.7	81.7	739.8	817.2	21.1	6.9	55.2
11	2.97%	38.0	75.3	81.7	815.1	898.9	6.4	2.1	57.3
12	2.97%	38.0	75.3	81.7	890.4	980.6	6.4	2.1	59.4
13	2.97%	38.0	75.3	81.7	965.7	1,062.3	6.4	2.1	61.5
14	2.97%	38.0	75.3	81.7	1,041.1	1,144.0	6.4	2.1	63.6
15	3.01%	38.4	76.1	81.7	1,117.2	1,225.7	5.6	1.8	65.4
16	3.48%	44.4	88.1	81.7	1,205.3	1,307.5	-6.4	-2.1	63.3
17	3.57%	45.6	90.5	81.7	1,295.8	1,389.2	-8.8	-2.9	60.4
18	3.57%	45.6	90.5	81.7	1,386.3	1,470.9	-8.8	-2.9	57.5
19	3.57%	45.6	90.5	81.7	1,476.9	1,552.6	-8.8	-2.9	54.7
20	3.62%	46.2	91.6	81.7	1,568.4	1,634.3	-9.9	-3.2	51.5
21	5.34%	68.2	135.4	81.7	1,703.8	1,716.0	-53.6	-17.5	34.0
22	4.18%	53.4	106.0	81.7	1,809.8	1,797.8	-24.3	-7.9	26.1
23	3.75%	47.9	95.1	81.7	1,904.9	1,879.5	-13.4	-4.4	21.7
24	3.32%	42.5	84.2	81.7	1,989.1	1,961.2	-2.5	-0.8	20.9
25	3.56%	45.5	90.2	81.7	2,079.3	2,042.9	-8.4	-2.7	18.2
26	4.40%	56.2	111.5	81.7	2,190.8	2,124.6	-29.8	-9.7	8.4
27	4.23%	54.0	107.1	81.7	2,297.9	2,206.3	-25.4	-8.3	0.2
28	2.43%	31.0	61.5	81.7	2,359.3	2,288.1	20.3	6.6	6.8
29	1.36%	17.4	34.5	81.7	2,393.9	2,369.8	47.2	15.4	22.2
30	2.34%	29.9	59.3	81.7	2,453.1	2,451.5	22.4	7.3	29.5
31	3.16%	40.4	80.1	81.7	2,533.2	2,533.2	1.7	0.5	30.0
Totals			2,533.2	2,533.2					



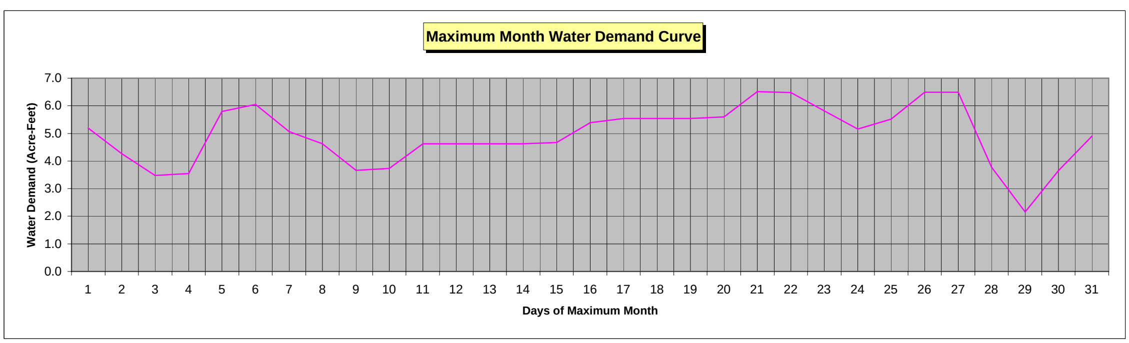


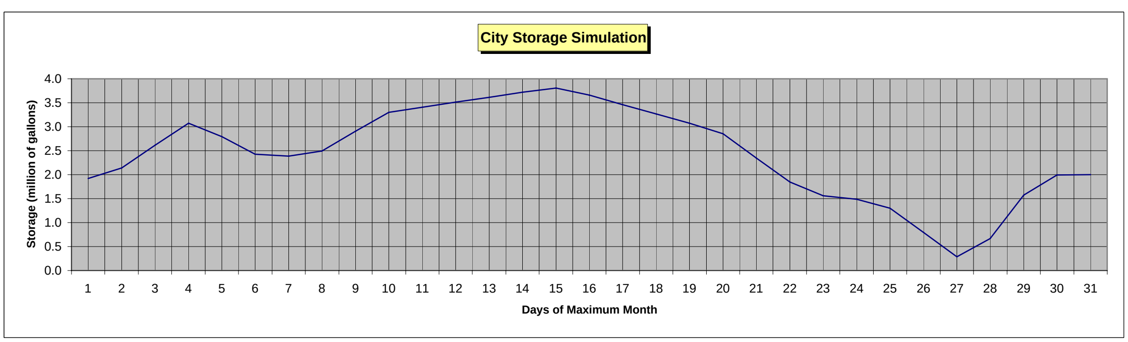
Grafton - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	6.51 ac-ft	3.3 cfs		2.1 mgd
Max Month 2050 Water Demand =	153.1 ac-ft	2.5 cfs		1.6 mgd
Max Month Project Flows =	153.1 ac-ft	2.5 cfs		1.6 mgd
Starting Storage =	2.0 million gallons			
Required Storage +	3.8 million gallons	or		11.7 ac-ft
Storage estimated cost =	$1,903,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	4.28 mg	13.1 ac-ft		
Peak day shortage in storage =	0.51 mg	1.57 ac-ft		0.79 cfs

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.39%	2.6	5.2	4.9	5.2	4.9	-0.3	-0.1	1.9
2	2.78%	2.1	4.3	4.9	9.5	9.9	0.7	0.2	2.1
3	2.27%	1.7	3.5	4.9	12.9	14.8	1.5	0.5	2.6
4	2.31%	1.8	3.5	4.9	16.5	19.8	1.4	0.5	3.1
5	3.78%	2.9	5.8	4.9	22.3	24.7	-0.9	-0.3	2.8
6	3.95%	3.1	6.1	4.9	28.3	29.6	-1.1	-0.4	2.4
7	3.31%	2.6	5.1	4.9	33.4	34.6	-0.1	0.0	2.4
8	3.02%	2.3	4.6	4.9	38.0	39.5	0.3	0.1	2.5
9	2.39%	1.8	3.7	4.9	41.7	44.4	1.3	0.4	2.9
10	2.44%	1.9	3.7	4.9	45.4	49.4	1.2	0.4	3.3
11	3.02%	2.3	4.6	4.9	50.0	54.3	0.3	0.1	3.4
12	3.02%	2.3	4.6	4.9	54.6	59.3	0.3	0.1	3.5
13	3.02%	2.3	4.6	4.9	59.2	64.2	0.3	0.1	3.6
14	3.02%	2.3	4.6	4.9	63.9	69.1	0.3	0.1	3.7
15	3.05%	2.4	4.7	4.9	68.5	74.1	0.3	0.1	3.8
16	3.52%	2.7	5.4	4.9	73.9	79.0	-0.5	-0.1	3.7
17	3.62%	2.8	5.5	4.9	79.5	84.0	-0.6	-0.2	3.5
18	3.62%	2.8	5.5	4.9	85.0	88.9	-0.6	-0.2	3.3
19	3.62%	2.8	5.5	4.9	90.5	93.8	-0.6	-0.2	3.1
20	3.66%	2.8	5.6	4.9	96.1	98.8	-0.7	-0.2	2.9
21	4.25%	3.3	6.5	4.9	102.7	103.7	-1.6	-0.5	2.3
22	4.23%	3.3	6.5	4.9	109.1	108.7	-1.5	-0.5	1.8
23	3.80%	2.9	5.8	4.9	114.9	113.6	-0.9	-0.3	1.6
24	3.37%	2.6	5.2	4.9	120.1	118.5	-0.2	-0.1	1.5
25	3.60%	2.8	5.5	4.9	125.6	123.5	-0.6	-0.2	1.3
26	4.24%	3.3	6.5	4.9	132.1	128.4	-1.6	-0.5	0.8
27	4.24%	3.3	6.5	4.9	138.6	133.3	-1.6	-0.5	0.3
28	2.47%	1.9	3.8	4.9	142.4	138.3	1.2	0.4	0.7
29	1.41%	1.1	2.2	4.9	144.5	143.2	2.8	0.9	1.6
30	2.38%	1.8	3.7	4.9	148.2	148.2	1.3	0.4	2.0
31	3.20%	2.5	4.9	4.9	153.1	153.1	0.0	0.0	2.0
Totals			153.1	153.1					



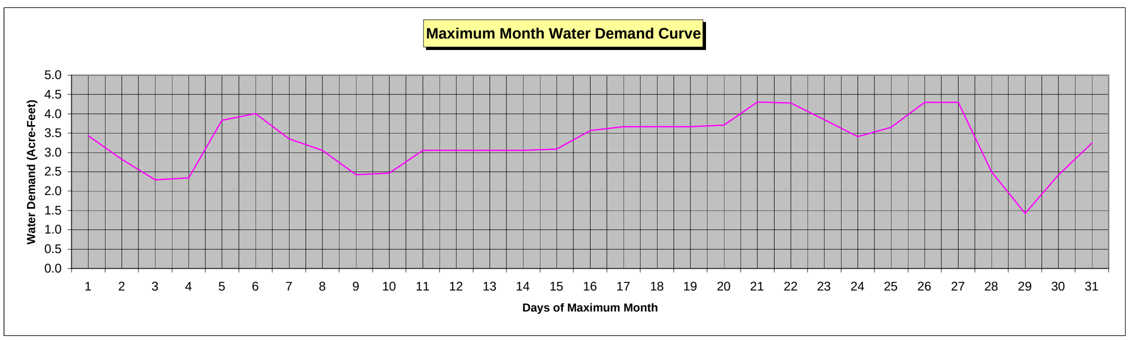


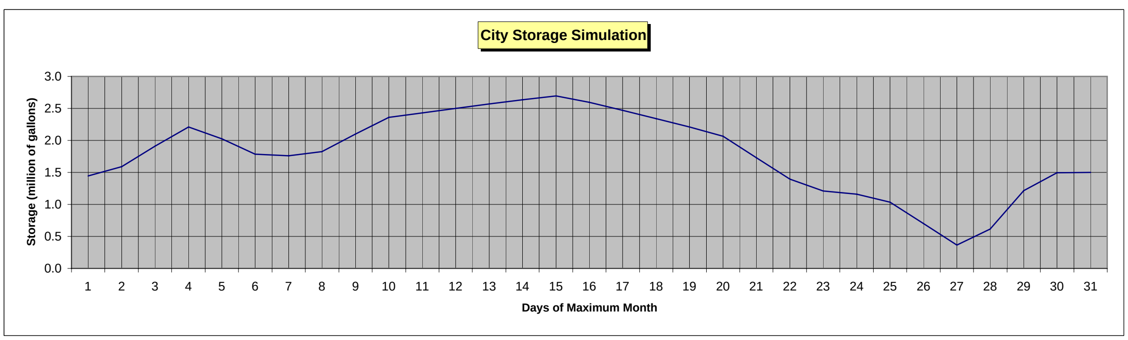
Grafton - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	4.31 ac-ft	2.2 cfs	1.4 mgd
Max Month 2050 Water Demand =	101.3 ac-ft	1.6 cfs	1.1 mgd
Max Month Project Flows =	101.3 ac-ft	1.6 cfs	1.1 mgd
Starting Storage =	1.5 million gallons		
Required Storage +	2.7 million gallons	or	8.3 ac-ft
Storage estimated cost =	$1,347,000 (assumes $0.50 per gallon cost)		
Monthly shortage in storage (31 days) =	2.83 mg	8.7 ac-ft	
Peak day shortage in storage =	0.34 mg	1.04 ac-ft	0.52 cfs

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.39%	1.7	3.4	3.3	3.4	3.3	-0.2	-0.1	1.4
2	2.78%	1.4	2.8	3.3	6.3	6.5	0.4	0.1	1.6
3	2.27%	1.2	2.3	3.3	8.6	9.8	1.0	0.3	1.9
4	2.31%	1.2	2.3	3.3	10.9	13.1	0.9	0.3	2.2
5	3.78%	1.9	3.8	3.3	14.7	16.3	-0.6	-0.2	2.0
6	3.95%	2.0	4.0	3.3	18.7	19.6	-0.7	-0.2	1.8
7	3.31%	1.7	3.3	3.3	22.1	22.9	-0.1	0.0	1.8
8	3.02%	1.5	3.1	3.3	25.1	26.1	0.2	0.1	1.8
9	2.39%	1.2	2.4	3.3	27.6	29.4	0.8	0.3	2.1
10	2.44%	1.2	2.5	3.3	30.0	32.7	0.8	0.3	2.4
11	3.02%	1.5	3.1	3.3	33.1	35.9	0.2	0.1	2.4
12	3.02%	1.5	3.1	3.3	36.1	39.2	0.2	0.1	2.5
13	3.02%	1.5	3.1	3.3	39.2	42.5	0.2	0.1	2.6
14	3.02%	1.5	3.1	3.3	42.3	45.7	0.2	0.1	2.6
15	3.05%	1.6	3.1	3.3	45.3	49.0	0.2	0.1	2.7
16	3.52%	1.8	3.6	3.3	48.9	52.3	-0.3	-0.1	2.6
17	3.62%	1.8	3.7	3.3	52.6	55.6	-0.4	-0.1	2.5
18	3.62%	1.8	3.7	3.3	56.2	58.8	-0.4	-0.1	2.3
19	3.62%	1.8	3.7	3.3	59.9	62.1	-0.4	-0.1	2.2
20	3.66%	1.9	3.7	3.3	63.6	65.4	-0.4	-0.1	2.1
21	4.25%	2.2	4.3	3.3	67.9	68.6	-1.0	-0.3	1.7
22	4.23%	2.2	4.3	3.3	72.2	71.9	-1.0	-0.3	1.4
23	3.80%	1.9	3.8	3.3	76.1	75.2	-0.6	-0.2	1.2
24	3.37%	1.7	3.4	3.3	79.5	78.4	-0.1	0.0	1.2
25	3.60%	1.8	3.7	3.3	83.1	81.7	-0.4	-0.1	1.0
26	4.24%	2.2	4.3	3.3	87.4	85.0	-1.0	-0.3	0.7
27	4.24%	2.2	4.3	3.3	91.7	88.2	-1.0	-0.3	0.4
28	2.47%	1.3	2.5	3.3	94.2	91.5	0.8	0.2	0.6
29	1.41%	0.7	1.4	3.3	95.6	94.8	1.8	0.6	1.2
30	2.38%	1.2	2.4	3.3	98.1	98.0	0.9	0.3	1.5
31	3.20%	1.6	3.2	3.3	101.3	101.3	0.0	0.0	1.5
Totals			101.3	101.3					





Fargo - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

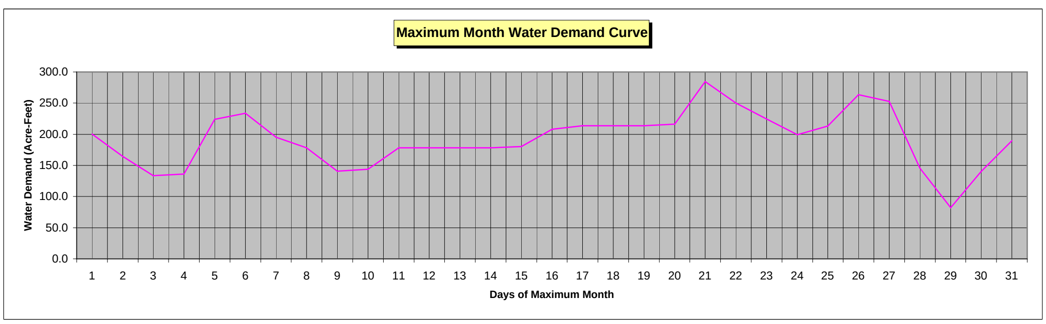
Peak Day 2050 Water Demand =	284.73 ac-ft	143.6 cfs	92.8 mgd	64425.9 gpm
Max Month 2050 Water Demand =	5954.9 ac-ft	96.8 cfs	62.6 mgd	43465.0 gpm
Max Month Project Flows =	5954.9 ac-ft	96.8 cfs	62.6 mgd	

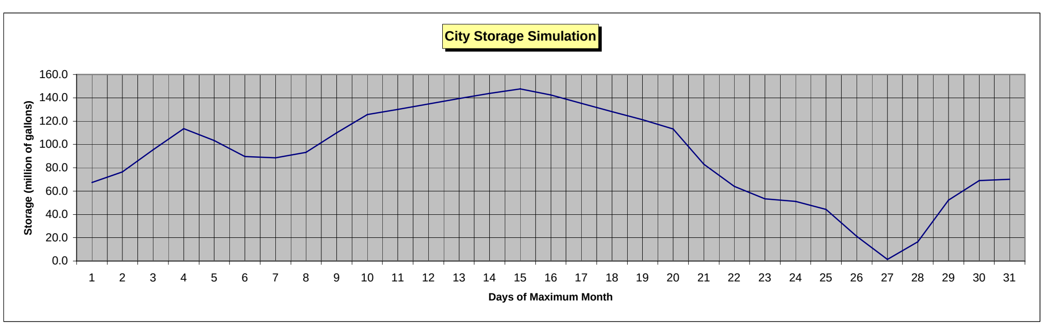
Starting Storage =	70.0 million gallons			
Required Storage +	147.7 million gallons	or	453 ac-ft	
Storage estimated cost =	$73,847,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	174.1 mg	534.3 ac-ft		
Peak day shortage in storage =	30.2 mg	92.7 ac-ft	46.7 cfs	20966.5 gpm

Groundwater Analysis:

Fargo currently has no developed groundwater resources to draw on to meet peak day water demands. However, the West Fargo South Aquifer approximately 6 miles south of Fargo is generally an untapped aquifer of limited quality and quantity, but is sufficient to meet some short duration intense water daily peaking water needs. To meet Fargo's peak day requirements, additional well capacity of 21,000 gpm will need to be developed.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.37%	101.1	200.5	192.1	200.5	192.1	-8.4	-2.7	67.3
2	2.76%	82.8	164.2	192.1	364.7	384.2	27.9	9.1	76.4
3	2.24%	67.3	133.5	192.1	498.1	576.3	58.6	19.1	95.5
4	2.29%	68.7	136.3	192.1	634.4	768.4	55.8	18.2	113.6
5	3.76%	112.8	223.7	192.1	858.2	960.5	-31.6	-10.3	103.3
6	3.93%	118.0	234.0	192.1	1,092.1	1,152.6	-41.9	-13.6	89.7
7	3.28%	98.5	195.4	192.1	1,287.5	1,344.7	-3.3	-1.1	88.6
8	2.99%	89.8	178.1	192.1	1,465.6	1,536.7	13.9	4.5	93.2
9	2.37%	71.0	140.9	192.1	1,606.6	1,728.8	51.2	16.7	109.8
10	2.41%	72.5	143.7	192.1	1,750.3	1,920.9	48.4	15.8	125.6
11	2.99%	89.8	178.1	192.1	1,928.4	2,113.0	13.9	4.5	130.2
12	2.99%	89.8	178.1	192.1	2,106.6	2,305.1	13.9	4.5	134.7
13	2.99%	89.8	178.1	192.1	2,284.7	2,497.2	13.9	4.5	139.2
14	2.99%	89.8	178.1	192.1	2,462.8	2,689.3	13.9	4.5	143.8
15	3.02%	90.8	180.1	192.1	2,642.9	2,881.4	12.0	3.9	147.7
16	3.50%	105.0	208.3	192.1	2,851.2	3,073.5	-16.2	-5.3	142.4
17	3.59%	107.8	213.9	192.1	3,065.1	3,265.6	-21.8	-7.1	135.3
18	3.59%	107.8	213.9	192.1	3,279.0	3,457.7	-21.8	-7.1	128.2
19	3.59%	107.8	213.9	192.1	3,492.9	3,649.8	-21.8	-7.1	121.1
20	3.63%	109.1	216.4	192.1	3,709.2	3,841.9	-24.3	-7.9	113.2
21	4.78%	143.6	284.8	192.1	3,994.0	4,034.0	-92.7	-30.2	83.0
22	4.20%	126.2	250.3	192.1	4,244.3	4,226.1	-58.2	-19.0	64.1
23	3.77%	113.3	224.7	192.1	4,469.0	4,418.2	-32.6	-10.6	53.4
24	3.34%	100.4	199.1	192.1	4,668.0	4,610.2	-7.0	-2.3	51.2
25	3.58%	107.4	213.0	192.1	4,881.1	4,802.3	-21.0	-6.8	44.3
26	4.42%	132.7	263.3	192.1	5,144.4	4,994.4	-71.2	-23.2	21.1
27	4.25%	127.5	252.8	192.1	5,397.2	5,186.5	-60.7	-19.8	1.4
28	2.44%	73.4	145.6	192.1	5,542.8	5,378.6	46.5	15.2	16.5
29	1.38%	41.5	82.3	192.1	5,625.1	5,570.7	109.8	35.8	52.3
30	2.36%	70.8	140.5	192.1	5,765.6	5,762.8	51.6	16.8	69.1
31	3.18%	95.4	189.3	192.1	5,954.9	5,954.9	2.8	0.9	70.0
Totals			5,954.9	5,954.9					





Fargo - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

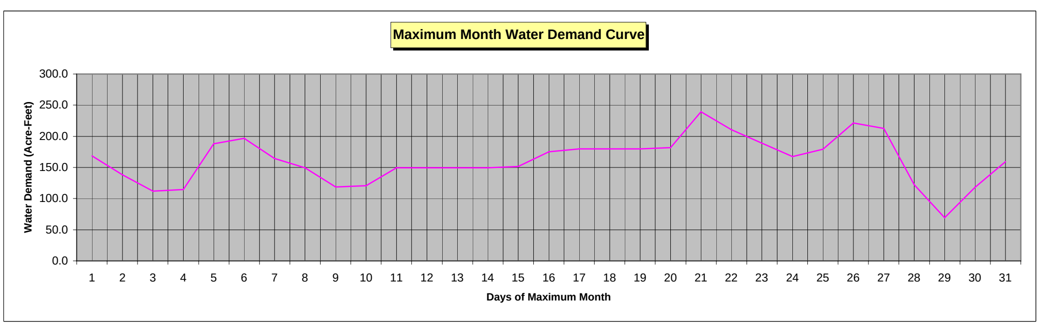
Basic Design Data:

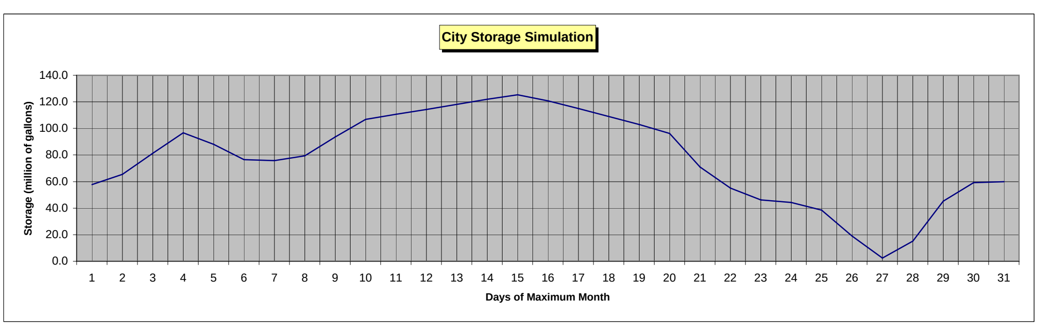
Peak Day 2050 Water Demand =	239.32 ac-ft	120.7 cfs	78.0 mgd	54150.9 gpm
Max Month 2050 Water Demand =	5005 ac-ft	81.4 cfs	52.6 mgd	36531.7 gpm
Max Month Project Flows =	5005 ac-ft	81.4 cfs	52.6 mgd	
Starting Storage =	60.0 million gallons			
Required Storage +	125.3 million gallons	or	385 ac-ft	
Storage estimated cost =	$62,651,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	146.3 mg	449.1 ac-ft		
Peak day shortage in storage =	25.4 mg	77.9 ac-ft	39.3 cfs	17622.0 gpm

Groundwater Analysis:

Fargo currently has no developed groundwater resources to draw on to meet peak day water demands. However, the West Fargo South Aquifer approximately 6 miles south of Fargo is generally an untapped aquifer of limited quality and quantity, but is sufficient to meet some short duration intense water daily peaking water needs. To meet Fargo's peak day requirements, additional well capacity of 17,700 gpm will need to be developed.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.37%	84.9	168.5	161.5	168.5	161.5	-7.0	-2.3	57.7
2	2.76%	69.6	138.0	161.5	306.5	322.9	23.5	7.6	65.3
3	2.24%	56.6	112.2	161.5	418.7	484.4	49.3	16.1	81.4
4	2.29%	57.7	114.5	161.5	533.2	645.8	46.9	15.3	96.7
5	3.76%	94.8	188.1	161.5	721.3	807.3	-26.6	-8.7	88.0
6	3.93%	99.1	196.6	161.5	917.9	968.7	-35.2	-11.5	76.5
7	3.28%	82.8	164.2	161.5	1,082.1	1,130.2	-2.7	-0.9	75.7
8	2.99%	75.5	149.7	161.5	1,231.8	1,291.6	11.7	3.8	79.5
9	2.37%	59.7	118.4	161.5	1,350.3	1,453.1	43.0	14.0	93.5
10	2.41%	60.9	120.8	161.5	1,471.1	1,614.5	40.7	13.2	106.7
11	2.99%	75.5	149.7	161.5	1,620.8	1,776.0	11.7	3.8	110.6
12	2.99%	75.5	149.7	161.5	1,770.5	1,937.4	11.7	3.8	114.4
13	2.99%	75.5	149.7	161.5	1,920.3	2,098.9	11.7	3.8	118.2
14	2.99%	75.5	149.7	161.5	2,070.0	2,260.3	11.7	3.8	122.0
15	3.02%	76.3	151.4	161.5	2,221.4	2,421.8	10.1	3.3	125.3
16	3.50%	88.3	175.1	161.5	2,396.4	2,583.2	-13.6	-4.4	120.9
17	3.59%	90.6	179.8	161.5	2,576.2	2,744.7	-18.3	-6.0	114.9
18	3.59%	90.6	179.8	161.5	2,755.9	2,906.1	-18.3	-6.0	108.9
19	3.59%	90.6	179.8	161.5	2,935.7	3,067.6	-18.3	-6.0	103.0
20	3.63%	91.7	181.9	161.5	3,117.6	3,229.0	-20.4	-6.7	96.3
21	4.78%	120.7	239.3	161.5	3,356.9	3,390.5	-77.9	-25.4	70.9
22	4.20%	106.1	210.4	161.5	3,567.3	3,551.9	-48.9	-15.9	55.0
23	3.77%	95.2	188.8	161.5	3,756.1	3,713.4	-27.4	-8.9	46.1
24	3.34%	84.4	167.3	161.5	3,923.4	3,874.8	-5.9	-1.9	44.2
25	3.58%	90.3	179.1	161.5	4,102.5	4,036.3	-17.6	-5.7	38.4
26	4.42%	111.6	221.3	161.5	4,323.8	4,197.7	-59.8	-19.5	18.9
27	4.25%	107.1	212.5	161.5	4,536.3	4,359.2	-51.0	-16.6	2.3
28	2.44%	61.7	122.4	161.5	4,658.6	4,520.6	39.1	12.7	15.0
29	1.38%	34.9	69.2	161.5	4,727.8	4,682.1	92.3	30.1	45.1
30	2.36%	59.5	118.1	161.5	4,845.9	4,843.5	43.4	14.1	59.2
31	3.18%	80.2	159.1	161.5	5,005.0	5,005.0	2.3	0.8	60.0
Totals			5,005.0	5,005.0					



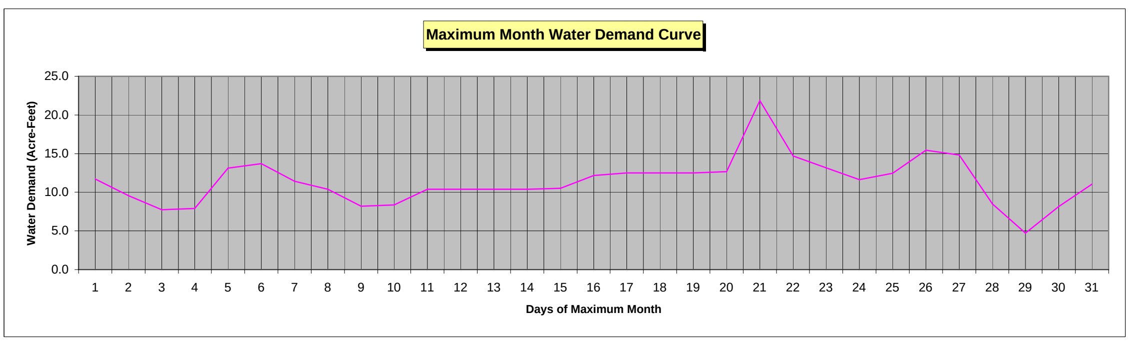


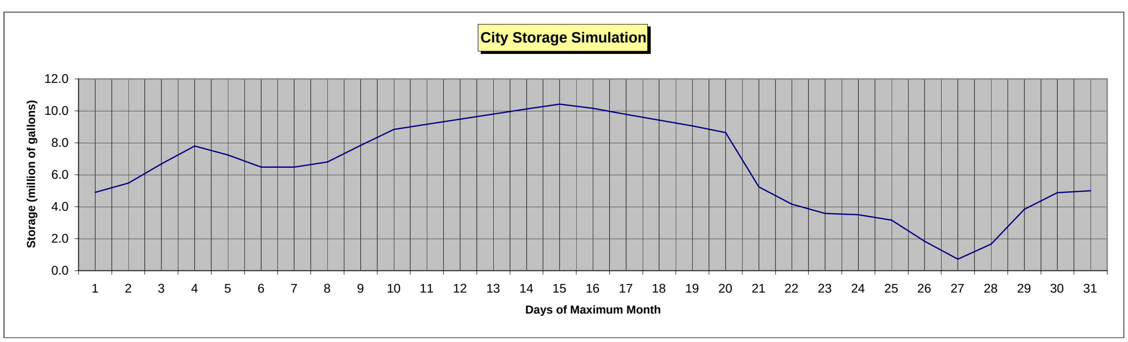
East Grand Forks - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	21.84 ac-ft	11.0 cfs		7.1 mgd
Max Month 2050 Water Demand =	353.1 ac-ft	5.7 cfs		3.7 mgd
Max Month Project Flows =	353.1 ac-ft	5.7 cfs		3.7 mgd
Starting Storage =	5.0 million gallons			
Required Storage +	10.4 million gallons	or		32 ac-ft
Storage estimated cost =	$5,206,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	11.1 mg	34.2 ac-ft		
Peak day shortage in storage =	3.4 mg	10.5 ac-ft		5.3 cfs

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.32%	5.9	11.7	11.4	11.7	11.4	-0.3	-0.1	4.9
2	2.71%	4.8	9.6	11.4	21.3	22.8	1.8	0.6	5.5
3	2.19%	3.9	7.8	11.4	29.0	34.2	3.6	1.2	6.7
4	2.24%	4.0	7.9	11.4	37.0	45.6	3.5	1.1	7.8
5	3.71%	6.6	13.1	11.4	50.1	57.0	-1.7	-0.6	7.2
6	3.88%	6.9	13.7	11.4	63.8	68.3	-2.3	-0.8	6.5
7	3.23%	5.8	11.4	11.4	75.2	79.7	0.0	0.0	6.5
8	2.94%	5.2	10.4	11.4	85.6	91.1	1.0	0.3	6.8
9	2.32%	4.1	8.2	11.4	93.8	102.5	3.2	1.0	7.8
10	2.37%	4.2	8.4	11.4	102.1	113.9	3.0	1.0	8.8
11	2.94%	5.2	10.4	11.4	112.5	125.3	1.0	0.3	9.2
12	2.94%	5.2	10.4	11.4	122.9	136.7	1.0	0.3	9.5
13	2.94%	5.2	10.4	11.4	133.3	148.1	1.0	0.3	9.8
14	2.94%	5.2	10.4	11.4	143.7	159.5	1.0	0.3	10.1
15	2.98%	5.3	10.5	11.4	154.2	170.9	0.9	0.3	10.4
16	3.45%	6.1	12.2	11.4	166.4	182.2	-0.8	-0.3	10.2
17	3.54%	6.3	12.5	11.4	178.9	193.6	-1.1	-0.4	9.8
18	3.54%	6.3	12.5	11.4	191.5	205.0	-1.1	-0.4	9.4
19	3.54%	6.3	12.5	11.4	204.0	216.4	-1.1	-0.4	9.1
20	3.59%	6.4	12.7	11.4	216.6	227.8	-1.3	-0.4	8.6
21	6.19%	11.0	21.8	11.4	238.5	239.2	-10.5	-3.4	5.2
22	4.16%	7.4	14.7	11.4	253.2	250.6	-3.3	-1.1	4.2
23	3.73%	6.6	13.2	11.4	266.3	262.0	-1.8	-0.6	3.6
24	3.30%	5.9	11.6	11.4	278.0	273.4	-0.2	-0.1	3.5
25	3.53%	6.3	12.5	11.4	290.4	284.8	-1.1	-0.4	3.2
26	4.37%	7.8	15.4	11.4	305.9	296.1	-4.1	-1.3	1.8
27	4.20%	7.5	14.8	11.4	320.7	307.5	-3.4	-1.1	0.7
28	2.40%	4.3	8.5	11.4	329.2	318.9	2.9	1.0	1.7
29	1.34%	2.4	4.7	11.4	333.9	330.3	6.7	2.2	3.8
30	2.31%	4.1	8.2	11.4	342.0	341.7	3.2	1.1	4.9
31	3.13%	5.6	11.1	11.4	353.1	353.1	0.3	0.1	5.0
Totals			353.1	353.1					



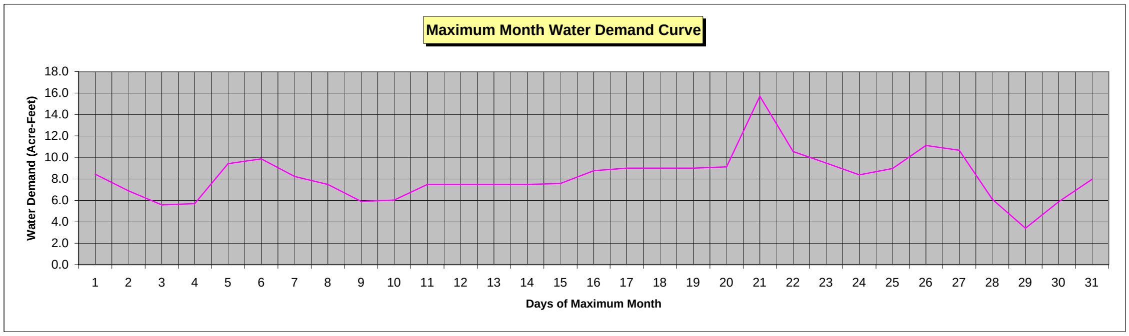


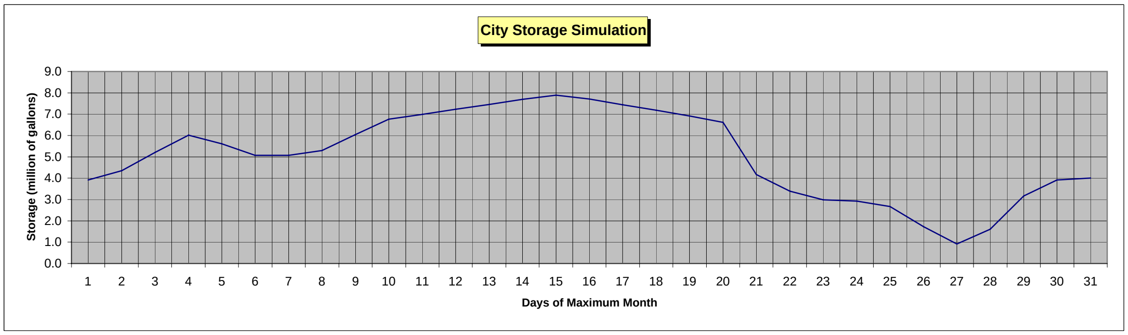
East Grand Forks - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	15.72 ac-ft	7.9 cfs		5.1 mgd
Max Month 2050 Water Demand =	254.1 ac-ft	4.1 cfs		2.7 mgd
Max Month Project Flows =	254.1 ac-ft	4.1 cfs		2.7 mgd
Starting Storage =	4.0 million gallons			
Required Storage +	7.9 million gallons	or		24 ac-ft
Storage estimated cost =	$3,948,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	8.0 mg	24.6 ac-ft		
Peak day shortage in storage =	2.5 mg	7.5 ac-ft		3.8 cfs

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.32%	4.3	8.4	8.2	8.4	8.2	-0.2	-0.1	3.9
2	2.71%	3.5	6.9	8.2	15.3	16.4	1.3	0.4	4.3
3	2.19%	2.8	5.6	8.2	20.9	24.6	2.6	0.9	5.2
4	2.24%	2.9	5.7	8.2	26.6	32.8	2.5	0.8	6.0
5	3.71%	4.8	9.4	8.2	36.0	41.0	-1.2	-0.4	5.6
6	3.88%	5.0	9.9	8.2	45.9	49.2	-1.7	-0.5	5.1
7	3.23%	4.1	8.2	8.2	54.1	57.4	0.0	0.0	5.1
8	2.94%	3.8	7.5	8.2	61.6	65.6	0.7	0.2	5.3
9	2.32%	3.0	5.9	8.2	67.5	73.8	2.3	0.8	6.0
10	2.37%	3.0	6.0	8.2	73.5	82.0	2.2	0.7	6.8
11	2.94%	3.8	7.5	8.2	81.0	90.2	0.7	0.2	7.0
12	2.94%	3.8	7.5	8.2	88.5	98.4	0.7	0.2	7.2
13	2.94%	3.8	7.5	8.2	95.9	106.6	0.7	0.2	7.5
14	2.94%	3.8	7.5	8.2	103.4	114.8	0.7	0.2	7.7
15	2.98%	3.8	7.6	8.2	111.0	123.0	0.6	0.2	7.9
16	3.45%	4.4	8.8	8.2	119.8	131.1	-0.6	-0.2	7.7
17	3.54%	4.5	9.0	8.2	128.8	139.3	-0.8	-0.3	7.4
18	3.54%	4.5	9.0	8.2	137.8	147.5	-0.8	-0.3	7.2
19	3.54%	4.5	9.0	8.2	146.8	155.7	-0.8	-0.3	6.9
20	3.59%	4.6	9.1	8.2	155.9	163.9	-0.9	-0.3	6.6
21	6.19%	7.9	15.7	8.2	171.6	172.1	-7.5	-2.5	4.2
22	4.16%	5.3	10.6	8.2	182.2	180.3	-2.4	-0.8	3.4
23	3.73%	4.8	9.5	8.2	191.7	188.5	-1.3	-0.4	3.0
24	3.30%	4.2	8.4	8.2	200.0	196.7	-0.2	-0.1	2.9
25	3.53%	4.5	9.0	8.2	209.0	204.9	-0.8	-0.3	2.7
26	4.37%	5.6	11.1	8.2	220.1	213.1	-2.9	-1.0	1.7
27	4.20%	5.4	10.7	8.2	230.8	221.3	-2.5	-0.8	0.9
28	2.40%	3.1	6.1	8.2	236.9	229.5	2.1	0.7	1.6
29	1.34%	1.7	3.4	8.2	240.3	237.7	4.8	1.6	3.2
30	2.31%	3.0	5.9	8.2	246.1	245.9	2.3	0.8	3.9
31	3.13%	4.0	8.0	8.2	254.1	254.1	0.2	0.1	4.0
Totals			254.1	254.1					





Drayton - Scenario One and Two Peak Day Analysis
Red River Valley Water Supply Project

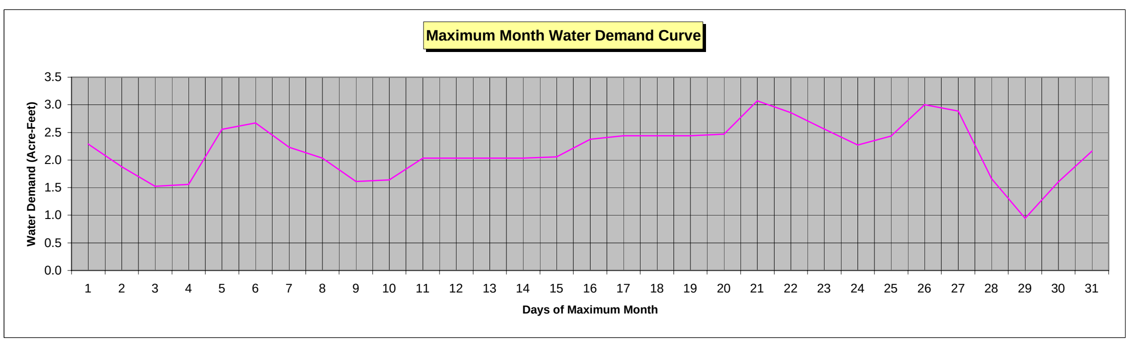
Basic Design Data:

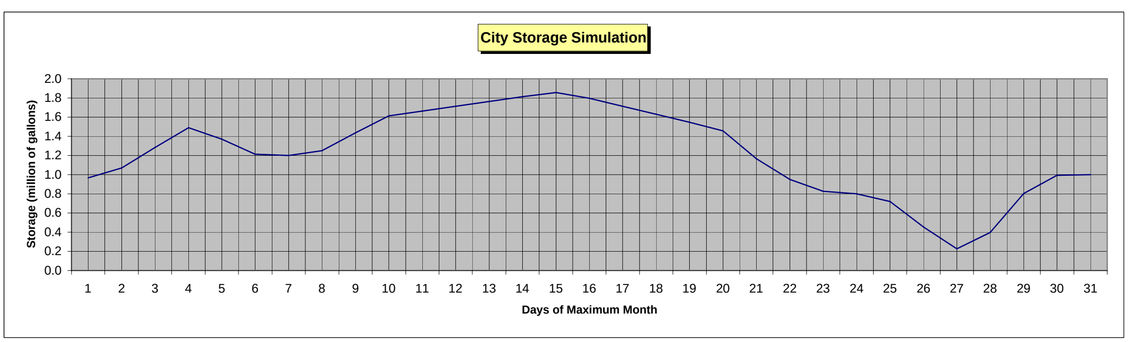
Peak Day 2050 Water Demand =	3.07 ac-ft	1.5 cfs	1.0 mgd
Max Month 2050 Water Demand =	67.8 ac-ft	1.1 cfs	0.7 mgd
Max Month Project Flows =	67.8 ac-ft	1.1 cfs	0.7 mgd

Starting Storage =	1.0 million gallons		
Required Storage +	1.9 million gallons	or	6 ac-ft
Storage estimated cost =	$929,000 (assumes $0.50 per gallon cost)		

Monthly shortage in storage (31 days) =	2.0 mg	6.0 ac-ft	
Peak day shortage in storage =	0.3 mg	0.9 ac-ft	0.45 cfs

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.37%	1.2	2.3	2.2	2.3	2.2	-0.1	0.0	1.0
2	2.77%	0.9	1.9	2.2	4.2	4.4	0.3	0.1	1.1
3	2.25%	0.8	1.5	2.2	5.7	6.6	0.7	0.2	1.3
4	2.30%	0.8	1.6	2.2	7.2	8.7	0.6	0.2	1.5
5	3.77%	1.3	2.6	2.2	9.8	10.9	-0.4	-0.1	1.4
6	3.94%	1.3	2.7	2.2	12.5	13.1	-0.5	-0.2	1.2
7	3.29%	1.1	2.2	2.2	14.7	15.3	0.0	0.0	1.2
8	3.00%	1.0	2.0	2.2	16.7	17.5	0.2	0.0	1.2
9	2.37%	0.8	1.6	2.2	18.3	19.7	0.6	0.2	1.4
10	2.42%	0.8	1.6	2.2	20.0	21.9	0.5	0.2	1.6
11	3.00%	1.0	2.0	2.2	22.0	24.1	0.2	0.0	1.7
12	3.00%	1.0	2.0	2.2	24.1	26.2	0.2	0.0	1.7
13	3.00%	1.0	2.0	2.2	26.1	28.4	0.2	0.0	1.8
14	3.00%	1.0	2.0	2.2	28.1	30.6	0.2	0.0	1.8
15	3.03%	1.0	2.1	2.2	30.2	32.8	0.1	0.0	1.9
16	3.51%	1.2	2.4	2.2	32.6	35.0	-0.2	-0.1	1.8
17	3.60%	1.2	2.4	2.2	35.0	37.2	-0.3	-0.1	1.7
18	3.60%	1.2	2.4	2.2	37.4	39.4	-0.3	-0.1	1.6
19	3.60%	1.2	2.4	2.2	39.9	41.6	-0.3	-0.1	1.5
20	3.64%	1.2	2.5	2.2	42.3	43.7	-0.3	-0.1	1.5
21	4.53%	1.5	3.1	2.2	45.4	45.9	-0.9	-0.3	1.2
22	4.21%	1.4	2.9	2.2	48.3	48.1	-0.7	-0.2	0.9
23	3.78%	1.3	2.6	2.2	50.8	50.3	-0.4	-0.1	0.8
24	3.35%	1.1	2.3	2.2	53.1	52.5	-0.1	0.0	0.8
25	3.59%	1.2	2.4	2.2	55.5	54.7	-0.2	-0.1	0.7
26	4.43%	1.5	3.0	2.2	58.5	56.9	-0.8	-0.3	0.5
27	4.25%	1.5	2.9	2.2	61.4	59.1	-0.7	-0.2	0.2
28	2.45%	0.8	1.7	2.2	63.1	61.2	0.5	0.2	0.4
29	1.39%	0.5	0.9	2.2	64.0	63.4	1.2	0.4	0.8
30	2.37%	0.8	1.6	2.2	65.6	65.6	0.6	0.2	1.0
31	3.19%	1.1	2.2	2.2	67.8	67.8	0.0	0.0	1.0
Totals			67.8	67.8					





Cass Rural Water Users District - Scenario Two Peak Day Analysis
Red River Valley Water Supply Project

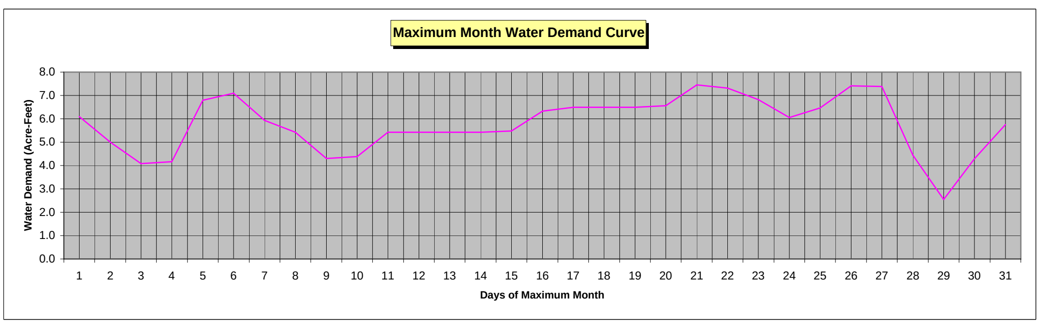
Basic Design Data:

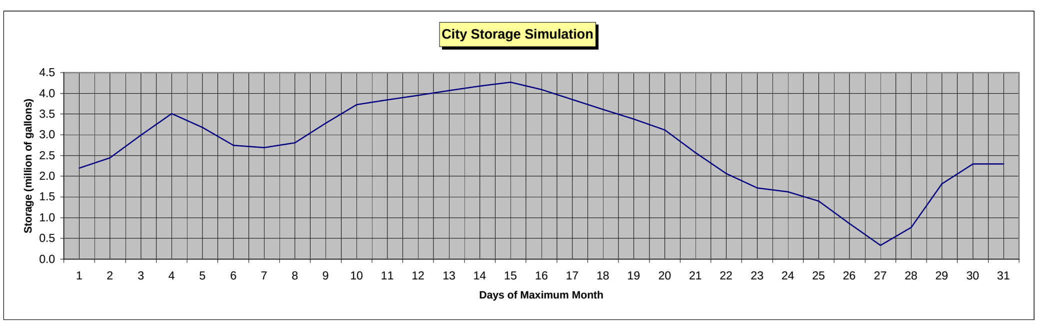
Peak Day 2050 Water Demand =	5.96 ac-ft	3.0 cfs	1.9 mgd	1348.6 gpm
Max Month 2050 Water Demand =	178.7 ac-ft	2.9 cfs	1.9 mgd	1304.3 gpm
Max Month Project Flows =	178.7 ac-ft	2.9 cfs	1.9 mgd	
Starting Storage =	2.3 million gallons			
Required Storage +	4.3 million gallons	or	13 ac-ft	
Storage estimated cost =	$2,135,000 (assumes $0.50 per gallon cost)			
Monthly shortage in storage (31 days) =	4.9 mg	14.9 ac-ft		
Peak day shortage in storage =	0.6 mg	1.7 ac-ft	0.9 cfs	382.7 gpm

Groundwater Analysis:

Cass Rural Water Users District currently has wells in the West Fargo North Aquifer that serves the Phase I service area. This aquifer is being mined so Reclamation proposes that the water system purchase water from the city of Fargo for the Phase I area. However, the aquifer is being recharge so some limited use of this water for peaking is reasonable. CRWUD would keep one or two of their existing wells in service to meet their peaking need of 390 gpm.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.41%	3.1	6.1	5.8	6.1	5.8	-0.3	-0.1	2.2
2	2.80%	2.5	5.0	5.8	11.1	11.5	0.8	0.2	2.4
3	2.28%	2.1	4.1	5.8	15.2	17.3	1.7	0.5	3.0
4	2.33%	2.1	4.2	5.8	19.3	23.1	1.6	0.5	3.5
5	3.80%	3.4	6.8	5.8	26.1	28.8	-1.0	-0.3	3.2
6	3.97%	3.6	7.1	5.8	33.2	34.6	-1.3	-0.4	2.7
7	3.32%	3.0	5.9	5.8	39.2	40.4	-0.2	-0.1	2.7
8	3.03%	2.7	5.4	5.8	44.6	46.1	0.3	0.1	2.8
9	2.41%	2.2	4.3	5.8	48.9	51.9	1.5	0.5	3.3
10	2.45%	2.2	4.4	5.8	53.3	57.6	1.4	0.4	3.7
11	3.03%	2.7	5.4	5.8	58.7	63.4	0.3	0.1	3.8
12	3.03%	2.7	5.4	5.8	64.1	69.2	0.3	0.1	4.0
13	3.03%	2.7	5.4	5.8	69.5	74.9	0.3	0.1	4.1
14	3.03%	2.7	5.4	5.8	74.9	80.7	0.3	0.1	4.2
15	3.07%	2.8	5.5	5.8	80.4	86.5	0.3	0.1	4.3
16	3.54%	3.2	6.3	5.8	86.7	92.2	-0.6	-0.2	4.1
17	3.63%	3.3	6.5	5.8	93.2	98.0	-0.7	-0.2	3.9
18	3.63%	3.3	6.5	5.8	99.7	103.8	-0.7	-0.2	3.6
19	3.63%	3.3	6.5	5.8	106.2	109.5	-0.7	-0.2	3.4
20	3.68%	3.3	6.6	5.8	112.8	115.3	-0.8	-0.3	3.1
21	4.17%	3.8	7.5	5.8	120.2	121.1	-1.7	-0.6	2.6
22	4.09%	3.7	7.3	5.8	127.6	126.8	-1.5	-0.5	2.1
23	3.81%	3.4	6.8	5.8	134.4	132.6	-1.1	-0.3	1.7
24	3.38%	3.0	6.0	5.8	140.4	138.3	-0.3	-0.1	1.6
25	3.62%	3.3	6.5	5.8	146.9	144.1	-0.7	-0.2	1.4
26	4.15%	3.7	7.4	5.8	154.3	149.9	-1.7	-0.5	0.9
27	4.13%	3.7	7.4	5.8	161.7	155.6	-1.6	-0.5	0.3
28	2.49%	2.2	4.4	5.8	166.1	161.4	1.3	0.4	0.8
29	1.42%	1.3	2.5	5.8	168.7	167.2	3.2	1.0	1.8
30	2.40%	2.2	4.3	5.8	173.0	172.9	1.5	0.5	2.3
31	3.22%	2.9	5.8	5.8	178.7	178.7	0.0	0.0	2.3
Totals			178.7	178.7					





Cass Rural Water Users District - Scenario One Peak Day Analysis
Red River Valley Water Supply Project

Basic Design Data:

Peak Day 2050 Water Demand =	3.88 ac-ft	2.0 cfs	1.3 mgd	877.9 gpm
Max Month 2050 Water Demand =	116.5 ac-ft	1.9 cfs	1.2 mgd	850.3 gpm
Max Month Project Flows =	116.5 ac-ft	1.9 cfs	1.2 mgd	

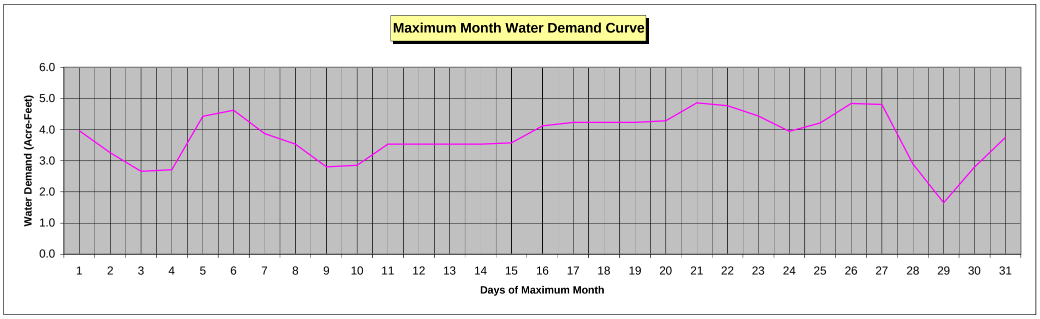
Starting Storage =	1.5 million gallons		
Required Storage +	2.8 million gallons	or	9 ac-ft
Storage estimated cost =	$1,392,000 (assumes $0.50 per gallon cost)		

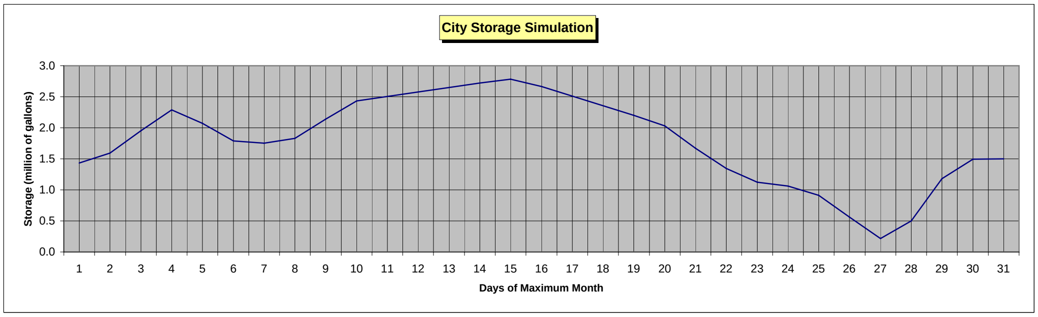
Monthly shortage in storage (31 days) =	3.2 mg	9.7 ac-ft		
Peak day shortage in storage =	0.4 mg	1.1 ac-ft	0.6 cfs	249.5 gpm

Groundwater Analysis:

Cass Rural Water Users District currently has wells in the West Fargo North Aquifer that serves the Phase I service area. This aquifer is being mined so Reclamation proposes that the water system purchase water from the city of Fargo for the Phase I area. However, the aquifer is being recharge so some limited use of this water for peaking is reasonable. CRWUD would keep one or two of their existing wells in service to meet their peaking need of 250 gpm.

Day of Max Month	Daily Water Demand Distribution (%)	Daily Water Demand (cfs)	Daily Water Demand (ac-ft)	Daily Water Delivery (ac-ft)	Accum. Water Demand (ac-ft)	Accum. System Deliver (ac-ft)	Water Storage or Surplus (ac-ft)	Water Storage or Surplus (10^6 gallons)	Net Storage (10^6 gallons)
1	3.41%	2.0	4.0	3.8	4.0	3.8	-0.2	-0.1	1.4
2	2.80%	1.6	3.3	3.8	7.2	7.5	0.5	0.2	1.6
3	2.28%	1.3	2.7	3.8	9.9	11.3	1.1	0.4	2.0
4	2.33%	1.4	2.7	3.8	12.6	15.0	1.0	0.3	2.3
5	3.80%	2.2	4.4	3.8	17.0	18.8	-0.7	-0.2	2.1
6	3.97%	2.3	4.6	3.8	21.7	22.5	-0.9	-0.3	1.8
7	3.32%	2.0	3.9	3.8	25.5	26.3	-0.1	0.0	1.8
8	3.03%	1.8	3.5	3.8	29.1	30.1	0.2	0.1	1.8
9	2.41%	1.4	2.8	3.8	31.9	33.8	1.0	0.3	2.1
10	2.45%	1.4	2.9	3.8	34.7	37.6	0.9	0.3	2.4
11	3.03%	1.8	3.5	3.8	38.3	41.3	0.2	0.1	2.5
12	3.03%	1.8	3.5	3.8	41.8	45.1	0.2	0.1	2.6
13	3.03%	1.8	3.5	3.8	45.3	48.9	0.2	0.1	2.7
14	3.03%	1.8	3.5	3.8	48.9	52.6	0.2	0.1	2.7
15	3.07%	1.8	3.6	3.8	52.4	56.4	0.2	0.1	2.8
16	3.54%	2.1	4.1	3.8	56.6	60.1	-0.4	-0.1	2.7
17	3.63%	2.1	4.2	3.8	60.8	63.9	-0.5	-0.2	2.5
18	3.63%	2.1	4.2	3.8	65.0	67.6	-0.5	-0.2	2.4
19	3.63%	2.1	4.2	3.8	69.2	71.4	-0.5	-0.2	2.2
20	3.68%	2.2	4.3	3.8	73.5	75.2	-0.5	-0.2	2.0
21	4.17%	2.5	4.9	3.8	78.4	78.9	-1.1	-0.4	1.7
22	4.09%	2.4	4.8	3.8	83.2	82.7	-1.0	-0.3	1.3
23	3.81%	2.2	4.4	3.8	87.6	86.4	-0.7	-0.2	1.1
24	3.38%	2.0	3.9	3.8	91.5	90.2	-0.2	-0.1	1.1
25	3.62%	2.1	4.2	3.8	95.8	94.0	-0.5	-0.1	0.9
26	4.15%	2.4	4.8	3.8	100.6	97.7	-1.1	-0.4	0.6
27	4.13%	2.4	4.8	3.8	105.4	101.5	-1.1	-0.3	0.2
28	2.49%	1.5	2.9	3.8	108.3	105.2	0.9	0.3	0.5
29	1.42%	0.8	1.7	3.8	110.0	109.0	2.1	0.7	1.2
30	2.40%	1.4	2.8	3.8	112.8	112.7	1.0	0.3	1.5
31	3.22%	1.9	3.8	3.8	116.5	116.5	0.0	0.0	1.5
Totals			116.5	116.5					





Appendix B – Hydrology

INTRODUCTION

This appendix contains supplemental information and analysis used in the development of chapter three (Hydrology) of the Needs and Options Report. The appendix provides detailed information and analysis that could not be reasonably included in chapter three. Portions of this appendix make reference to additional data available in the data CD. These materials are noted and directions for their use are included.

B.1 - WATER DEMANDS

B.1.1 – Max Month Definition

The term "max month" is used throughout the Needs and Options Report and the appendixes. Although this term is used in a variety of instances, it has root in one general meaning.

> **Max Month Definition**: This term is used in reference to demands. Each demand, whether it be for a municipal, rural, or industrial permit, was reviewed on a monthly basis for the given time period (the demands developed as part of the Needs and Options chapter two are based on 1985 to 2001) . The maximum value for each month of that period was determined and set aside into a single year demand. For example, the highest value for January may come from the third year of the period while the highest value for February may come from the fifth year of that same period. These highest months are combined into one composite year. That composite year is used for every year within the analysis or more specifically modeling. An example of the max month distribution for the Fargo permits is shown in table B.1.1.

Table B.1.1 - Max Month Demand Distribution for Fargo Permits

Modeled Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1931	Jan 1997	Feb 1997	Mar 1997	Apr 1988	May 1988	Jun 1988	Jul 1989	Aug 1990	Sep 1988	Oct 1988	Nov 1988	Dec 1989
1932	Jan 1997	Feb 1997	Mar 1997	Apr 1988	May 1988	Jun 1988	Jul 1989	Aug 1990	Sep 1988	Oct 1988	Nov 1988	Dec 1989
1933	Etc.											

B.1.2 – Water Demands for Surface Water Modeling

Using water demand results presented in chapter two, the water demands required as input for surface water modeling were developed. Two water demand scenarios were developed. Scenario One uses Reclamation population projections (Reclamation 2003) and the intermediate water demands results from the NDSU industrial water needs investigation (NDSU 2004). Scenario Two uses population projections provided by the water users and the high water demand results from the same NDSU industrial water needs investigation.

Tables B.1.2 and B.1.3 show the estimated average and maximum annual water demands in ac-ft, the maximum month water demand in ac-ft and cfs and the peak day water demand in ac-ft and cfs for the surface water dependent systems. The total maximum year water demand under Scenario One is 101,024 ac-ft. The total maximum year water demand under Scenario Two is 128,270 ac-ft.

The groundwater section in chapter three evaluates the groundwater dependent water systems and identifies two rural water systems, Cass Rural Water Users and Grand Forks Traill Water Users, which would have inadequate groundwater supplies in the future. Reclamation assumed these shortages would be met by surface water sources so their shortages are included in tables B.1.2 and B.1.3. Langdon Rural Water District is uses a surface water source so it is also included in tables B.1.2 and B.1.3.

Tables B.1.2 and B.1.3 also list the municipal water systems that are served from surface water sources in the future. Six municipal water systems hold both surface water and groundwater permits. Moorhead was the only system of the six that has the capability to treat both surface water and groundwater. The analysis assumed of the remaining five cities; Breckenridge, Lisbon, and Park River would use their groundwater permits and are not included in the tables. Valley City and West Fargo would use their surface water permits as their primary water source for the future. Therefore, the analysis assumed that eight systems would use surface water, seven systems would use groundwater (not included in tables), and Moorhead would use both sources.

Tables B.1.2 and B.1.3 also list the surface water dependent existing and new future industrial demands based on the results presented in chapter two. ADM Corn Processing in Walhalla lists their water source as groundwater, but the well is adjacent to the Pembina River, so it is treated as a surface water source in this analysis. Cargill, Inc. - West Fargo, Cass-Clay Creameries, Inc. and Central Livestock all use West Fargo South Aquifer as their current source, but are included as a surface water source in this analysis because the long-term viability of their aquifer is of concern. All future industrial water demands for the Fargo/Cass County, Grand Forks/Grand Forks County, Moorhead/Clay County and Wahpeton/Richland County areas are assumed to be supplied by surface water because no viable groundwater sources are available in the area.

Estimated future water demands for recreation are included at the end of the tables B.1.2 and B.1.3. These water demands were assumed to be served from surface water sources due to the lack of available groundwater sources.

Table B.1.2 – Surface Water Demands – Scenario One.

Water System	Average Annual Water Demand (ac-ft)	Maximum Year Water Demand (ac-ft)	Maximum Month Water Demand (ac-ft)	Maximum Month Water Demand (cfs)	Peak Daily Water Demand (ac-ft)	Peak Daily Water Demand (cfs)
Rural Water Systems:						
Cass Rural Water Users	340	702	116.5	2.0	3.88	1.96
Grand Forks Traill Water District	0	605	155.5	2.6	5.18	2.61
Langdon Rural Water District	100	143	17.1	0.3	0.99	0.50
ND Municipal Systems:						
Drayton	281	607	67.8	1.1	3.07	1.55
Fargo	26,571	37,682	5,005.0	84.1	239.32	120.66
Grafton	706	927	101.3	1.7	4.31	2.17
Grand Forks	12,922	19,205	2,533.2	42.6	135.35	68.24
Langdon	272	577	65.7	1.1	3.56	1.79
West Fargo	3,486	4,261	669.3	11.2	28.65	14.45
Valley City	685	894	116.5	2.0	6.92	3.49
MN Municipal Systems:						
East Grand Forks	1,662	2,384	254.1	4.3	15.72	7.92
Moorhead	6,909	8,646	1,065.3	17.9	44.56	22.47
Existing Industry:						
ADM Corn Processing	128	298	24.8	0.4	1.10	0.55
American Crystal Sugar Co. – Drayton	378	1,156	518.6	8.7	16.95	8.54
American Crystal Sugar Co. – Hillsboro	269	733	319.2	5.4	9.51	4.80
American Crystal Sugar Co. – Moorhead	24	104	54.3	0.9	1.81	0.91
Cargill Corn Processing Plant	1,930	2,104	196.9	3.3	9.21	4.64
Cargill, Inc. - West Fargo	135	162	13.5	0.2	0.45	0.23
Cass-Clay Creameries, Inc.	119	151	12.6	0.2	0.42	0.21
Central Livestock	66	361	30.0	0.5	0.71	0.36
Future Industry :						
Fargo/Cass County	7,282	7,282	618.5	10.4	19.95	10.06
Grand Forks/Grand Forks County	6,771	6,771	575.1	9.7	18.55	9.35
Moorhead/Clay County	1,150	1,150	97.7	1.6	3.15	1.59
Wahpeton/Richland County	3,705	3,705	314.7	5.3	10.15	5.12
Future Recreation:						
Cass County	201	288	76.9	1.3	3.49	1.76
Clay County	33	48	12.7	0.2	0.58	0.29
Grand Forks County	34	48	12.9	0.2	0.58	0.29
Otter Tail County	23	33	8.8	0.1	0.40	0.20
Totals	76,179	101,024	13,054.4	219.39	588.51	296.71

Table B.1.3 – Surface Water Demands – Scenario Two.

Water System	Average Annual Water Demand (ac-ft)	Maximum Year Water Demand (ac-ft)	Maximum Month Water Demand (ac-ft)	Maximum Month Water Demand (cfs)	Peak Daily Water Demand (ac-ft)	Peak Daily Water Demand (cfs)
Rural Water Systems:						
Cass Rural Water Users	782	1,244	178.7	3.0	5.96	3.00
Grand Forks Traill Water District	218	1,142	225.8	3.8	7.53	3.80
Langdon Rural Water District	184	264	31.5	0.5	1.84	0.93
ND Municipal Systems:						
Drayton	281	607	67.8	1.1	3.07	1.55
Fargo	31,613	44,833	5,954.9	100.1	284.73	143.55
Grafton	1,067	1,401	153.1	2.6	6.51	3.28
Grand Forks	13,727	20,348	2,685.8	45.1	144.77	72.99
Langdon	272	577	65.7	1.1	3.56	1.79
West Fargo	3,569	4,362	685.2	11.5	29.33	14.79
Valley City	880	1,148	149.6	2.5	8.89	4.48
MN Municipal Systems:						
East Grand Forks	2,310	3,312	353.1	5.9	21.84	11.01
Moorhead	8,465	10,696	1,333.8	22.4	57.18	28.83
Existing Industry:						
ADM Corn Processing	128	298	24.8	0.4	1.10	0.55
American Crystal Sugar Co. – Drayton	378	1,156	518.6	8.7	16.95	8.54
American Crystal Sugar Co. – Hillsboro	269	733	319.2	5.4	9.51	4.80
American Crystal Sugar Co. – Moorhead	24	104	54.3	0.9	1.81	0.91
Cargill Corn Processing Plant	1,930	2,104	196.9	3.3	9.21	4.64
Cargill, Inc. - West Fargo	135	162	13.5	0.2	0.45	0.23
Cass-Clay Creameries, Inc.	119	151	12.6	0.2	0.42	0.21
Central Livestock	66	361	30.0	0.5	0.71	0.36
Future Industry :						
Fargo/Cass County	12,850	12,850	1091.4	18.3	35.21	17.75
Grand Forks/Grand Forks County	11,814	11,814	1003.4	16.9	32.37	16.32
Moorhead/Clay County	1,740	1,740	147.8	2.5	4.77	2.40
Wahpeton/Richland County	6,448	6,448	547.6	9.2	17.67	8.91
Future Recreation:						
Cass County	201	288	76.9	1.3	3.49	1.76
Clay County	33	48	12.7	0.2	0.58	0.29
Grand Forks County	34	48	12.9	0.2	0.58	0.29
Otter Tail County	23	33	8.8	0.1	0.40	0.20
Totals	99,558	128,270	15,956.5	268.16	710.41	358.17

Monthly Surface Water Demand Scenarios

Chapter two, section 2.4 of the Needs and Options Report provides examples of how monthly water demand scenarios were developed for surface water supplied water systems. From the fifteen years of data, the maximum demand value for each month was selected and used in the development of the following tables.

Tables B.1.4 and B.1.5 show the annual maximum month water demand for both scenarios of the same surface water dependent water systems as identified previously in tables B.1.2 and B.1.3. Water demands are presented in acre-feet which are the units used in the surface water model. Both annual maximum month water demand scenarios were used as input into the hydrologic surface water model.

Table B.1.4 – Annual Maximum Month Water Demand in Acre-Feet – Scenario One

Water Systems	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Demand Total (ac-ft)
Rural Water Systems:													
Cass Rural Water Users	34.2	32.0	30.0	50.0	75.6	86.6	116.5	101.9	55.8	47.9	25.9	45.4	701.6
Grand Forks Traill Water District	25.4	25.6	0.0	155.5	82.6	140.6	40.8	73.6	4.5	31.6	25.0	0.0	605.1
Langdon Rural Water District	13.1	8.7	10.8	12.0	12.5	17.1	12.4	11.1	9.7	9.8	12.2	13.5	142.9
ND Municipal Systems:													
Drayton	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
Fargo	2,408.1	2,144.4	2,513.1	2,619.0	3,501.7	4,549.3	5,005.0	3,812.2	3,099.0	2,540.4	2,838.1	2,651.8	37,681.9
Grafton	68.1	72.1	60.8	72.2	85.4	97.6	101.3	92.0	82.5	69.7	64.1	61.1	926.8
Grand Forks	1,249.2	1,217.4	1,314.3	1,286.3	1,565.1	2,108.3	2,533.2	1,998.7	1,559.0	1,536.9	1,506.9	1,329.3	19,204.6
Langdon	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
West Fargo	64.9	66.1	60.7	60.8	79.8	116.5	103.9	110.7	66.8	57.6	53.0	52.7	893.6
Valley City	257.0	240.2	265.6	274.6	345.1	445.7	669.3	505.1	338.7	317.6	340.6	261.1	4,260.7
MN Municipal Systems:													
East Grand Forks	184.7	157.8	172.6	150.0	223.6	219.1	244.4	254.1	220.4	190.0	188.6	178.5	2,383.9
Moorhead	559.9	608.5	646.0	661.1	711.4	952.5	1,065.3	845.8	798.5	621.5	598.9	576.1	8,645.7
Existing Industry:													
ADM Corn Processing	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	297.8
American Crystal Sugar Co. – Drayton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	508.5	518.6	121.5	0.0	1,155.8
American Crystal Sugar Co. – Hillsboro	0.0	0.0	319.2	285.4	128.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	732.6
American Crystal Sugar Co. – Moorhead	0.0	0.0	40.5	54.3	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	104.3
Cargill Corn Processing Plant	154.5	161.2	180.8	179.3	180.2	183.9	196.9	181.9	184.0	149.5	158.3	193.6	2,104.1
Cargill, Inc. - West Fargo	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	161.9
Cass-Clay Creameries, Inc.	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	150.8
Central Livestock	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	360.5

Table B.1.4 – Annual Maximum Month Water Demand in Acre-Feet – Scenario One (continued).

Water Systems	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Demand Total (ac-ft)
Future Industry :													
Fargo/Cass County	618.5	558.6	618.5	598.5	618.5	598.5	618.5	618.5	598.5	618.5	598.5	618.5	7,282.0
Grand Forks/Grand Forks County	575.1	519.4	575.1	556.5	575.1	556.5	575.1	575.1	556.5	575.1	556.5	575.1	6,771.0
Moorhead/Clay County	97.7	88.2	97.7	94.5	97.7	94.5	97.7	97.7	94.5	97.7	94.5	97.7	1,150.0
Wahpeton/Richland County	314.7	284.2	314.7	304.5	314.7	304.5	314.7	314.7	304.5	314.7	304.5	314.7	3,705.0
Future Recreation:													
Cass County	0.0	0.0	0.0	2.9	30.7	59.2	70.7	76.9	35.1	12.6	0.0	0.0	288.1
Clay County	0.0	0.0	0.0	0.5	5.1	9.8	11.7	12.7	5.8	2.1	0.0	0.0	47.7
Grand Forks County	0.0	0.0	0.0	0.5	5.2	10.0	11.9	12.9	5.9	2.1	0.0	0.0	48.4
Otter Tail County	0.0	0.0	0.0	0.3	3.5	6.8	8.1	8.8	4.0	1.4	0.0	0.0	32.9
Totals	6,832.9	6,387.2	7,431.4	7,578.6	8,807.5	10,718.2	11,975.8	9,881.2	8,702.3	7,898.6	7,656.4	7,153.2	101,023.4

Table B.1.5 – Annual Maximum Month Water Demand in Acre-Feet – Scenario Two.

Water Systems	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Demand Total (ac-ft)
Rural Water Systems:													
Cass Rural Water Users	72.3	69.4	66.8	92.8	125.8	140.1	178.7	159.9	100.2	90.1	61.5	86.8	1,244.4
Grand Forks Traill Water District	65.6	65.9	29.2	225.8	136.1	207.5	84.5	125.0	39.9	73.3	65.1	24.5	1,142.4
Langdon Rural Water District	24.2	16.0	19.9	22.2	23.2	31.5	23.0	20.4	18.0	18.2	22.6	24.9	264.2
ND Municipal Systems:													
Drayton	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
Fargo	2,865.1	2,551.3	2,990.0	3,116.0	4,166.3	5,412.6	5,954.9	4,535.7	3,687.1	3,022.6	3,376.7	3,155.1	44,833.3
Grafton	102.9	109.0	91.9	109.2	129.0	147.5	153.1	139.2	124.8	105.3	96.9	92.3	1,401.2
Grand Forks	1,321.6	1,289.0	1,389.4	1,363.2	1,658.3	2,226.6	2,685.8	2,124.8	1,652.4	1,630.1	1,597.3	1,409.2	20,347.9
Langdon	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
West Fargo	83.4	84.9	78.0	78.1	102.5	149.6	133.5	142.2	85.7	74.0	68.1	67.6	1,147.6
Valley City	263.1	245.9	271.9	281.1	353.3	456.2	685.2	517.1	346.7	325.2	348.7	267.3	4,361.8
MN Municipal Systems:													
East Grand Forks	256.7	219.4	239.9	208.5	310.8	304.5	339.6	353.1	306.2	264.0	262.0	248.0	3,312.9
Moorhead	685.3	747.6	795.8	815.2	879.7	1,189.1	1,333.8	1,052.2	991.4	764.3	735.3	706.1	10,695.7
Existing Industry:													
ADM Corn Processing	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	297.8
American Crystal Sugar Co. – Drayton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	508.5	518.6	121.5	0.0	1,155.8
American Crystal Sugar Co. – Hillsboro	0.0	0.0	319.2	285.4	128.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	732.6
American Crystal Sugar Co. – Moorhead	0.0	0.0	40.5	54.3	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	104.3
Cargill Corn Processing Plant	154.5	161.2	180.8	179.3	180.2	183.9	196.9	181.9	184.0	149.5	158.3	193.6	2,104.1
Cargill, Inc. - West Fargo	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	161.9
Cass-Clay Creameries, Inc.	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	150.8
Central Livestock	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	360.5

Table B.1.5 – Annual Maximum Month Water Demand in Acre-Feet – Scenario Two (continued).

Water Systems	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Demand Total (ac-ft)
Future Industry :													
Fargo/Cass County	1,091.4	985.8	1,091.4	1,056.2	1,091.4	1,056.2	1,091.4	1,091.4	1,056.2	1,091.4	1,056.2	1,091.4	12,850.0
Grand Forks/Grand Forks County	1,003.4	906.3	1,003.4	971.0	1,003.4	971.0	1,003.4	1,003.4	971.0	1,003.4	971.0	1,003.4	11,814.0
Moorhead/Clay County	147.8	133.5	147.8	143.0	147.8	143.0	147.8	147.8	143.0	147.8	143.0	147.8	1,740.0
Wahpeton/Richland County	547.6	494.6	547.6	530.0	547.6	530.0	547.6	547.6	530.0	547.6	530.0	547.6	6,448.0
Future Recreation:													
Cass County	0.0	0.0	0.0	2.9	30.7	59.2	70.7	76.9	35.1	12.6	0.0	0.0	288.1
Clay County	0.0	0.0	0.0	0.5	5.1	9.8	11.7	12.7	5.8	2.1	0.0	0.0	47.7
Grand Forks County	0.0	0.0	0.0	0.5	5.2	10.0	11.9	12.9	5.9	2.1	0.0	0.0	48.4
Otter Tail County	0.0	0.0	0.0	0.3	3.5	6.8	8.1	8.8	4.0	1.4	0.0	0.0	32.9
Totals	8,892.8	8,282.6	9,514.7	9,695.3	11,194.0	13,396.4	14,840.2	12,429.7	10,966.0	10,026.8	9,783.6	9,250.0	128,272.1

B.1.3 – Development of Water Demands for GDU Import to Sheyenne River Alternative

Water demand methods for the GDU Import to Sheyenne River Alternative are different than the methods developed for the other alternatives. For the other alternatives, maximum monthly water demands were developed based on the estimated water need for each water system for each month of the year. A more detailed description of the methods used is provided in chapter two, section four. Water demands for the GDU Import to Sheyenne River Alternative accounted for maximum month demands and peak day demands. These demands would be sufficient to ensure adequate water in the Sheyenne and Red Rivers to meet peak day needs for selected surface water dependent water systems in the Red River Valley.

Three methods were used to develop the water demands for the GDU Import to Sheyenne River Alternative. One method used maximum month and peak day demand estimates from each water system. The other methods used maximum month demand estimates and Grand Forks daily use data. Provided below is a description of the three methods used to develop peak day water demands.

Maximum Month and Peak Day Method – This method uses maximum month and peak day water demand data from each water system to develop adjusted (increased) monthly water demands which address both maximum month demands and peak day water demands. The maximum month water demands were increased proportionally based on the relationship between a water system's maximum month and peak day water demands.

For example, the city of Fargo has an estimated overall maximum month of 5,005 ac-ft in July while their peak day in July is 239.32 ac-ft. Both of these demands are under water demand Scenario One. To make sure Fargo has enough water in July, there must be at least 239 ac-ft in the Sheyenne and Red Rivers allocated to Fargo all 31 days of July or 7,421 ac-ft. So the ratio between originally estimated maximum month and adjusted maximum month to meet peak day demands is 7,421 ac-ft/5,005 ac-ft = 1.48. The peak day factor of 1.48 was used for the other 11 months for the Fargo analysis. Each water system had its own peak factor and they ranged from 1.00 to 1.92. The overall increase in water demand using this method resulted in an increase from 76,640 ac-ft to 115,140 ac-ft, or an increase of 50.2% under Scenario One and from 89,935 ac-ft to 135,142 ac-ft or an increase of 50.2% under Scenario Two. Note that this method used the same peaking factors, so the net increase is 50.2% for both scenarios. See tables B.1.6 and B.1.7 for Scenarios One and Two adjusted water demands for all of the surface water dependent water systems which have daily peaking factors.

The advantage of this method is that the maximum month and the peak day are developed individually for each water system. The disadvantage to this method is that the ratio of 1.50, used in the Fargo example, might be too high in the winter months. Generally, peaking factors are lower in the winter and higher in the summer. This method assumes the peaking factor is similar throughout the whole year.

Table B.1.6. Maximum Month Peak Day Water Demands – Scenario One (using Maximum Month and Peak Day Method)

Water System	2050 Pop.	Peak Day (gpc/d)	Adjust Factor for Peak Day	Max Month Demand in Acre Feet												Total (ac-ft)
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Drayton	920	473.6	1.00	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
adjusted for peak day				64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
Fargo	204,300	381.8	1.48	2,408.1	2,144.4	2,513.1	2,619.0	3,501.7	4,549.3	5,005.0	3,812.2	3,099.0	2,540.4	2,838.1	2,651.8	37,681.9
adjusted for peak day				3,570.4	3,179.4	3,726.0	3,883.1	5,191.8	6,745.0	7,420.7	5,652.3	4,594.7	3,766.6	4,207.9	3,931.7	55,869.7
Grafton	4,130	339.5	1.32	68.1	72.1	60.8	72.2	85.4	97.6	101.3	92.0	82.5	69.7	64.1	61.1	926.8
adjusted for peak day				89.7	95.0	80.1	95.1	112.4	128.5	133.4	121.2	108.7	91.8	84.5	80.4	1,220.7
Grand Forks	83,800	526.7	1.66	1,249.2	1,217.4	1,314.3	1,286.3	1,565.1	2,108.3	2,533.2	1,998.7	1,559.0	1,536.9	1,506.9	1,329.3	19,204.6
adjusted for peak day				2,070.7	2,018.0	2,178.6	2,132.1	2,594.2	3,494.8	4,199.0	3,313.1	2,584.2	2,547.6	2,497.7	2,203.4	31,833.5
Langdon	2,100	537.8	1.48	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
adjusted for peak day				93.2	97.0	92.1	65.6	67.2	68.9	70.7	73.9	71.4	53.1	46.0	53.4	852.6
Valley City	5,840	386.2	1.78	64.9	66.1	60.7	60.8	79.8	116.5	103.9	110.7	66.8	57.6	53.0	52.7	893.6
adjusted for peak day				115.7	117.8	108.2	108.4	142.2	207.6	185.3	197.4	119.0	102.7	94.5	93.8	1,592.7
West Fargo	33,900	275.4	1.33	257.0	240.2	265.6	274.6	345.1	445.7	669.3	505.1	338.7	317.6	340.6	261.1	4,260.7
adjusted for peak day				341.0	318.7	352.5	364.4	457.9	591.4	888.2	670.3	449.4	421.5	451.9	346.5	5,653.7
East Grand Forks	9,800	522.7	1.92	184.7	157.8	172.6	150.0	223.6	219.1	244.4	254.1	220.4	190.0	188.6	178.5	2,383.9
adjusted for peak day				354.3	302.7	331.1	287.8	428.9	420.3	468.7	487.3	422.6	364.4	361.6	342.3	4,572.1
Moorhead	50,211	289.3	1.30	559.9	608.5	646.0	661.1	711.4	952.5	1,065.3	845.8	798.5	621.5	598.9	576.1	8,645.7
adjusted for peak day				726.3	789.3	838.0	857.6	922.8	1,235.6	1,381.9	1,097.2	1,035.7	806.2	776.9	747.4	11,215.1
Cass Rural Water	16,244	154.2	1.22	34.2	32.0	30.0	50.0	75.6	86.6	116.5	101.9	55.8	47.9	25.9	45.4	701.6
adjusted for peak day				41.8	39.1	36.7	61.2	92.4	105.9	142.5	124.7	68.2	58.6	31.6	55.5	858.3
Grand Forks - Traill Water Users	12,176	212.1	1.00	26.4	26.6	0.0	156.5	83.6	141.6	41.8	74.6	5.5	32.6	26.0	0.0	615.1
adjusted for peak day				26.4	26.6	0.0	156.5	83.6	141.6	41.8	74.6	5.5	32.6	26.0	0.0	615.1
Langdon Rural Water	1,568	206.3	1.75	13.1	8.7	10.8	12.0	12.5	17.1	12.4	11.1	9.7	9.8	12.2	13.5	142.9
adjusted for peak day				22.8	15.1	18.8	21.0	21.9	29.8	21.7	19.3	17.0	17.2	21.3	23.5	249.5
Results																
Max Month Total				4,992.6	4,695.5	5,204.1	5,421.4	6,759.6	8,814.6	9,990.8	7,894.7	6,325.0	5,526.6	5,742.6	5,272.8	76,640.3
Adjusted Max Month Total				7,516.2	7,055.0	7,830.0	8,067.1	10,146.0	13,203.2	15,003.7	11,869.6	9,517.4	8,328.8	8,657.3	7,945.3	115,139.6
Increase in Max Month				2,523.7	2,359.4	2,625.8	2,645.7	3,386.3	4,388.6	5,012.9	3,974.9	3,192.5	2,802.2	2,914.7	2,672.5	38,499.3
% Increase				50.55%	50.25%	50.46%	48.80%	50.10%	49.79%	50.18%	50.35%	50.47%	50.70%	50.76%	50.68%	50.23%

Table B.1.7. Maximum Month Peak Day Water Demands – Scenario Two (using Maximum Month and Peak Day Method)

Water System	2050 Pop.	Peak Day gpc/d	Adjust Factor for Peak Day	Max Month Demand in Acre Feet												Total (ac-ft)
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Drayton	920	473.6	1.00	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
adjusted for peak day				64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
Fargo	243,073	381.8	1.48	2,865.1	2,551.3	2,990.0	3,116.0	4,166.3	5,412.6	5,954.9	4,535.7	3,687.1	3,022.6	3,376.7	3,155.1	44,833.3
adjusted for peak day				4,248.0	3,782.8	4,433.2	4,620.0	6,177.2	8,025.1	8,829.1	6,725.0	5,466.7	4,481.5	5,006.5	4,677.9	66,472.9
Grafton	6,244	339.5	1.32	102.9	109.0	91.9	109.2	129.0	147.5	153.1	139.2	124.8	105.3	96.9	92.3	1,401.2
adjusted for peak day				135.6	143.6	121.1	143.8	170.0	194.3	201.7	183.3	164.3	138.7	127.7	121.6	1,845.6
Grand Forks	89,631	526.7	1.67	1,321.6	1,289.0	1,389.4	1,363.2	1,658.3	2,226.6	2,685.8	2,124.8	1,652.4	1,630.1	1,597.3	1,409.2	20,347.9
adjusted for peak day				2,210.0	2,155.5	2,323.3	2,279.5	2,773.0	3,723.3	4,491.2	3,553.1	2,763.1	2,725.9	2,671.0	2,356.5	34,025.5
Langdon	2,100	537.8	1.48	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
adjusted for peak day				93.2	97.0	92.1	65.6	67.2	68.9	70.7	73.9	71.4	53.1	46.0	53.4	852.6
Valley City	7,500	386.2	1.78	83.4	84.9	78.0	78.1	102.5	149.6	133.5	142.2	85.7	74.0	68.1	67.6	1,147.6
adjusted for peak day				148.6	151.3	138.9	139.3	182.7	266.7	237.9	253.5	152.8	131.8	121.4	120.5	2,045.4
West Fargo	34,705	275.4	1.33	263.1	245.9	271.9	281.1	353.3	456.2	685.2	517.1	346.7	325.2	348.7	267.3	4,361.8
adjusted for peak day				349.1	326.3	360.9	373.0	468.8	605.4	909.3	686.2	460.1	431.5	462.7	354.7	5,787.9
East Grand Forks	13,619	522.7	1.92	256.7	219.4	239.9	208.5	310.8	304.5	339.6	353.1	306.2	264.0	262.0	248.0	3,312.9
adjusted for peak day				492.3	420.7	460.1	399.9	596.1	584.1	651.4	677.2	587.3	506.4	502.6	475.7	6,353.8
Moorhead	64,432	289.3	1.33	685.3	747.6	795.8	815.2	879.7	1,189.1	1,333.8	1,052.2	991.4	764.3	735.3	706.1	10,695.7
adjusted for peak day				911.1	993.9	1,058.0	1,083.7	1,169.5	1,580.9	1,773.3	1,398.9	1,318.0	1,016.1	977.6	938.8	14,219.9
Cass Rural Water	19,533	154.2	1.07	72.3	69.4	66.8	92.8	125.8	140.1	178.7	159.9	100.2	90.1	61.5	86.8	1,244.4
adjusted for peak day				77.1	74.1	71.4	99.1	134.3	149.5	190.7	170.6	107.0	96.1	65.7	92.6	1,328.2
Grand Forks - Traill Water Users	15,000	212.1	1.00	65.6	65.9	29.2	225.8	136.1	207.5	84.5	125.0	39.9	73.3	65.1	24.5	1,142.4
adjusted for peak day				65.6	65.9	29.2	225.8	136.1	207.5	84.5	125.0	39.9	73.3	65.1	24.5	1,142.4
Langdon Rural Water	2,900	206.3	1.75	24.2	16.0	19.9	22.2	23.2	31.5	23.0	20.4	18.0	18.2	22.6	24.9	264.2
adjusted for peak day				42.2	28.0	34.8	38.8	40.5	55.1	40.1	35.7	31.4	31.8	39.4	43.5	461.4
Results																
Max Month Total				5,867.2	5,520.3	6,103.0	6,391.0	7,960.8	10,345.7	11,669.8	9,258.0	7,441.6	6,469.5	6,722.7	6,185.3	89,935.0
Adjusted Max Month Total				8,836.8	8,295.3	9,190.8	9,503.0	11,945.7	15,494.5	17,529.8	13,920.8	11,202.9	9,752.8	10,142.9	9,327.0	135,142.2
Increase in Max Month				2,969.6	2,775.0	3,087.7	3,112.0	3,984.9	5,148.8	5,859.9	4,662.7	3,761.4	3,283.2	3,420.2	3,141.7	45,207.2
% Increase				50.61%	50.27%	50.59%	48.69%	50.06%	49.77%	50.21%	50.36%	50.55%	50.75%	50.88%	50.79%	50.27%

Maximum Month and Grand Forks Data Method - To resolve the problem discussed in the first method, daily historic water use from the city of Grand Forks was used to determine a more reasonable variation in peaking ratios. Fifteen years of Grand Forks data (1987-2001) were used to develop monthly peaking ratios. Table B.1.8 shows the calculated monthly to peak day peaking factors for 15 years of Grand Forks water use data. The peaking factor presented in the table is the ratio or difference between how much water was used in a month as compared to what the peak day was in that same month. Highlighted in blue is the highest peaking factor for each month. Highlighted in yellow is the peaking factor that occurred in the month with the highest water use. This peaking factor is important because the hydrologic modeling was based on maximum month water demands.

Three rows at the bottom of table B.1.8 show the average peaking factor for each month, the peaking factor in the month with the maximum water use, and the overall maximum peaking factor. The average results show the months with the lower ratios are in the winter and the months with the higher ratios are in the summer. The next row shows the factors for the month with the highest water use. For example, the highest water use month in January for the city of Grand Forks was in 1989 with a ratio of 1.13, which is less than the overall highest ratio for January which was 1.24 in 1997. The last row shows the overall maximum peaking factors for each month. Here again, the lower ratios are in the winter, but there are some anomalies in the data such that it would not plot as a nice bell-shaped curve, as the average data would. The months of April and May of 1997 have very high peaking factors at 1.99 and 1.79, respectively. Investigation of these numbers revealed that Grand Forks used exceptionally high volumes of water after the 1997 spring flood for cleaning the sanitary system and flushing distribution lines.

Table B.1.8. – Monthly to Peak Day Peaking Factors for the city of Grand Forks

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	1.17	1.08	1.11	1.36	1.23	1.26	1.25	1.20	1.11	1.17	1.21	1.34
1988	1.15	1.12	1.06	1.38	1.31	1.47	1.56	1.21	1.42	1.17	1.16	1.12
1989	1.13	1.06	1.09	1.19	1.56	1.47	1.41	1.49	1.32	1.07	1.29	1.28
1990	1.24	1.21	1.24	1.22	1.58	1.63	1.36	1.41	1.17	1.27	1.24	1.18
1991	1.21	1.00	1.01	1.09	1.31	1.07	1.51	1.71	1.27	1.15	1.08	1.10
1992	1.23	1.33	1.08	1.16	1.33	1.43	1.27	1.16	1.26	1.22	1.04	1.04
1993	1.08	1.28	1.24	1.25	1.18	1.43	1.23	1.26	1.23	1.26	1.35	1.22
1994	1.06	1.05	1.05	1.28	1.11	1.36	1.64	1.34	1.06	1.09	1.19	1.23
1995	1.04	1.06	1.15	1.15	1.15	1.44	1.37	1.33	1.07	1.03	1.02	1.10
1996	1.12	1.11	1.18	1.20	1.13	1.21	1.38	1.18	1.24	1.09	1.15	1.14
1997	1.24	1.03	1.16	1.99	1.79	1.19	1.18	1.30	1.20	1.14	1.12	1.40
1998	1.07	1.17	1.06	1.30	1.29	1.29	1.32	1.35	1.13	1.15	1.26	1.27
1999	1.14	1.26	1.05	1.13	1.31	1.21	1.56	1.13	1.26	1.07	1.09	1.26
2000	1.17	1.13	1.18	1.22	1.24	1.46	1.26	1.17	1.19	1.16	1.13	1.11
2001	1.07	1.11	1.11	1.11	1.18	1.17	1.34	1.28	1.13	1.11	1.14	1.31
Average	1.14	1.13	1.12	1.27	1.31	1.34	1.38	1.30	1.20	1.14	1.17	1.21
Factor in Max Month Water Use	1.13	1.03	1.06	1.20	1.29	1.63	1.41	1.49	1.24	1.16	1.14	1.26
Overall Max Factor	1.24	1.33	1.24	1.99	1.79	1.63	1.64	1.71	1.42	1.27	1.35	1.40

Either of the peaking factors presented in the last two rows of table B.1.8 could be used. The peaking factor in the month with maximum water use is the most conservative approach and yields lower water demand results and represent the lower end of the range. Using the overall maximum peaking factors results in higher water demand results and represents the high end of the range.

Table B.1.9 below illustrates the difference in results between the three methods presented. Method 1 is the adjusted water demands using maximum month and peak day water demands for each water system. Method 2 is the peaking factors that occurred in the maximum water use months for the city of Grand Forks. Method 3 used the overall maximum peaking factors for the city of Grand Forks. The city of Fargo under demand Scenario One is used as an example.

Table B.1.9. Fargo Maximum Month Peak Results Comparing Three Estimating Methods.

Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	3,570	3,179	3,726	3,883	5,192	6,745	7,421	5,652	4,595	3,767	4,208	3,932	55,870
2	2,719	2,212	2,675	3,134	4,514	7,410	7,034	5,663	3,828	2,953	3,243	3,350	48,735
3	2,995	2,860	3,126	5,211	6,272	7,410	8,202	6,522	4,413	3,232	3,835	3,707	57,784
Average	3,095	2,751	3,176	4,076	5,326	7,188	7,552	5,946	4,279	3,317	3,762	3,663	54,130

Each of the three methods has its advantages and disadvantages. Method 1 may over-estimate the winter water demand months since the same peaking factor is used throughout the year. However, method 1 uses data specific to the water system, so it is more accurate from that standpoint. Method 2 under estimates the summer months when compared to Method 1. It uses peaking factors from Grand Forks which might not be directly related to Fargo or other cities. The strength of Method 2 is that it distributes peaking factors more accurately on a seasonal basis. Method 3 tends to estimate high demands as compared to Method 1, but there is less risk in being short from a capacity standpoint using these water demands.

The last row of the table shows the average of all three methods which incorporates all their strengths and weaknesses. Reclamation determined the most reasonable approach was to average the results of all three methods and use that as the adjusted maximum month peak day water demand.

Tables B.1.10 and B.1.11 show the results for Method 2, peaking factor in the month with maximum water use, for both Scenario One and Scenario Two. Tables B.1.12 and B.1.13 show the results for Method 3; overall maximum peaking factor for both Scenarios One and Two. Tables B.1.14 and B.1.15 show the results for all methods and the average adjusted water demand. The average adjusted water demand results were used in the hydrologic modeling of the GDU Import to Sheyenne River Alternative.

Table B.1.10. Maximum Month Peak Day Water Demand – Scenario One.
(using Peaking Factor from Maximum Month Water Use Method)

Water System	2050 Pop.	Peak Day (gpc/d)	Max Month Demand in Acre-Feet												Total (ac-ft)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Monthly Adjustment Factor			**1.13**	**1.03**	**1.06**	**1.20**	**1.29**	**1.63**	**1.41**	**1.49**	**1.24**	**1.16**	**1.14**	**1.26**	
Drayton	920	473.6	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
adjusted for peak day			72.2	57.8	72.2	41.3	39.2	54.9	69.9	57.1	50.5	77.4	65.4	85.0	742.9
Fargo	204,300	381.8	2,408.1	2,144.4	2,513.1	2,619.0	3,501.7	4,549.3	5,005.0	3,812.2	3,099.0	2,540.4	2,838.1	2,651.8	37,681.9
adjusted for peak day			2,718.9	2,212.0	2,675.5	3,133.6	4,514.4	7,409.7	7,034.0	5,662.9	3,828.0	2,953.3	3,242.8	3,350.3	48,735.3
Grafton	4,130	339.5	68.1	72.1	60.8	72.2	85.4	97.6	101.3	92.0	82.5	69.7	64.1	61.1	926.8
adjusted for peak day			76.9	74.4	64.7	86.4	110.0	158.9	142.3	136.7	101.9	81.0	73.3	77.2	1,183.7
Grand Forks	83,800	526.7	1,249.2	1,217.4	1,314.3	1,286.3	1,565.1	2,108.3	2,533.2	1,998.7	1,559.0	1,536.9	1,506.9	1,329.3	19,204.6
adjusted for peak day			1,410.4	1,255.8	1,399.3	1,539.0	2,017.7	3,434.0	3,560.2	2,969.0	1,925.8	1,786.7	1,721.7	1,679.4	24,699.0
Langdon	2,100	537.8	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
adjusted for peak day			71.2	67.7	66.4	53.1	58.6	76.0	67.3	74.3	59.7	41.8	35.6	45.6	717.3
Valley City	5,840	386.2	64.9	66.1	60.7	60.8	79.8	116.5	103.9	110.7	66.8	57.6	53.0	52.7	893.6
adjusted for peak day			73.3	68.2	64.6	72.8	102.9	189.7	146.1	164.5	82.5	67.0	60.6	66.5	1,158.6
West Fargo	33,900	275.4	257.0	240.2	265.6	274.6	345.1	445.7	669.3	505.1	338.7	317.6	340.6	261.1	4,260.7
adjusted for peak day			290.2	247.8	282.8	328.5	444.9	725.9	940.7	750.3	418.4	369.3	389.2	329.9	5,517.7
East Grand Forks	9,800	522.7	184.7	157.8	172.6	150.0	223.6	219.1	244.4	254.1	220.4	190.0	188.6	178.5	2,383.9
adjusted for peak day			208.6	162.8	183.8	179.5	288.3	356.9	343.5	377.4	272.2	220.9	215.5	225.5	3,034.9
Moorhead	50,211	289.3	559.9	608.5	646.0	661.1	711.4	952.5	1,065.3	845.8	798.5	621.5	598.9	576.1	8,645.7
adjusted for peak day			632.2	627.7	687.8	791.0	917.2	1,551.4	1,497.2	1,256.5	986.3	722.5	684.3	727.9	11,082.0
Cass Rural Water	16,244	154.2	34.2	32.0	30.0	50.0	75.6	86.6	116.5	101.9	55.8	47.9	25.9	45.4	701.6
adjusted for peak day			38.6	33.0	31.9	59.9	97.4	141.0	163.7	151.4	68.9	55.7	29.6	57.4	928.3
Grand Forks - Traill Water Users	12,176	212.1	26.4	26.6	0.0	156.5	83.6	141.6	41.8	74.6	5.5	32.6	26.0	0.0	615.1
adjusted for peak day			29.8	27.5	0.0	187.2	107.8	230.6	58.7	110.8	6.8	37.9	29.7	0.0	826.8
Langdon Rural Water	1,568	206.3	13.1	8.7	10.8	12.0	12.5	17.1	12.4	11.1	9.7	9.8	12.2	13.5	142.9
adjusted for peak day			14.8	8.9	11.5	14.4	16.2	27.8	17.5	16.4	12.0	11.4	13.9	17.0	181.8
Results															
Max Month Total			4,992.6	4,695.5	5,204.1	5,421.4	6,759.6	8,814.6	9,990.8	7,894.7	6,325.0	5,526.6	5,742.6	5,272.8	76,640.3
Adjusted Max Month Total			5,625.3	4,841.1	5,536.1	6,449.1	8,681.5	14,246.6	14,003.8	11,672.4	7,802.1	6,408.7	6,549.7	6,643.9	98,460.4
Increase in Max Month			632.7	145.5	331.9	1,027.7	1,921.9	5,432.1	4,013.1	3,777.7	1,477.1	882.1	807.1	1,371.1	21,820.1
% Increase			12.67%	3.10%	6.38%	18.96%	28.43%	61.63%	40.17%	47.85%	23.35%	15.96%	14.05%	26.00%	28.47%

Table B.1.11. Maximum Month Peak Day Water Demand – Scenario Two (using Peaking Factor from Maximum Month Water Use Method)

Water System	2050 Pop.	Peak Day (gpc/d)	Max Month Demand in Acre-Feet												Total (ac-ft)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Monthly Adjustment Factor			**1.13**	**1.03**	**1.06**	**1.20**	**1.29**	**1.63**	**1.41**	**1.49**	**1.24**	**1.16**	**1.14**	**1.26**	
Drayton	920	473.6	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
adjusted for peak day			72.2	57.8	72.2	41.3	39.2	54.9	69.9	57.1	50.5	77.4	65.4	85.0	742.9
Fargo	204,300	381.8	2,865.1	2,551.3	2,990.0	3,116.0	4,166.3	5,412.6	5,954.9	4,535.7	3,687.1	3,022.6	3,376.7	3,155.1	44,833.3
adjusted for peak day			3,234.9	2,631.8	3,183.2	3,728.3	5,371.1	8,815.9	8,368.9	6,737.6	4,554.6	3,513.8	3,858.2	3,986.1	57,984.5
Grafton	4,130	339.5	102.9	109.0	91.9	109.2	129.0	147.5	153.1	139.2	124.8	105.3	96.9	92.3	1,401.2
adjusted for peak day			116.2	112.5	97.9	130.6	166.4	240.2	215.2	206.7	154.1	122.4	110.8	116.7	1,789.7
Grand Forks	83,800	526.7	1,321.6	1,289.0	1,389.4	1,363.2	1,658.3	2,226.6	2,685.8	2,124.8	1,652.4	1,630.1	1,597.3	1,409.2	20,347.9
adjusted for peak day			1,492.2	1,329.7	1,479.2	1,631.1	2,137.9	3,626.6	3,774.6	3,156.3	2,041.1	1,895.1	1,825.1	1,780.4	26,169.3
Langdon	2,100	537.8	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
adjusted for peak day			71.2	67.7	66.4	53.1	58.6	76.0	67.3	74.3	59.7	41.8	35.6	45.6	717.3
Valley City	5,840	386.2	83.4	84.9	78.0	78.1	102.5	149.6	133.5	142.2	85.7	74.0	68.1	67.6	1,147.6
adjusted for peak day			94.1	87.6	83.0	93.5	132.1	243.7	187.6	211.3	105.9	86.0	77.8	85.4	1,488.0
West Fargo	33,900	275.4	263.1	245.9	271.9	281.1	353.3	456.2	685.2	517.1	346.7	325.2	348.7	267.3	4,361.8
adjusted for peak day			297.1	253.7	289.5	336.3	455.5	743.1	963.0	768.1	428.3	378.0	398.4	337.7	5,648.8
East Grand Forks	9,800	522.7	256.7	219.4	239.9	208.5	310.8	304.5	339.6	353.1	306.2	264.0	262.0	248.0	3,312.9
adjusted for peak day			289.8	226.3	255.4	249.5	400.7	496.0	477.3	524.5	378.3	306.9	299.4	313.4	4,217.6
Moorhead	50,211	289.3	685.3	747.6	795.8	815.2	879.7	1,189.1	1,333.8	1,052.2	991.4	764.3	735.3	706.1	10,695.7
adjusted for peak day			773.7	771.2	847.2	975.3	1,134.1	1,936.7	1,874.6	1,563.0	1,224.6	888.5	840.2	892.1	13,721.2
Cass Rural Water	16,244	154.2	72.3	69.4	66.8	92.8	125.8	140.1	178.7	159.9	100.2	90.1	61.5	86.8	1,244.4
adjusted for peak day			81.6	71.6	71.2	111.0	162.2	228.1	251.1	237.5	123.8	104.7	70.3	109.7	1,622.8
Grand Forks - Traill Water Users	12,176	212.1	65.6	65.9	29.2	225.8	136.1	207.5	84.5	125.0	39.9	73.3	65.1	24.5	1,142.4
adjusted for peak day			74.0	68.0	31.1	270.2	175.4	338.0	118.8	185.7	49.3	85.2	74.4	31.0	1,501.1
Langdon Rural Water	1,568	206.3	24.2	16.0	19.9	22.2	23.2	31.5	23.0	20.4	18.0	18.2	22.6	24.9	264.2
adjusted for peak day			27.3	16.5	21.2	26.6	29.9	51.4	32.3	30.4	22.2	21.2	25.8	31.5	336.2
Results															
Max Month Total			5,867.2	5,520.3	6,103.0	6,391.0	7,960.8	10,345.7	11,669.8	9,258.0	7,441.6	6,469.5	6,722.7	6,185.3	89,935.0
Adjusted Max Month Total			6,607.7	5,690.6	6,491.2	7,595.6	10,214.9	16,699.1	16,346.3	13,673.1	9,173.3	7,498.3	7,664.0	7,790.3	115,444.3
Increase in Max Month			740.5	170.3	388.1	1,204.6	2,254.1	6,353.3	4,676.4	4,415.1	1,731.8	1,028.7	941.2	1,605.0	25,509.3
% Increase			12.62%	3.09%	6.36%	18.85%	28.32%	61.41%	40.07%	47.69%	23.27%	15.90%	14.00%	25.95%	28.36%

Table B.1.12. Maximum Month Peak Day Water Demand – Scenario One.
(using Overall Maximum Month Peaking Factor Method)

Water System	2050 Pop.	Peak Day gpc/d	Max Month Demand in Acre-Feet												Total (ac-ft)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Monthly Adjustment Factor			**1.24**	**1.33**	**1.24**	**1.99**	**1.79**	**1.63**	**1.64**	**1.71**	**1.42**	**1.27**	**1.35**	**1.40**	
Drayton	920	473.6	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
adjusted for peak day			79.5	74.7	84.4	68.6	54.5	54.9	81.5	65.7	58.2	84.7	77.3	94.1	878.2
Fargo	204,300	381.8	2,408.1	2,144.4	2,513.1	2,619.0	3,501.7	4,549.3	5,005.0	3,812.2	3,099.0	2,540.4	2,838.1	2,651.8	37,681.9
adjusted for peak day			2,994.8	2,860.1	3,126.5	5,211.1	6,272.0	7,409.7	8,201.6	6,521.6	4,413.3	3,232.0	3,834.7	3,707.2	57,784.4
Grafton	4,130	339.5	68.1	72.1	60.8	72.2	85.4	97.6	101.3	92.0	82.5	69.7	64.1	61.1	926.8
adjusted for peak day			84.7	96.2	75.7	143.7	152.9	158.9	166.0	157.5	117.5	88.6	86.6	85.4	1,413.5
Grand Forks	83,800	526.7	1,249.2	1,217.4	1,314.3	1,286.3	1,565.1	2,108.3	2,533.2	1,998.7	1,559.0	1,536.9	1,506.9	1,329.3	19,204.6
adjusted for peak day			1,553.5	1,623.8	1,635.1	2,559.3	2,803.2	3,434.0	4,151.1	3,419.3	2,220.2	1,955.3	2,036.0	1,858.4	29,249.3
Langdon	2,100	537.8	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
adjusted for peak day			78.4	87.6	77.6	88.3	81.5	76.0	78.5	85.6	68.8	45.7	42.1	50.5	860.5
Valley City	5,840	386.2	64.9	66.1	60.7	60.8	79.8	116.5	103.9	110.7	66.8	57.6	53.0	52.7	893.6
adjusted for peak day			80.7	88.2	75.5	121.0	142.9	189.7	170.3	189.4	95.1	73.3	71.6	73.6	1,371.5
West Fargo	33,900	275.4	257.0	240.2	265.6	274.6	345.1	445.7	669.3	505.1	338.7	317.6	340.6	261.1	4,260.7
adjusted for peak day			319.6	320.4	330.5	546.3	618.1	725.9	1,096.8	864.1	482.3	404.1	460.2	365.0	6,533.4
East Grand Forks	9,800	522.7	184.7	157.8	172.6	150.0	223.6	219.1	244.4	254.1	220.4	190.0	188.6	178.5	2,383.9
adjusted for peak day			229.7	210.5	214.8	298.5	400.6	356.9	400.5	434.7	313.8	241.7	254.8	249.5	3,606.1
Moorhead	50,211	289.3	559.9	608.5	646.0	661.1	711.4	952.5	1,065.3	845.8	798.5	621.5	598.9	576.1	8,645.7
adjusted for peak day			696.3	811.6	803.7	1,315.5	1,274.2	1,551.4	1,745.7	1,447.0	1,137.1	790.7	809.2	805.5	13,188.0
Cass Rural Water	16,244	154.2	34.2	32.0	30.0	50.0	75.6	86.6	116.5	101.9	55.8	47.9	25.9	45.4	701.6
adjusted for peak day			42.5	42.6	37.3	99.6	135.3	141.0	190.8	174.3	79.4	61.0	34.9	63.5	1,102.3
Grand Forks - Traill Water Users	12,176	212.1	26.4	26.6	0.0	156.5	83.6	141.6	41.8	74.6	5.5	32.6	26.0	0.0	615.1
adjusted for peak day			32.8	35.5	0.0	311.3	149.7	230.6	68.4	127.6	7.8	41.5	35.2	0.0	1,040.5
Langdon Rural Water	1,568	206.3	13.1	8.7	10.8	12.0	12.5	17.1	12.4	11.1	9.7	9.8	12.2	13.5	142.9
adjusted for peak day			16.3	11.6	13.4	23.9	22.5	27.8	20.4	18.9	13.9	12.5	16.5	18.8	216.3
Results															
Max Month Total			4,992.6	4,695.5	5,204.1	5,421.4	6,759.6	8,814.6	9,990.8	7,894.7	6,325.0	5,526.6	5,742.6	5,272.8	76,640.3
Adjusted Max Month Total			6,186.9	6,235.3	6,457.8	10,598.2	12,017.2	14,246.6	16,313.2	13,425.4	8,987.8	7,004.1	7,730.0	7,344.7	116,547.0
Increase in Max Month			1,194.3	1,539.8	1,253.7	5,176.8	5,257.5	5,432.1	6,322.4	5,530.6	2,662.8	1,477.4	1,987.4	2,071.9	39,906.7
% Increase			23.92%	32.79%	24.09%	95.49%	77.78%	61.63%	63.28%	70.05%	42.10%	26.73%	34.61%	39.29%	52.07%

Table B.1.13. Maximum Month Peak Day Water Demand – Scenario Two.
(using Overall Maximum Month Peaking Factor Method)

Water System	2050 Pop.	Peak Day gpc/d	Max Month Demand in Acre-Feet												Total (ac-ft)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Monthly Adjustment Factor			**1.24**	**1.33**	**1.24**	**1.99**	**1.79**	**1.63**	**1.64**	**1.71**	**1.42**	**1.27**	**1.35**	**1.40**	
Drayton	920	473.6	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
adjusted for peak day			79.5	74.7	84.4	68.6	54.5	54.9	81.5	65.7	58.2	84.7	77.3	94.1	878.2
Fargo	204,300	381.8	2,865.1	2,551.3	2,990.0	3,116.0	4,166.3	5,412.6	5,954.9	4,535.7	3,687.1	3,022.6	3,376.7	3,155.1	44,833.3
adjusted for peak day			3,563.1	3,402.9	3,719.8	6,200.0	7,462.3	8,815.9	9,758.1	7,759.3	5,250.9	3,845.4	4,562.5	4,410.8	68,751.0
Grafton	4,130	339.5	102.9	109.0	91.9	109.2	129.0	147.5	153.1	139.2	124.8	105.3	96.9	92.3	1,401.2
adjusted for peak day			128.0	145.4	114.4	217.2	231.1	240.2	250.9	238.1	177.7	134.0	131.0	129.1	2,137.1
Grand Forks	83,800	526.7	1,321.6	1,289.0	1,389.4	1,363.2	1,658.3	2,226.6	2,685.8	2,124.8	1,652.4	1,630.1	1,597.3	1,409.2	20,347.9
adjusted for peak day			1,643.6	1,719.3	1,728.5	2,712.4	2,970.3	3,626.6	4,401.2	3,635.0	2,353.2	2,073.9	2,158.2	1,970.1	30,992.3
Langdon	2,100	537.8	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
adjusted for peak day			78.4	87.6	77.6	88.3	81.5	76.0	78.5	85.6	68.8	45.7	42.1	50.5	860.5
Valley City	5,840	386.2	83.4	84.9	78.0	78.1	102.5	149.6	133.5	142.2	85.7	74.0	68.1	67.6	1,147.6
adjusted for peak day			103.7	113.2	97.0	155.5	183.6	243.7	218.7	243.3	122.1	94.1	92.0	94.5	1,761.4
West Fargo	33,900	275.4	263.1	245.9	271.9	281.1	353.3	456.2	685.2	517.1	346.7	325.2	348.7	267.3	4,361.8
adjusted for peak day			327.2	328.0	338.3	559.3	632.8	743.1	1,122.9	884.6	493.8	413.7	471.1	373.7	6,688.5
East Grand Forks	9,800	522.7	256.7	219.4	239.9	208.5	310.8	304.5	339.6	353.1	306.2	264.0	262.0	248.0	3,312.9
adjusted for peak day			319.2	292.6	298.5	414.9	556.7	496.0	556.6	604.1	436.1	335.9	354.1	346.8	5,011.3
Moorhead	50,211	289.3	685.3	747.6	795.8	815.2	879.7	1,189.1	1,333.8	1,052.2	991.4	764.3	735.3	706.1	10,695.7
adjusted for peak day			852.2	997.2	990.0	1,621.9	1,575.6	1,936.7	2,185.7	1,800.0	1,411.8	972.3	993.6	987.1	16,324.3
Cass Rural Water	16,244	154.2	72.3	69.4	66.8	92.8	125.8	140.1	178.7	159.9	100.2	90.1	61.5	86.8	1,244.4
adjusted for peak day			89.9	92.6	83.2	184.7	225.3	228.1	292.8	273.5	142.7	114.6	83.2	121.3	1,931.8
Grand Forks - Traill Water Users	12,176	212.1	65.6	65.9	29.2	225.8	136.1	207.5	84.5	125.0	39.9	73.3	65.1	24.5	1,142.4
adjusted for peak day			81.5	87.9	36.3	449.3	243.7	338.0	138.5	213.8	56.8	93.2	88.0	34.3	1,861.5
Langdon Rural Water	1,568	206.3	24.2	16.0	19.9	22.2	23.2	31.5	23.0	20.4	18.0	18.2	22.6	24.9	264.2
adjusted for peak day			30.1	21.4	24.8	44.3	41.6	51.4	37.7	35.0	25.6	23.2	30.5	34.8	400.1
Results															
Max Month Total			5,867.2	5,520.3	6,103.0	6,391.0	7,960.8	10,345.7	11,669.8	9,258.0	7,441.6	6,469.5	6,722.7	6,185.3	89,935.0
Adjusted Max Month Total			7,265.0	7,322.2	7,569.0	12,458.8	14,127.1	16,699.1	19,037.3	15,721.7	10,563.4	8,192.6	9,040.5	8,610.6	136,607.4
Increase in Max Month			1,397.8	1,801.9	1,466.0	6,067.8	6,166.3	6,353.3	7,367.5	6,463.7	3,121.8	1,723.1	2,317.8	2,425.3	46,672.4
% Increase			23.82%	32.64%	24.02%	94.94%	77.46%	61.41%	63.13%	69.82%	41.95%	26.63%	34.48%	39.21%	51.90%

Table B.1.14. Final Maximum Month Peak Day Water Demands – Scenario One.
(using Average of Three Adjustment Methods)

Water System	Max Month Demand in Acre-Feet												Total (ac-ft)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Drayton - Max Month	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
Method 1	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
Method 2	72.2	57.8	72.2	41.3	39.2	54.9	69.9	57.1	50.5	77.4	65.4	85.0	742.9
Method 3	79.5	74.7	84.4	68.6	54.5	54.9	81.5	65.7	58.2	84.7	77.3	94.1	878.2
Average	71.9	62.8	74.8	48.1	41.3	47.8	67.1	53.7	49.9	76.3	66.7	82.1	742.5
Diff. Max Month & Average	7.9	6.8	7.0	13.6	10.9	14.1	17.3	15.3	9.0	9.7	9.4	14.8	136.0
Fargo - Max Month	2,408.1	2,144.4	2,513.1	2,619.0	3,501.7	4,549.3	5,005.0	3,812.2	3,099.0	2,540.4	2,838.1	2,651.8	37,681.9
Method 1	3,570.4	3,179.4	3,726.0	3,883.1	5,191.8	6,745.0	7,420.7	5,652.3	4,594.7	3,766.6	4,207.9	3,931.7	55,869.7
Method 2	2,718.9	2,212.0	2,675.5	3,133.6	4,514.4	7,409.7	7,034.0	5,662.9	3,828.0	2,953.3	3,242.8	3,350.3	48,735.3
Method 3	2,994.8	2,860.1	3,126.5	5,211.1	6,272.0	7,409.7	8,201.6	6,521.6	4,413.3	3,232.0	3,834.7	3,707.2	57,784.4
Average	3,094.7	2,750.5	3,176.0	4,075.9	5,326.1	7,188.1	7,552.1	5,945.6	4,278.7	3,317.3	3,761.8	3,663.1	54,129.8
Diff. Max Month & Average	686.6	606.1	662.9	1,456.9	1,824.4	2,638.9	2,547.1	2,133.4	1,179.7	776.9	923.7	1,011.3	16,447.9
Grafton - Max Month	68.1	72.1	60.8	72.2	85.4	97.6	101.3	92.0	82.5	69.7	64.1	61.1	926.8
Method 1	89.7	95.0	80.1	95.1	112.4	128.5	133.4	121.2	108.7	91.8	84.5	80.4	1,220.7
Method 2	76.9	74.4	64.7	86.4	110.0	158.9	142.3	136.7	101.9	81.0	73.3	77.2	1,183.7
Method 3	84.7	96.2	75.7	143.7	152.9	158.9	166.0	157.5	117.5	88.6	86.6	85.4	1,413.5
Average	83.7	88.5	73.5	108.4	125.1	148.8	147.2	138.5	109.4	87.1	81.5	81.0	1,272.7
Diff. Max Month & Average	15.7	16.4	12.7	36.2	39.8	51.2	46.0	46.4	26.9	17.5	17.3	19.9	345.8
Grand Forks - Max Month	1,249.2	1,217.4	1,314.3	1,286.3	1,565.1	2,108.3	2,533.2	1,998.7	1,559.0	1,536.9	1,506.9	1,329.3	19,204.6
Method 1	2,070.7	2,018.0	2,178.6	2,132.1	2,594.2	3,494.8	4,199.0	3,313.1	2,584.2	2,547.6	2,497.7	2,203.4	31,833.5
Method 2	1,410.4	1,255.8	1,399.3	1,539.0	2,017.7	3,434.0	3,560.2	2,969.0	1,925.8	1,786.7	1,721.7	1,679.4	24,699.0
Method 3	1,553.5	1,623.8	1,635.1	2,559.3	2,803.2	3,434.0	4,151.1	3,419.3	2,220.2	1,955.3	2,036.0	1,858.4	29,249.3
Average	1,678.2	1,632.5	1,737.7	2,076.8	2,471.7	3,454.2	3,970.1	3,233.8	2,243.4	2,096.5	2,085.2	1,913.8	28,593.9
Diff. Max Month & Average	429.0	415.1	423.3	790.5	906.6	1,345.9	1,436.9	1,235.1	684.4	559.6	578.3	584.5	9,389.3
Langdon - Max Month	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
Method 1	93.2	97.0	92.1	65.6	67.2	68.9	70.7	73.9	71.4	53.1	46.0	53.4	852.6
Method 2	71.2	67.7	66.4	53.1	58.6	76.0	67.3	74.3	59.7	41.8	35.6	45.6	717.3
Method 3	78.4	87.6	77.6	88.3	81.5	76.0	78.5	85.6	68.8	45.7	42.1	50.5	860.5
Average	81.0	84.1	78.7	69.0	69.1	73.6	72.2	77.9	66.6	46.9	41.2	49.8	810.1
Diff. Max Month & Average	17.9	18.5	16.3	24.6	23.6	27.0	24.3	27.9	18.3	10.9	10.1	13.7	233.1
Valley City - Max Month	64.9	66.1	60.7	60.8	79.8	116.5	103.9	110.7	66.8	57.6	53.0	52.7	893.6
Method 1	115.7	117.8	108.2	108.4	142.2	207.6	185.3	197.4	119.0	102.7	94.5	93.8	1,592.7
Method 2	73.3	68.2	64.6	72.8	102.9	189.7	146.1	164.5	82.5	67.0	60.6	66.5	1,158.6
Method 3	80.7	88.2	75.5	121.0	142.9	189.7	170.3	189.4	95.1	73.3	71.6	73.6	1,371.5
Average	89.9	91.4	82.8	100.8	129.3	195.7	167.2	183.8	98.8	81.0	75.6	78.0	1,374.3
Diff. Max Month & Average	25.0	25.3	22.1	39.9	49.5	79.2	63.3	73.0	32.1	23.4	22.6	25.3	480.7

Water System	Max Month Demand in Acre-Feet												Total (ac-ft)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
West Fargo - Max Month	257.0	240.2	265.6	274.6	345.1	445.7	669.3	505.1	338.7	317.6	340.6	261.1	4,260.7
Method 1	341.0	318.7	352.5	364.4	457.9	591.4	888.2	670.3	449.4	421.5	451.9	346.5	5,653.7
Method 2	290.2	247.8	282.8	328.5	444.9	725.9	940.7	750.3	418.4	369.3	389.2	329.9	5,517.7
Method 3	319.6	320.4	330.5	546.3	618.1	725.9	1,096.8	864.1	482.3	404.1	460.2	365.0	6,533.4
Average	317.0	295.6	321.9	413.1	507.0	681.0	975.2	761.6	450.0	398.3	433.8	347.1	5,901.6
Diff. Max Month & Average	59.9	55.4	56.3	138.5	161.9	235.4	305.9	256.4	111.3	80.6	93.2	86.0	1,641.0
East Grand Forks - Max Month	184.7	157.8	172.6	150.0	223.6	219.1	244.4	254.1	220.4	190.0	188.6	178.5	2,383.9
Method 1	354.3	302.7	331.1	287.8	428.9	420.3	468.7	487.3	422.6	364.4	361.6	342.3	4,572.1
Method 2	208.6	162.8	183.8	179.5	288.3	356.9	343.5	377.4	272.2	220.9	215.5	225.5	3,034.9
Method 3	229.7	210.5	214.8	298.5	400.6	356.9	400.5	434.7	313.8	241.7	254.8	249.5	3,606.1
Average	264.2	225.4	243.2	255.3	372.6	378.1	404.2	433.2	336.2	275.6	277.3	272.4	3,737.7
Diff. Max Month & Average	79.5	67.5	70.6	105.2	149.0	158.9	159.8	179.1	115.9	85.7	88.7	94.0	1,353.8
Moorhead - Max Month	559.9	608.5	646.0	661.1	711.4	952.5	1,065.3	845.8	798.5	621.5	598.9	576.1	8,645.7
Method 1	726.3	789.3	838.0	857.6	922.8	1,235.6	1,381.9	1,097.2	1,035.7	806.2	776.9	747.4	11,215.1
Method 2	632.2	627.7	687.8	791.0	917.2	1,551.4	1,497.2	1,256.5	986.3	722.5	684.3	727.9	11,082.0
Method 3	696.3	811.6	803.7	1,315.5	1,274.2	1,551.4	1,745.7	1,447.0	1,137.1	790.7	809.2	805.5	13,188.0
Average	684.9	742.9	776.5	988.0	1,038.1	1,446.2	1,541.6	1,266.9	1,053.0	773.1	756.8	760.2	11,828.3
Diff. Max Month & Average	125.0	134.4	130.5	326.9	326.7	493.6	476.3	421.0	254.6	151.6	157.9	184.1	3,182.7
Cass Rural Water - Max Month	34.2	32.0	30.0	50.0	75.6	86.6	116.5	101.9	55.8	47.9	25.9	45.4	701.6
Method 1	41.8	39.1	36.7	61.2	92.4	105.9	142.5	124.7	68.2	58.6	31.6	55.5	858.3
Method 2	38.6	33.0	31.9	59.9	97.4	141.0	163.7	151.4	68.9	55.7	29.6	57.4	928.3
Method 3	42.5	42.6	37.3	99.6	135.3	141.0	190.8	174.3	79.4	61.0	34.9	63.5	1,102.3
Average	41.0	38.2	35.3	73.6	108.4	129.3	165.7	150.1	72.2	58.4	32.0	58.8	963.0
Diff. Max Month & Average	6.8	6.3	5.3	23.5	32.8	42.7	49.2	48.2	16.4	10.5	6.2	13.4	261.4
Grand Forks - Traill Water Users - Max Month	26.4	26.6	0.0	156.5	83.6	141.6	41.8	74.6	5.5	32.6	26.0	0.0	615.1
Method 1	26.4	26.6	0.0	156.5	83.6	141.6	41.8	74.6	5.5	32.6	26.0	0.0	615.1
Method 2	29.8	27.5	0.0	187.2	107.8	230.6	58.7	110.8	6.8	37.9	29.7	0.0	826.8
Method 3	32.8	35.5	0.0	311.3	149.7	230.6	68.4	127.6	7.8	41.5	35.2	0.0	1,040.5
Average	29.6	29.9	0.0	218.3	113.7	201.0	56.3	104.4	6.7	37.3	30.3	0.0	827.5
Diff. Max Month & Average	3.3	3.2	0.0	61.9	30.1	59.4	14.5	29.7	1.2	4.7	4.3	0.0	212.3
Langdon Rural Water - Max Month	13.1	8.7	10.8	12.0	12.5	17.1	12.4	11.1	9.7	9.8	12.2	13.5	142.9
Method 1	22.8	15.1	18.8	21.0	21.9	29.8	21.7	19.3	17.0	17.2	21.3	23.5	249.5
Method 2	14.8	8.9	11.5	14.4	16.2	27.8	17.5	16.4	12.0	11.4	13.9	17.0	181.8
Method 3	16.3	11.6	13.4	23.9	22.5	27.8	20.4	18.9	13.9	12.5	16.5	18.8	216.3
Average	17.9	11.9	14.6	19.8	20.2	28.4	19.8	18.2	14.3	13.7	17.2	19.8	215.9
Diff. Max Month & Average	4.9	3.2	3.8	7.7	7.6	11.4	7.4	7.2	4.6	3.9	5.0	6.3	73.0

Water System	Max Month Demand in Acre-Feet												Total (ac-ft)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Results													
Max Month Total	4,992.6	4,695.5	5,204.1	5,421.4	6,759.6	8,814.6	9,990.8	7,894.7	6,325.0	5,526.6	5,742.6	5,272.8	76,640.3
Adjusted Max Month Total	6,454.0	6,053.8	6,614.9	8,447.0	10,322.6	13,972.3	15,138.8	12,367.5	8,779.3	7,261.6	7,659.4	7,326.1	110,397.3
Increase in Max Month	1,461.4	1,358.3	1,410.8	3,025.6	3,563.0	5,157.7	5,148.0	4,472.8	2,454.3	1,734.9	1,916.8	2,053.3	33,757.0
% Increase	29.27%	28.93%	27.11%	55.81%	52.71%	58.51%	51.53%	56.66%	38.80%	31.39%	33.38%	38.94%	44.05%

Table B.1.15. Final Maximum Month Peak Day Water Demands – Scenario Two.
(using Average of Three Adjustment Methods)

Water System	Max Month Demand in Acre-Feet												Total (ac-ft)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Drayton - Max Month	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
Method 1	64.0	56.0	67.8	34.5	30.4	33.7	49.7	38.4	40.9	66.6	57.2	67.3	606.6
Method 2	72.2	57.8	72.2	41.3	39.2	54.9	69.9	57.1	50.5	77.4	65.4	85.0	742.9
Method 3	79.5	74.7	84.4	68.6	54.5	54.9	81.5	65.7	58.2	84.7	77.3	94.1	878.2
Average	71.9	62.8	74.8	48.1	41.3	47.8	67.1	53.7	49.9	76.3	66.7	82.1	742.5
Diff. Max Month & Average	7.9	6.8	7.0	13.6	10.9	14.1	17.3	15.3	9.0	9.7	9.4	14.8	136.0
Fargo - Max Month	2,865.1	2,551.3	2,990.0	3,116.0	4,166.3	5,412.6	5,954.9	4,535.7	3,687.1	3,022.6	3,376.7	3,155.1	44,833.3
Method 1	4,248.0	3,782.8	4,433.2	4,620.0	6,177.2	8,025.1	8,829.1	6,725.0	5,466.7	4,481.5	5,006.5	4,677.9	66,472.9
Method 2	3,234.9	2,631.8	3,183.2	3,728.3	5,371.1	8,815.9	8,368.9	6,737.6	4,554.6	3,513.8	3,858.2	3,986.1	57,984.5
Method 3	3,563.1	3,402.9	3,719.8	6,200.0	7,462.3	8,815.9	9,758.1	7,759.3	5,250.9	3,845.4	4,562.5	4,410.8	68,751.0
Average	3,682.0	3,272.5	3,778.7	4,849.4	6,336.9	8,552.3	8,985.4	7,074.0	5,090.7	3,946.9	4,475.7	4,358.3	64,402.8
Diff. Max Month & Average	816.9	721.2	788.7	1,733.4	2,170.6	3,139.7	3,030.5	2,538.3	1,403.6	924.3	1,099.0	1,203.2	19,569.5
Grafton - Max Month	102.9	109.0	91.9	109.2	129.0	147.5	153.1	139.2	124.8	105.3	96.9	92.3	1,401.2
Method 1	135.6	143.6	121.1	143.8	170.0	194.3	201.7	183.3	164.3	138.7	127.7	121.6	1,845.6
Method 2	116.2	112.5	97.9	130.6	166.4	240.2	215.2	206.7	154.1	122.4	110.8	116.7	1,789.7
Method 3	128.0	145.4	114.4	217.2	231.1	240.2	250.9	238.1	177.7	134.0	131.0	129.1	2,137.1
Average	126.6	133.8	111.1	163.9	189.2	224.9	222.6	209.4	165.4	131.7	123.1	122.5	1,924.1
Diff. Max Month & Average	23.7	24.8	19.2	54.7	60.1	77.4	69.5	70.2	40.6	26.4	26.2	30.1	522.9
Grand Forks - Max Month	1,321.6	1,289.0	1,389.4	1,363.2	1,658.3	2,226.6	2,685.8	2,124.8	1,652.4	1,630.1	1,597.3	1,409.2	20,347.9
Method 1	2,210.0	2,155.5	2,323.3	2,279.5	2,773.0	3,723.3	4,491.2	3,553.1	2,763.1	2,725.9	2,671.0	2,356.5	34,025.5
Method 2	1,492.2	1,329.7	1,479.2	1,631.1	2,137.9	3,626.6	3,774.6	3,156.3	2,041.1	1,895.1	1,825.1	1,780.4	26,169.3
Method 3	1,643.6	1,719.3	1,728.5	2,712.4	2,970.3	3,626.6	4,401.2	3,635.0	2,353.2	2,073.9	2,158.2	1,970.1	30,992.3

Water System	Max Month Demand in Acre-Feet												Total (ac-ft)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Average	1,781.9	1,734.8	1,843.7	2,207.7	2,627.1	3,658.8	4,222.4	3,448.1	2,385.8	2,231.6	2,218.1	2,035.6	30,395.7
Diff. Max Month & Average	460.3	445.8	454.3	844.5	968.7	1,432.2	1,536.5	1,323.3	733.4	601.5	620.8	626.4	10,047.8
Langdon - Max Month	63.1	65.7	62.4	44.4	45.5	46.7	47.9	50.0	48.3	36.0	31.1	36.1	577.0
Method 1	93.2	97.0	92.1	65.6	67.2	68.9	70.7	73.9	71.4	53.1	46.0	53.4	852.6
Method 2	71.2	67.7	66.4	53.1	58.6	76.0	67.3	74.3	59.7	41.8	35.6	45.6	717.3
Method 3	78.4	87.6	77.6	88.3	81.5	76.0	78.5	85.6	68.8	45.7	42.1	50.5	860.5
Average	81.0	84.1	78.7	69.0	69.1	73.6	72.2	77.9	66.6	46.9	41.2	49.8	810.1
Diff. Max Month & Average	17.9	18.5	16.3	24.6	23.6	27.0	24.3	27.9	18.3	10.9	10.1	13.7	233.1
Valley City - Max Month	83.4	84.9	78.0	78.1	102.5	149.6	133.5	142.2	85.7	74.0	68.1	67.6	1,147.6
Method 1	148.6	151.3	138.9	139.3	182.7	266.7	237.9	253.5	152.8	131.8	121.4	120.5	2,045.4
Method 2	94.1	87.6	83.0	93.5	132.1	243.7	187.6	211.3	105.9	86.0	77.8	85.4	1,488.0
Method 3	103.7	113.2	97.0	155.5	183.6	243.7	218.7	243.3	122.1	94.1	92.0	94.5	1,761.4
Average	115.5	117.4	106.3	129.4	166.1	251.3	214.8	236.0	126.9	104.0	97.1	100.2	1,764.9
Diff. Max Month & Average	32.1	32.5	28.4	51.3	63.6	101.7	81.3	93.8	41.2	30.0	29.0	32.5	617.4
West Fargo - Max Month	263.1	245.9	271.9	281.1	353.3	456.2	685.2	517.1	346.7	325.2	348.7	267.3	4,361.8
Method 1	349.1	326.3	360.9	373.0	468.8	605.4	909.3	686.2	460.1	431.5	462.7	354.7	5,787.9
Method 2	297.1	253.7	289.5	336.3	455.5	743.1	963.0	768.1	428.3	378.0	398.4	337.7	5,648.8
Method 3	327.2	328.0	338.3	559.3	632.8	743.1	1,122.9	884.6	493.8	413.7	471.1	373.7	6,688.5
Average	324.5	302.7	329.6	422.9	519.0	697.2	998.4	779.6	460.7	407.7	444.1	355.4	6,041.7
Diff. Max Month & Average	61.4	56.7	57.6	141.8	165.7	241.0	313.2	262.5	114.0	82.6	95.4	88.1	1,679.9
East Grand Forks - Max Month	256.7	219.4	239.9	208.5	310.8	304.5	339.6	353.1	306.2	264.0	262.0	248.0	3,312.9
Method 1	492.3	420.7	460.1	399.9	596.1	584.1	651.4	677.2	587.3	506.4	502.6	475.7	6,353.8
Method 2	289.8	226.3	255.4	249.5	400.7	496.0	477.3	524.5	378.3	306.9	299.4	313.4	4,217.6
Method 3	319.2	292.6	298.5	414.9	556.7	496.0	556.6	604.1	436.1	335.9	354.1	346.8	5,011.3
Average	367.1	313.2	338.0	354.8	517.8	525.4	561.8	601.9	467.3	383.1	385.4	378.6	5,194.2
Diff. Max Month & Average	110.4	93.8	98.1	146.2	207.0	220.8	222.1	248.8	161.0	119.0	123.3	130.6	1,881.3
Moorhead - Max Month	685.3	747.6	795.8	815.2	879.7	1,189.1	1,333.8	1,052.2	991.4	764.3	735.3	706.1	10,695.7
Method 1	911.1	993.9	1,058.0	1,083.7	1,169.5	1,580.9	1,773.3	1,398.9	1,318.0	1,016.1	977.6	938.8	14,219.9
Method 2	773.7	771.2	847.2	975.3	1,134.1	1,936.7	1,874.6	1,563.0	1,224.6	888.5	840.2	892.1	13,721.2
Method 3	852.2	997.2	990.0	1,621.9	1,575.6	1,936.7	2,185.7	1,800.0	1,411.8	972.3	993.6	987.1	16,324.3
Average	845.7	920.8	965.1	1,227.0	1,293.1	1,818.1	1,944.6	1,587.3	1,318.2	959.0	937.1	939.3	14,755.1
Diff. Max Month & Average	160.4	173.2	169.3	411.8	413.4	629.0	610.7	535.1	326.8	194.7	201.8	233.2	4,059.4
Cass Rural Water - Max Month	72.3	69.4	66.8	92.8	125.8	140.1	178.7	159.9	100.2	90.1	61.5	86.8	1,244.4
Method 1	77.1	74.1	71.4	99.1	134.3	149.5	190.7	170.6	107.0	96.1	65.7	92.6	1,328.2
Method 2	81.6	71.6	71.2	111.0	162.2	228.1	251.1	237.5	123.8	104.7	70.3	109.7	1,622.8
Method 3	89.9	92.6	83.2	184.7	225.3	228.1	292.8	273.5	142.7	114.6	83.2	121.3	1,931.8
Average	82.9	79.5	75.2	131.6	173.9	201.9	244.9	227.2	124.5	105.1	73.1	107.9	1,627.6
Diff. Max Month & Average	10.6	10.0	8.4	38.8	48.1	61.9	66.2	67.3	24.3	15.1	11.5	21.1	383.2
Grand Forks - Traill Water Users - Max Month	65.6	65.9	29.2	225.8	136.1	207.5	84.5	125.0	39.9	73.3	65.1	24.5	1,142.4
Method 1	65.6	65.9	29.2	225.8	136.1	207.5	84.5	125.0	39.9	73.3	65.1	24.5	1,142.4
Method 2	74.0	68.0	31.1	270.2	175.4	338.0	118.8	185.7	49.3	85.2	74.4	31.0	1,501.1
Method 3	81.5	87.9	36.3	449.3	243.7	338.0	138.5	213.8	56.8	93.2	88.0	34.3	1,861.5

Average	73.7	73.9	32.2	315.1	185.0	294.5	114.0	174.8	48.6	83.9	75.9	29.9	1,501.7
Diff. Max Month & Average	8.1	8.0	3.0	89.3	49.0	87.0	29.4	49.8	8.8	10.6	10.7	5.4	359.2
Langdon Rural Water - Max Month	24.2	16.0	19.9	22.2	23.2	31.5	23.0	20.4	18.0	18.2	22.6	24.9	264.2
Method 1	42.2	28.0	34.8	38.8	40.5	55.1	40.1	35.7	31.4	31.8	39.4	43.5	461.4
Method 2	27.3	16.5	21.2	26.6	29.9	51.4	32.3	30.4	22.2	21.2	25.8	31.5	336.2
Method 3	30.1	21.4	24.8	44.3	41.6	51.4	37.7	35.0	25.6	23.2	30.5	34.8	400.1
Average	33.2	22.0	26.9	36.6	37.3	52.6	36.7	33.7	26.4	25.4	31.9	36.6	399.3
Diff. Max Month & Average	9.0	5.9	7.0	14.3	14.1	21.1	13.7	13.2	8.4	7.2	9.3	11.7	135.1
Results													
Max Month Total	5,867.2	5,520.3	6,103.0	6,391.0	7,960.8	10,345.7	11,669.8	9,258.0	7,441.6	6,469.5	6,722.7	6,185.3	89,935.0
Adjusted Max Month Total	7,585.9	7,117.5	7,760.3	9,955.4	12,155.9	16,398.7	17,684.5	14,503.7	10,331.0	8,501.5	8,969.3	8,596.2	129,559.8
Increase in Max Month	1,718.7	1,597.3	1,657.3	3,564.4	4,195.0	6,052.9	6,014.7	5,245.7	2,889.4	2,031.9	2,246.6	2,410.9	39,624.8
% Increase	29.29%	28.93%	27.15%	55.77%	52.70%	58.51%	51.54%	56.66%	38.83%	31.41%	33.42%	38.98%	44.06%

B.2 - GROUNDWATER

B.2.1 – Conversion of Irrigation Permits on the Elk Valley Aquifer to Augment Grand Forks-Traill Rural Water Users and Meet Peak Day Demand for Grand Forks

Purpose

Currently, GFTWD (Grand Forks-Traill Water Users) exclusively uses the EVA (Elk Valley Aquifer) for water supply. Reclamation has projections that show GFTWD with insufficient groundwater allocations under existing permits for the projected 2050 population. The North Dakota State Water Commission believes the current withdrawals from the EVA to be at, or near, the maximum supportable by natural recharge (Lindvig 1995). Therefore, Reclamation modeled the shortage as a demand on the Red River's surface water system requiring a pipeline from Grand Forks to tie into existing GFTWD infrastructure. Another, more simplistic, approach would be to find a mechanism for increasing their groundwater withdrawals from the EVA. With little chance of increasing demands on the aquifer, only permit conversion from one use to another can adequately address shortages for GFTWD.

The city of Grand Forks also is projected to have water shortages during a drought of similar magnitude of the 1930s drought. Historically, Grand Forks consumes about six percent of its annual municipal water supply during peak days. While project flows for all of the action alternatives within the Needs and Options Report satisfy Grand Fork's monthly demands, predicting peak days far enough in advance to ensure delivery of adequate water is virtually impossible. Therefore, an alternative water source responsible for only meeting the identified peak demands provides benefit to a community lacking adequate storage of untreated water. A readily available groundwater source can offer as needed water supply for meeting this daily peak demand while at the same time offer a redundant short term water supply. The EVA lies west of Grand Forks and is the most geographically advantageous aquifer to meet the identified peak demands. Since the EVA is already a heavily appropriated aquifer, permit conversion is the logical option for fulfilling the needs of Grand Forks and GFTWD with groundwater from the EVA.

Both Grand Forks and GFTWD would be expected to not need this water immediately as the identified shortages would not be realized until several years after the implementation of most alternatives that require this water.

Demands

Peak Demand for Grand Forks

Peak demand was defined by Reclamation as demand which exceeds the daily average of a one month period. As such, the volumes and rates of water may vary greatly from month to month, but the percentage remains fairly constant. Grand Forks has a Scenario One demand of 27.1 cfs (12,163 gpm) with an annual withdrawal of 1,152 ac-ft (375 mgals). Scenario Two is only slightly higher at 28.7 cfs (12,881 gpm) with a total annual withdrawal of 1,221 ac-ft (398 mgals).

Increased Groundwater Supply to Grand Forks-Traill Water Users

Grand Forks-Traill Water Users will require an additional annual allocation between 605 ac-ft (197 mgals) under Scenario One and 1,142 ac-ft (372 mgals) under Scenario Two. GFTWD would expectedly have the ability to meet peak demands by adding the wells required to increase their annual withdrawals.

Elk Valley Aquifer

The EVA underlies about 200 square miles of western Grand Forks County with portions extending south into northwest Traill and northeast Steele counties. The aquifer matrix tends to be comprised of coarser sediment texture in the north and transitions to finer grained sediments in the south (Kelly and Paulson 1970).

The major natural discharges from the aquifer are evapotranspiration and baseflow to surface waters (Kelly and Paulson 1970). Some of the major streams that receive inflow from the aquifer include the Turtle, Forest, and Goose rivers where they intersect the water table.

Human withdrawals are another major source of discharge from the EVA in the form of municipal, rural, and irrigation wells. There are currently 15,738 ac-ft of water appropriated from the aquifer for irrigation with another 14,152 ac-ft of pending permit applications.

Converting Irrigation Permits to Municipal or Rural Water Use

It is possible to convert a water permit from one beneficial use to a higher beneficial use under section 89-03-02-01 of the North Dakota Administrative Code. Section 61-04-06.1 of the North Dakota Century Code classifies municipal as a higher beneficial use than irrigation. There are several complicating factors in determining the value of converting irrigation water permits to municipal use. The first step is to arrive at a volume of water that can be transferred.

A transferal of permit will not be done using the allocation as listed on the permit; the permitted transfer is equal to the mean volume of water captured for beneficial use under the existing beneficial use (Ripley 2004). Reclamation identified 7,032 ac-ft (2.29 bgals) of irrigation permits with an average annual use of 3,325.5 ac-ft (1.08 bgals) in a suitable geographic location. In order to effectively meet the projected municipal and rural shortages, Reclamation would need about 1,757 ac-ft (572 mgals) of water converted to supply both Grand Forks and GFTWD under Scenario One. Using Scenario Two, Grand Forks and GFTWD require 2,363 ac-ft (770 mgals) of water per year.

Not all permits, or points of diversion covered by a permit, had historical uses of water listed on the SWC online database of water permits (http://www.swc.state.nd.us). Permits with either a zero allocation or a zero use history were anticipated to be of no value for conversion. As such, there were 38 points of diversion within active permits with an average use history of 87.5 ac-ft (28.5 mgals) per year. In order to adequately address the projected municipal and rural shortages, it would be necessary to acquire 53-71% of these permit allocations under the respective Scenario One or Scenario Two demands.

Wellfield Development

Two variables must be considered in the development of any wellfield. The first consideration is annual sustainable yield. At 2,363 ac-ft per year, Scenario Two is the higher annual withdrawal required. For an annual yield of this magnitude, 27 wells, or nests of production wells, with an average permitted value of 87.5 ac-ft per year would be required. Spatial distribution of the points of diversion would need to mimic the footprint of the acquired points of diversions in order to prevent a change in drawdown patterns observed under historical irrigation demands, figure B.2.1.

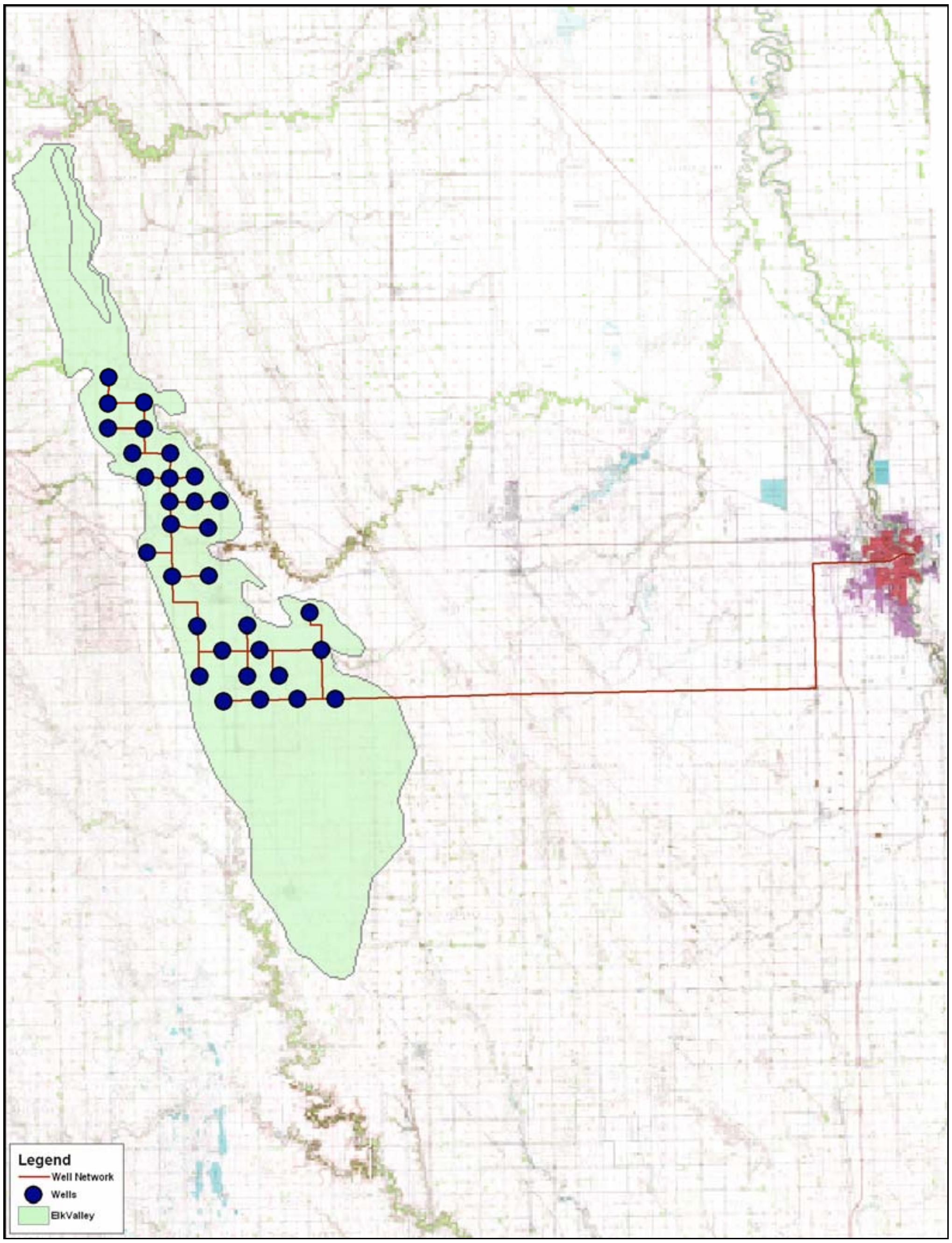


Figure B.2.1. Wellfield for serving Grand Forks and GFTWD.

The second consideration for a given wellfield is the required pumping rate. An estimate of individual well yields for the EVA is about 0.56 cfs (250 gpm) (Patch 2005). While some locations may have individual wells capable of up to 1,000 gpm, this should be considered an exception as opposed to the rule. The larger peak demand for Grand Forks is Scenario Two at 28.7 cfs (12,881 gpm). Using the 0.56 cfs as a minimum for individual well capacity, a wellfield capable of supplying Grand Forks' peak demand would require about 52 wells.

Given the assumption that GFTWD essentially has its peak demand already built into their wellfield, a total of 54 wells with each being capable of 0.56 cfs allows for sufficient excess production capacity to supply Grand Forks and GFTWD. Any well site capable of 1.1 cfs (500 gpm) would only require one well, where other sites would require linking together as in figure B.2.2 with a recommended spacing between wells of 500 to 600 feet to adequately minimize local drawdown and interference between wells. Appropriation permits through the SWC designate a point of diversion and allowable pumping rates. In reality, many of these points of diversions are not points, but are groups of wells within 500 to 600 feet of each other.

It is important to note that the lesser Scenario One demand for peak flows of 27.1 cfs (12,163 gpm) remains sufficiently close in size to Scenario Two to not warrant a different wellfield design at this point.

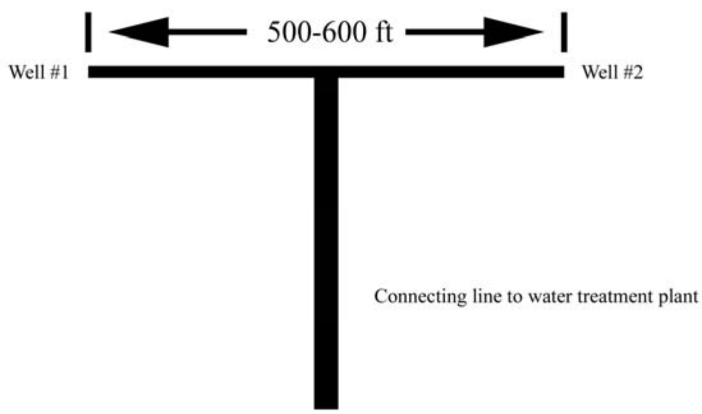


Figure B.2.2. Well spacing at individual sites.

Conclusions

The concept of purchasing irrigation permits on the EVA is actually quite simple. One could reasonably expect to convert the larger 2,363 ac-ft of irrigation water given enough lead time to begin the process and acquire water rights as ownership of the land changes and the economics of irrigation agriculture evolve. This supply feature has the added benefit of being able to phase in the wellfield as needed rather than building it all before the full demand is realized. While determining compensation for current permit holders to relinquish their water rights may constitute the major hurdle in developing this source of water, changes over time could allow it to be developed for the benefit of Grand Forks and GFTWD.

B.2.2 –Groundwater Supply for Wahpeton Industrial Demand

Purpose

The city of Wahpeton and its industries currently rely upon surface water in the Red River and groundwater resources of the Wahpeton Buried Valley Aquifer. The projected water demands for future industries in the city of Wahpeton exceed the combined capacity of surface and groundwater. This implies that water sources must be developed in other areas to support future economic growth in the Wahpeton area.

Demands

Two different demands for the industrial shortages were developed for use in Reclamation's modeling effort. The lower Scenario One results in an industrial shortage of 5,330 ac-ft per year with the higher Scenario Two around 8,516 ac-ft per year. Some of this demand can, and will, be met using surface water in times of plenty. However, this will be a junior appropriation permit and when surface water becomes scarce the industry will be forced to rely on groundwater. The breakdown for peak demands, annualized withdrawals, and average withdrawals from groundwater are shown in table B.2.1. Projected demand for the Wahpeton industry is simply the modeled demand put into the surface water model for Reclamation. Some of this demand will be met via surface water supplies and that portion of the demand that can not be met with surface water becomes a shortage, or demand on the groundwater.

Table B.2.1. Theoretical Groundwater Use by Wahpeton Industry, 1931-2001.

Demand Scenario	Total Projected Demand for industry (ac-ft/yr)	Maximum Month ac-ft	Lowest 1-yr use of Groundwater During 1930s Drought (ac-ft)	Highest 1-yr use of Groundwater During 1930s Drought (ac-ft)	Total use of Groundwater During 1930s Style Drought (ac-ft)	71 year Average Use of Groundwater (ac-ft)	71 year total Use of Groundwater (ac-ft)
One	5,814	512	3,739	5,330	46,150	758	53,818
Two	8,556	745	5,676	8,516	71,778	1,350	95,850

As the 71 year average shows, the majority of groundwater used in both scenarios is consumed during a prolonged drought. Only an occasional outlying year requires groundwater as a supplement although some minimum use for maintenance purposes should be expected. The intensity of the 1931-1940 drought is also revealed in table B.2.1. While the aquifer may receive little demand during the remaining 61 years, the 10 year drought scenario experienced during the 1930s could lower the water table around a wellfield enough to create capture problems for existing users. This interference could be minimized by maintaining a sufficient distance between the wellfield and shallow domestic wells.

Potential Sources of Water

There are aquifers in southeastern North Dakota that can serve as groundwater sources for the identified shortages. The most likely candidates are the Sheyenne Delta, Hankinson, Milnor Channel, Sonora, and Brightwood Aquifers. In general, these aquifers are a complex series of individual aquifers that are in close proximity to each other. Somewhat interconnected, they may exchange water between adjacent units on a limited basis. These and other aquifers of the Red River Valley are discussed in great detail within Chapter 3 of the Needs and Options Report.

Other Aquifers
Several other aquifers exist in southeastern North Dakota. Examples of these are the Wahpeton Buried Valley, Wahpeton Sand Plain, Colfax, Fairmount, and Dakota Aquifers. The two Wahpeton aquifers are already permitted to capacity and the remaining aquifers have very limited value due to insufficient permeability for high capacity wells.

Recommended Wellfield Development
A wellfield capable of fulfilling the identified industrial needs of Wahpeton in table B.2.1 can be developed using primarily the Brightwood and Spiritwood Aquifers with satellite wells in the Gwinner and Milnor Channel Aquifers.

The higher Scenario Two demand is used for initial calculations and any future lessening of this demand will allow for simple reduction in the capacity and hypothetical footprint of the proposed wellfield. All proposed well locations were based upon existing lithologic information available within the North Dakota State Water Commission's online database and very little information was available on the actual productivity of the sands and gravels in many of the areas.

The maximum month water demand shown for Scenario Two in table B.2.1 is 745 ac-ft. In order to meet this demand, a total of 30 wells will be required. All of the wells must be capable of producing a minimum of 250 gpm on average.

Figure B.2.3 depicts the most current description of the Brightwood Aquifer as defined by the North Dakota State Water Commission. Figure B.2.3 also provides approximate locations for individual wells based upon the lithologic information available. Extensive field investigations would be required to properly site each well within the general area. Since this wellfield must be reliable during a sustained 10 year drought event, all wells must fully penetrate the aquifer to maximize their ability to capture water. For this reason figure B.2.4 is provided to show estimates for maximum well depth in given areas to fully penetrate the lower sands and gravels documented in well logs for wells in this same area.

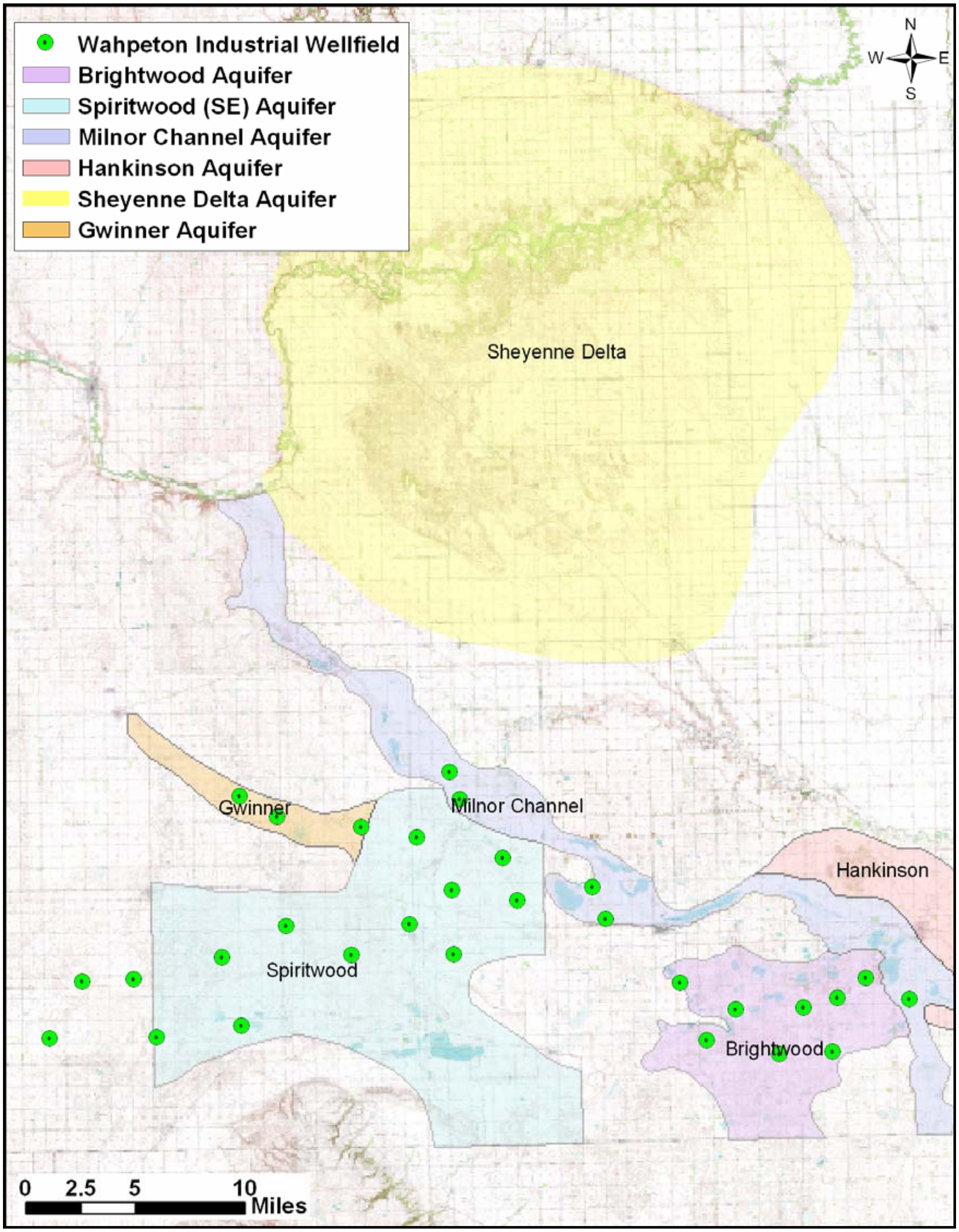


Figure B.2.3. Map of proposed wellfield and associated aquifers.

Note: Shapefiles of aquifer definitions were provided by the North Dakota State Water Commission.

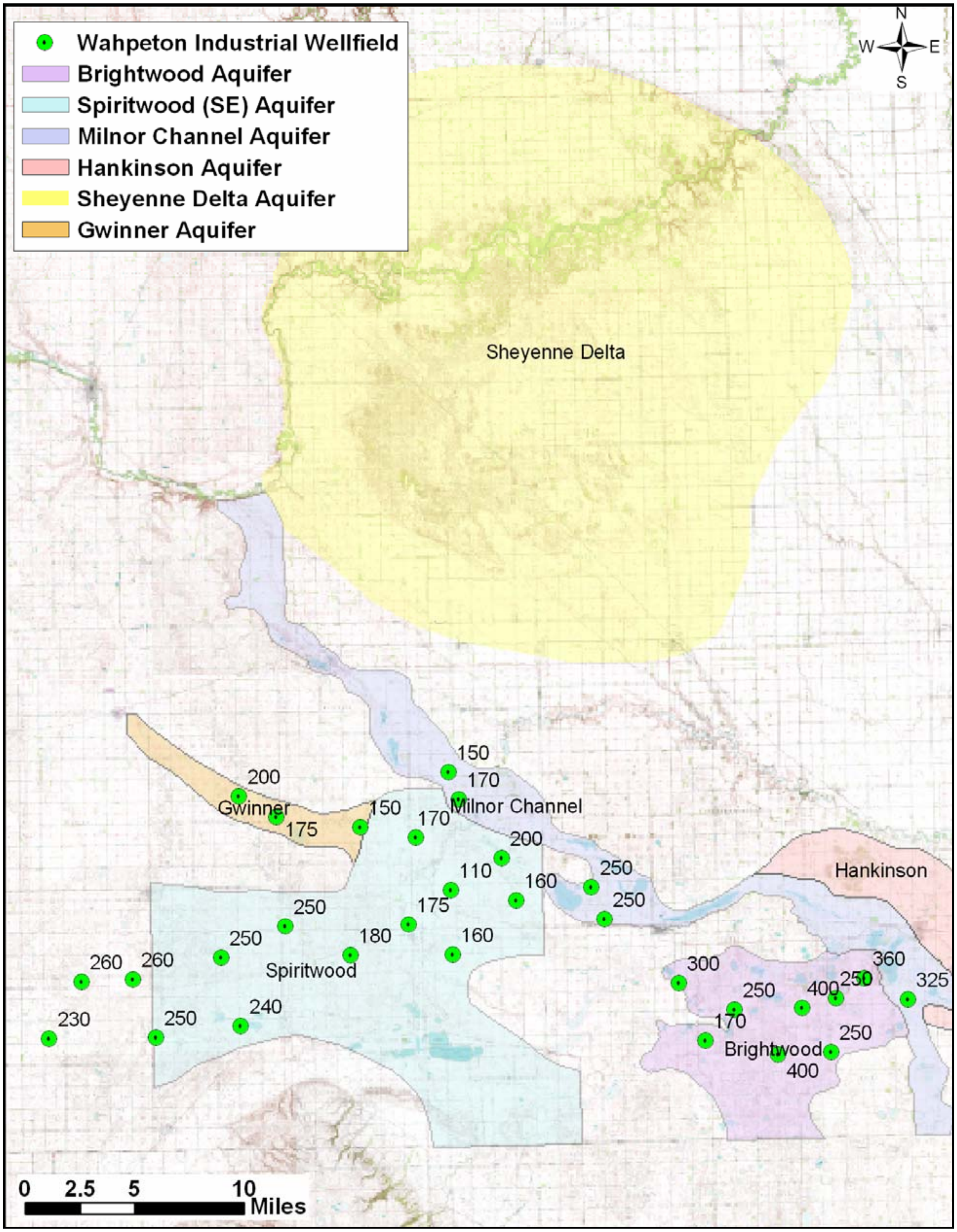


Figure B.2.4. Estimated well depths for fully penetrating the aquifer.

Conclusions

Given the broad range in demand scenarios, it would initially seem reasonable to contemplate two wellfields of similar geographic scope. However, given the anticipated heavy use of the aquifers and that the majority of the cost associated with this feature is in the conveyance pipeline, it may be more conservative to simply use the same wellfield pattern. This would reduce the drawdown within the wellfield if the lesser demand of Scenario One materializes. Using the demands as shown in table B.2.1, the individual well requirements can be determined as shown below in table B.2.2.

Table B.2.2. Requirements for Individual Wells, Permits, and Aquifer Yields.

Demand Scenario	Maximum Annual Withdrawal From Each Well (ac-ft/yr)	Maximum Withdrawal in One Month (ac-ft)	Lowest 1-yr Use During 1930s Drought (ac-ft)	Highest 1-yr Use During 1930s Drought (ac-ft)	Total Use During 1930s Drought (ac-ft)	71 Year Average Use (ac-ft)	71 Year Total Use (ac-ft)
One	177.7	17.1	124.6	177.7	1,538.3	25.3	1,794
Two	283.9	24.8	189.2	283.9	2,392.6	45.0	3,195

The effect of the modeled 10 year drought may be considerable on static water levels in the short-term. However, the 71 year average suggests that the long-term implications of a 10 year drought would be mitigated by many years of either little or no use. This implies that the long-term viability of the groundwater supply for Wahpeton would be largely dependent upon protection of the groundwater resource in the years preceding a drought.

B.2.3 – Aquifer Storage and Recovery Prospects for the Moorhead and West Fargo Aquifers

Purpose

The intent of this section is to present the available information on the Moorhead Aquifer and West Fargo North Aquifer (WFN) with respect to aquifer storage and recovery (ASR). The city of Moorhead currently maintains a municipal wellfield just north of Highway 10 on the eastern edge of the Moorhead Aquifer. Similarly, the city of West Fargo maintains a wellfield on the WFN. Since these aquifers do not have a direct connection to the surface that allows for infiltration of precipitation, both aquifers are undergoing long-term depletion of water stored within them. Cliff McLain, Water Division Manager for the Moorhead Public Service has expressed an interest in storing one billion gallons of water within the Moorhead Aquifer as drought contingency and a means of mitigating the significant decrease in water levels noted within the Moorhead’s municipal wells (McLain 2003). Similarly, the WFN has provided the city and industries of West Fargo with water since the early 1900s. For the WFN to continue indefinitely as a steady source of water for the city, it must either receive ASR or have dramatically curtailed use.

After the known information is presented, a reasonably conservative estimate on the amount of ASR and system criteria is given for scale and inclusion as a water supply feature.

Principles of Aquifer Storage and Recovery

Conceptually, ASR involves the injection of water into a highly permeable subsurface geologic feature for later extraction, often from the same well. Research and implementation of ASR projects continue to gain momentum as regional and local aquifers are tapped for water in excess of natural recharge. Generally speaking, physical and geochemical parameters for an ASR system may be the most technologically challenging pieces of the overall puzzle; however, other difficult aspects of ASR include regulatory requirements and the establishment of rights to the stored water which are not addressed within the content of this document.

Physical parameters for an ASR system must include estimates for the volume of water that can reasonably be stored and recovered. Obtaining good estimates for the physical parameters requires extensive field data on lithology, permeability, and current water levels. In lieu of extensive data collection, the available literature was reviewed for conceptual planning of the system requirements and technical feasibility. Additional field data collection and analysis would be required to verify and refine assumptions prior to pilot-scale tests of the aquifer response to ASR.

Geochemical characteristics of an aquifer affect the dissolved constituents in groundwater. Under natural recharge conditions, recharge to shallow aquifers has a geologically recent connection to rainfall. As water percolates down through the soils and aquifer medium, its chemical composition evolves as it seeks geochemical equilibrium with the mineralogy of the aquifer medium. Water entering the aquifer in an ASR system will often have a different geochemical signature than the native groundwater in the area. Adequate geochemical modeling must be undertaken to determine if the mixing of ASR water and native groundwater will lead to adverse chemical reactions. One problem associated with ASR is the formation of chemical precipitates that affect the permeability of the aquifer and the resultant water quality, potentially with respect to SDWA regulated trace elements such as arsenic.

State and federal regulations typically govern ASR with existing statutes and this can result in a non-typical permit application process. On the federal level, injection wells are governed by the Underground Injection Control (UIC) program of the SDWA. However, the North Dakota Department of Health administers the program for the USEPA. As such, ASR wells fall under the Class V well regulations because they are not specifically listed in the Class I, II, III, or IV descriptions. In general, only potable waters are eligible for injection into underground drinking water supplies. Typical treatment issues of concern include pathogens, trace metals, organic carbon, suspended solids, and disinfection by-products. Potential amendment of the treated water to meet geochemical compatibility with native groundwater and injection water treatment costs may actually exceed treatment costs for municipal supply. For further reading on ASR regulatory approaches, Shrier and Miller (2002) provide an overview of current regulatory approaches for ASR operations.

Moorhead Aquifer Storage and Recovery

Geologic Setting

The Moorhead Aquifer is an elongated feature with a north-south axis underlying the city of Moorhead, Minnesota. Well logs available in the County Well Index from the Minnesota Geological Survey (MGS 1998) show the eastern and western boundaries to be relatively abrupt in the center of the aquifer just north of I-94. However, the northern and southern boundaries are ill-defined and appear to grade into thin alternating layers of clay, sandy clay, and sand. At least one researcher (Ripley 2000) believes the Moorhead Aquifer is best described as a pair of poorly connected aquifers and references them accordingly as East Moorhead and West Moorhead, respectively.

Glacial Lake Agassiz once encompassed the area and is responsible for the lack of relief and the thick clayey deposits that reach to depths of 100 ft. At depth, alternating layers of clay, sandy clay, and sand are probably the result of glacial meltwater streams that preceded Glacial Lake Agassiz leaving meandering channels and associated deposits resulting in this division of the Moorhead Aquifer into an east and west response unit. Of interest are several references to shale layers within the geologic description of several well logs.

The description of a shale layer, or layers, in several well logs of the Moorhead Aquifer is difficult to interpret in the context of a sedimentary Quaternary stratigraphic sequence. The most logical explanation for shallow deposits (about 200 ft or less) being described as shale is driller misinterpretation of hard clay as shale. Another possibility would be detrital shale deposited by the same processes that resulted in the deposition of adjacent sand and gravel layers. Coherent shale layers may be present at depth and would be consistent with the overall stratigraphic sequence of the region and constitute a layer of significantly reduced permeability. More descriptive work on the Moorhead Aquifer is unavailable, but a nearby aquifer system probably of similar age, stratigraphy, and depositional setting is the West Fargo Aquifer System as described by Ripley (2000).

Aquifer Stratigraphy

Well logs for Moorhead municipal well number 6B describe a stratigraphic sequence of clay and sandy clay from the surface to 168 ft, then grading from fine sand to coarse sand and fine gravel to a depth of 266 ft. Clay extends from 266 ft to at least 280 ft below grade and forms the lower confining layer within the local area (MPS 2003). Overall, this area appears to be a textbook example of a confined aquifer.

The graded sand to gravel stratigraphic sequence from 168 ft to 266 ft represents the water producing interval of the aquifer with the well screen placed from 233 to 266 ft. Given the amount of water removed from the aquifer for municipal use since 1913, it must be assumed that this section of the aquifer is hydraulically connected to progressively thinner layers of sand and gravel at distance from the wellfield. No description exists for this connection and, if this is some variant of stream deposits it would be complex at best.

The Minnesota Department of Health delineated a Wellhead Protection Area (WHPA) in 2000 for current municipal wells numbered 6 and 6B (MDH 2000) using a travel time of 20 years, see figure B.2.5. The wellhead protection plan describes the aquifer as 65 ft thick with a transmissivity of 19,536 ft^2/day. Data from a 1987 pump test showed the static water table at 187 ft and the lower confining unit at 266 ft, producing a total aquifer thickness of 79 ft (MPS, 2003). At present it is unclear if there has been this much drawdown in the Moorhead Aquifer as is suggested by the conflicting data, or if simplifying assumptions and data interpretation resulted in this transmissivity value. Regardless, this value for transmissivity sufficiently describes a typical coarse sand and small gravel aquifer (Halford and Kuniansky 2002) that should be representative of the area immediately around the test site.

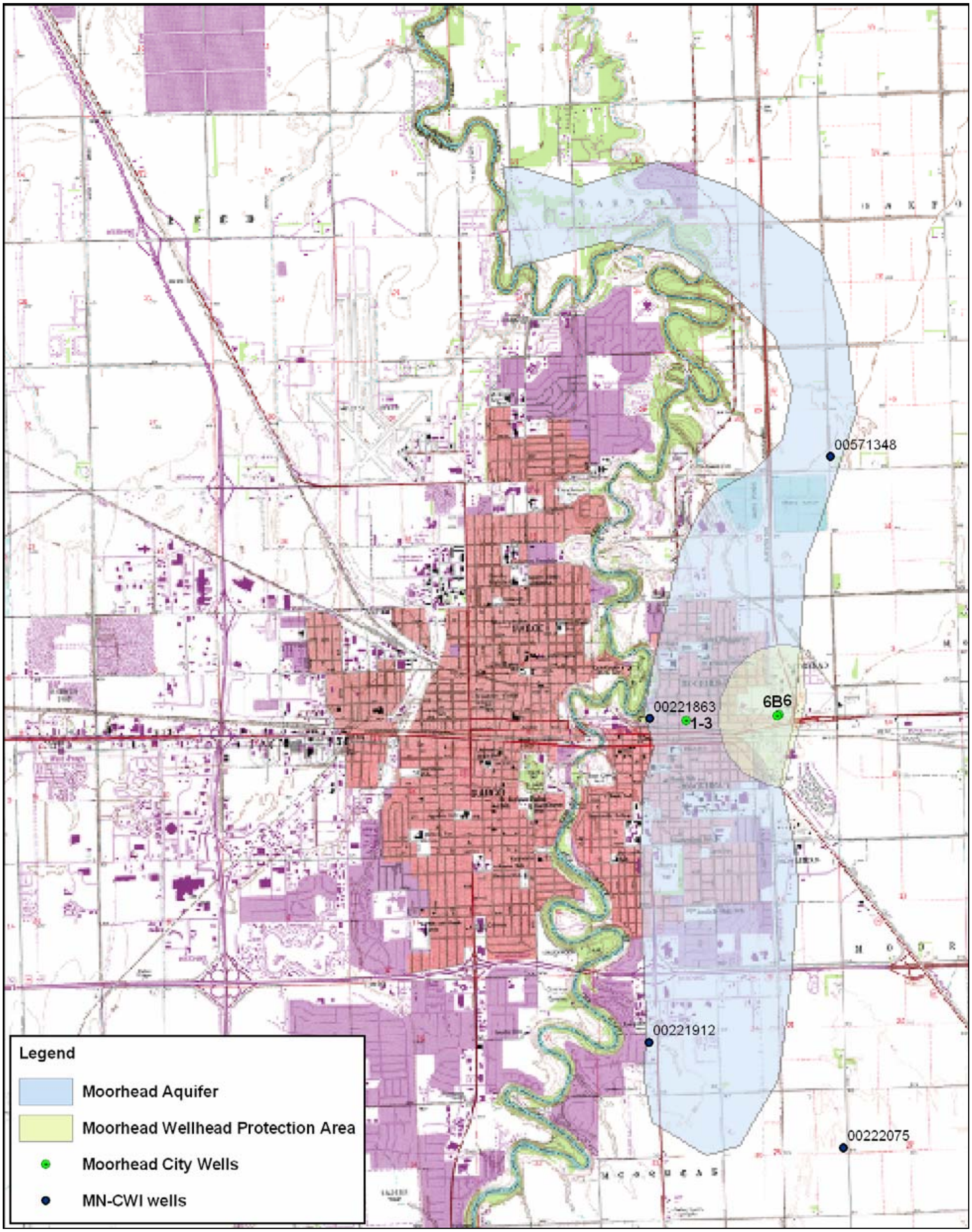


Figure B.2.5. Map depicting the Moorhead Aquifer and relevant features.

Note: Shapefiles of the Moorhead Aquifer and Wellhead Protection Area (WHPA) were provided courtesy of the Minnesota Department of Health.

Natural Recharge

Two lines of evidence support a conclusion of negligible natural recharge to the highly productive sand and gravel deposits. The thick overlying clay presents a considerable physical barrier to infiltration. A second line of evidence for lack of recent recharge is the lack of detectable tritium in a 1997 water sample collected from Moorhead's well number 6B (MDH 2000). Tritium (^{3}H) is a radioactive isotope of hydrogen released during atmospheric testing of hydrogen bombs. This testing began in 1953 and tritium levels below one tritium unit generally represents groundwater with origins older than 1953.

Water Quality

Little information is available on the water quality of the Moorhead Aquifer. Mixing of the aquifer water with surface water from the Red River and water from the Buffalo Aquifer leads to more emphasis being placed on the quality of the final product. Some approximate values of a few water quality indicators for the Moorhead Aquifer are: alkalinity, 270 mg/L as $CaCO_3$; hardness, 180 mg/L as $CaCO_3$; pH of 7.8; and conductivity approaching 1000 μs (McLain 2004).

Historical and Operational Use of the Moorhead Aquifer

The city of Moorhead installed its first wells into the Moorhead Aquifer in 1913 and averaged about 100 million gallons of water per year from the original wellfield. By 1930, a second wellfield was established to the east of the original wellfield. Annual withdrawals peaked in 1948 at 450 million gallons and have averaged 150 million gallons to present. Municipal withdrawals from the aquifer represent the vast majority of withdrawals and total in excess of 13 billion gallons of water. Non-municipal withdrawals such as the Fairmont Creamery wells (unique ID# 221863), do exist with little or no available historical records. Assessment of these domestic and industrial uses would require detailed record searches and assumptions that are outside the scope of this work. Thus, the total historical withdrawals can be estimated at 14.5 billion gallons (44,500 ac-ft) of water to allow for non-documented withdrawals. With no change in management philosophy, future municipal withdrawals are expected to average 100 million gallons a year for treatment and temperature considerations (McLain 2003), far less than the permit allocation of 225 million gallons per year. This is also notably less than the historical average and reflects growing concern over aquifer depletion and the importance of this aquifer in times of drought.

Water Levels

The potentiometric surface of the Moorhead Aquifer was only 6 ft below grade when first measured at the original 12th Street wellfield in 1913, site of wells 1-3. It can be inferred that the potentiometric surface of the aquifer was in relative equilibrium with the regional potentiometric surface to the east and discharged to the Red River in the west during the initial stage of aquifer development. This artesian pressure dropped significantly over time to where the aquifer is no longer artesian in the current wellfield area. Worth mentioning here is upon completion of the first well at the 22nd Street wellfield, the potentiometric surface of the aquifer had already lowered by an estimated 80 ft. While this certainly shows some connectivity between the 12th Street and 22nd Street locations, a somewhat circuitous connection or lower permeability barrier must exist to explain the lack of an even greater drawdown.

The aquifer also appears to reflect the pumping effects away from the municipal wellfield. In 1965, water levels for a new well (#221912) were recorded at 50 ft below grade. This site is 2.75 miles south by southwest from the 22nd Street wellfield. About 3.5 miles south by southeast of the wellfield (well #222075), water levels were recorded at about 47 ft below grade in 1964. By 1997, the reported water level in new well #571348 was 97 ft below grade about 2.1 miles north by northeast of the municipal wellfield. And as late as 1996, the potentiometric surface 1.8 miles northeast of the municipal wellfield was measured at 166 ft below grade. This demonstrates an apparent hydraulic connection to deep confined units at a distance.

Interestingly, this apparent decrease in artesian head surrounding the existing wellfield did not result in the loss of artesian conditions at any of the above mentioned sites. While similar decreases in the potentiometric surface are suspected at even greater distances, the lack of stratigraphic information makes the hydraulic connections less evident given increased distance from the municipal wellfield.

In reality, aquifer depletion has apparently resulted in only the water levels at the 12th and 22nd Street wellfields reaching unconfined conditions, at times about 20 ft below the upper confining layer. Figure B.2.6 graphically represents when the drawdown within the municipal wellfield resulted in unconfined conditions. Withdrawal rates appear to influence “static” water level measurements taken when looking at the spike of the late 1940s. This suggests some form of boundary condition that restricted the rate at which water from a distance reaches the wellfield to about 100 million gallons annually without significant annual drawdown until the early 1970s. From the 1970s to the mid-1990s, consistent withdrawals of 100-200 million gallons of water each year resulted in lower annual water levels that the aquifer no longer appears to support without long-term drawdown. Since 1998, lower aquifer withdrawals of about 60 million gallons per year have resulted in 5-6 ft of recovery, but this remains well below the desired production from this wellfield.

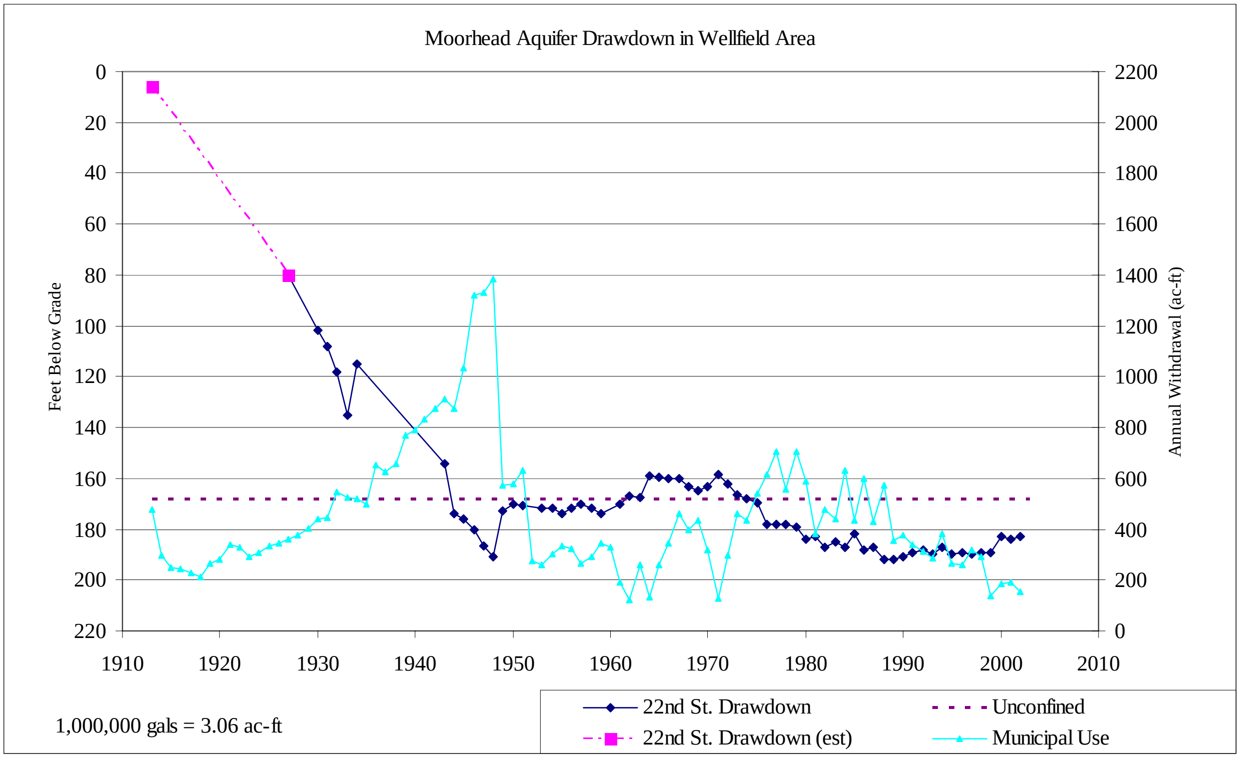


Figure B.2.6. Observed drawdown in the Moorhead municipal wellfield.

Confined Aquifer Storage

Water removed from a confined aquifer comes from the compressibility of the aquifer matrix and expansion of water as a result of decreased pressure. Of these two sources of water, the amount of water available from water expansion is orders of magnitude smaller in relation to that due to compressibility of the aquifer matrix in unconsolidated sand and gravel aquifers. Therefore, the component of confined storage due to expansion of water is ignored in the calculation of specific storage. Specific storage (S_s) is defined as the amount of water taken into or released from storage per unit volume of aquifer per unit decline in head. Confined aquifer storativity (S) is the product of specific storage (S_s) and aquifer thickness (b). Typical values for storativity (S) range from $5E^{-3}$ to $5E^{-5}$ in confined aquifers (Freeze and Cherry 1979).

The basic equation for calculating the volume of water taken into or released from confined storage is:

$$V_w = SA(dh) \qquad \text{Equation 1}$$

Where:

V_w (L^3)= Volume of water in confined storage.

S (dimensionless) = storativity = volume of water an aquifer takes into or releases from storage per unit surface area of the aquifer per unit change in head. [S = (Ss) (b)]

A (L^2) = 9 mi^2 = Area of aquifer.

The Moorhead Aquifer is believed to have a N-S axis with the Moorhead municipal wells about in the middle of the suggested north and south boundaries and relatively close to the eastern low flow boundary. This relatively coarse description provided in the WHPA plan (MDH 2000) may not sufficiently describe the lateral extent of the Moorhead Aquifer.

dh (L) = Change in head.

For confined conditions it is designated as lower edge of the upper confining unit (168 ft) minus the original static water level (6 ft) = 162 ft.

However, using the rough boundaries for the Moorhead Aquifer, surface area for the aquifer would equal no more than nine square miles (MDH 2000). If the aquifer encompasses an area of nine square miles (5,760 acres) and receives negligible recharge, it is possible to mathematically describe the historical drawdown in such a theoretical aquifer.

Known Characteristics:
Lithology = Fine sand grading to fine gravel, the unsaturated portion described in the wellfield is primarily fine-medium grain sand.
Saturated thickness (2003) = 84 ft
Unsaturated thickness (2003) = 14 ft at wellfield

Assumed Characteristics:
Lithology as described extends to a sufficient distance that time of travel is more of a consideration than change in lithology.
Storativity = 0.0025 to 0.005
Observed drawdown.

Drawdown extends outward in a semi-radial fashion to a distance of 1.5 miles, this is estimated by assuming the aquifer had a relatively uniform potentiometric surface in 1913 at six feet below grade. Then when we look at the development of the 22nd Street wellfield, wells 4-6B, its potentiometric surface had already been lowered to 80 ft below grade by 1927. The 12th Street potentiometric surface is estimated to have been around 115 ft below grade in 1927. The last concurrent water level recordings for the two sites measured was in 1948 where the 12th Street wellfield was 197 ft below grade and the 22nd Street wellfield at 190.8 ft. This evidence suggests a fair hydraulic connection from the 12th Street site to the 22nd Street site, a distance of about 4,000 ft. However, when going east of the 22nd Street site about 3,000 ft, the lithology shows a very high degree of variability with only thin stratigraphic sections of water bearing sands or gravel. This would suggest any hydraulic connection in the east to the sand and gravel aquifer at the 22nd Street site to be far more complex than a single meandering channel.

Based on the above, the volume of water removed from confined storage is calculated using equation 1:

V_w = SA(dh)
V_w = 0.005 x 5760 acres x 162 ft.
V_w = 4666 ac-ft of water in a highly compressible aquifer.
V_w = 0.00005 x 5760 acres x 162 ft.
V_w = 46.6 ac-ft of water in a relatively incompressible aquifer.

The purpose of the above exercise is to demonstrate the maximum and minimum amounts of water that could be released from storage in the aquifer as the artesian head decreases to zero at the lower edge of the upper confining unit. Once the artesian head reaches zero, the aquifer will begin to act as an unconfined aquifer and result in drainage from local pore spaces.

It is unlikely that the aquifer could be adequately described using either extreme for storativity over its entirety. However, the fine sand described as being present in parts of the aquifer would tend to have a higher susceptibility to compaction. This leads to the assumption that storativity for the Moorhead Aquifer is closer to the upper end of the spectrum, perhaps as high as 0.0025. Using a value of 0.0025, the aquifer could release about 2,300 ac-ft of water from confined storage. This constitutes about 5% of the total water removed from the aquifer and even doubling the size of the aquifer would not make confined storage a major source of water withdrawn from the aquifer. Recharge has already been discussed as negligible and this suggests the vast majority, about 95%, of water removed from the aquifer results from drainage of the water stored in hydraulically connected pore spaces (unconfined storage).

Unconfined Aquifer Storage

What remains to be discussed is the potential volume that may be placed into storage and successfully recovered. The earlier discussion of drawdown suggests that only a limited area around the municipal wellfield possesses an unsaturated zone available for ASR. Once the potentiometric surface of a confined aquifer has been lowered to the permeable sands and gravels below the upper confining unit, the aquifer starts to behave as an unconfined aquifer with water beginning to drain from the pore spaces. Drainage from unconfined conditions can be described by the specific yield of the aquifer. The stratigraphy immediately below the upper confining unit is described as fine grained sand (MPS 2003). Although it would be unrealistic to expect this fine grained sand to extend indefinitely, it is a reasonable description for the immediate area. Fine grained sands have S_y values of 0.01 - 0.46 with an average of 0.33; as a comparison, 0.13 - 0.40 is an established range for fine gravel with an average of 0.28 (Dingman 1994). Water removed from drainage due to S_y can be calculated via:

$$V_w = A \text{ x } b \text{ x } S_y \qquad \text{Equation 2}$$

Where:
A (L^2) = Area
b (L) = Thickness

Given the amount of water removed from the aquifer over the years, it would be difficult to justify that all drainage from storage is from the immediate wellfield area. The observed drawdown of the wellfield to unconfined conditions does not appear to exceed a radius of 1.5 miles in any direction. Using a generous boundary of confined/unconfined conditions extending in a semi-radial fashion to about 1.25 miles north and south of the municipal wellfield will provide an unconfined aquifer area of about 2.5 square miles, or 1,600 acres. This unsaturated zone could also be assumed to have a maximum thickness of about 20 ft at the wellfield and progressively thin towards the edge of the radial drawdown. Given the cone shaped drawdown effect of a well and the uncertainty concerning the stratigraphy, an average unsaturated thickness of about eight ft should be reasonable. This gives a total volume of unsaturated aquifer being about 12,800 ac-ft. Using an average S_y of 0.30, only about 3,840 ac-ft of available unconfined storage exists in the immediate area around the Moorhead municipal wellfield. Even if the entire aquifer had eight ft of unsaturated thickness, the assumed nine square mile aquifer would only possess about 13,800 ac-ft of unsaturated storage. This number leaves a significant portion of the 44,500 ac-ft withdrawn from the aquifer unaccounted for in terms of storage. It is possible that drainage of the saturated clays overlying the aquifer may have served as the source for some the previously unaccounted for withdrawals. However, it is more likely that much of this unaccounted for water came from storage outside of the earlier physical description of the Moorhead Aquifer. In this scenario, a considerable amount of water may still exist in storage, but remains time restricted in travel to the existing wellfield through areas of low permeability or longer routes of travel.

Aquifer Storage and Recovery Prospects

The 3,840 ac-ft, 1.25 billion gallons, of unsaturated storage around the wellfield exceeds the desired volume of ASR expressed by Moorhead. The potentiometric surface at the extreme edges of the aquifer is still above the lower surface of the confining layer. Thus, the wellfield will realistically continue to receive groundwater flow towards the wellfield for the foreseeable future. However, as the potentiometric surface continues to decrease at the aquifer extremes, the amount of groundwater supplied to the wellfield will continue to decrease as predicted by Darcy's Law for groundwater flow. This decreasing trend in groundwater flow will likely not keep pace even with the trend of smaller annual withdrawals, much less the desired annual withdrawal of about 100 million gallons per year (306 ac-ft).

The groundwater flow into the wellfield appears to exceed 180 ac-ft per year, but remains less than 300 ac-ft per year and there is no indication of how long this type of contribution should be expected. Any ASR system put into this portion of the Moorhead Aquifer should have a very high efficiency for recovery of stored water. Quite simply put, the existing higher potentiometric surface on the aquifer boundaries and the lack of other exits from the system implies that any water placed into storage would be kept available in the long term. The complexity in devising an ASR scenario for this aquifer is one of balancing induced and natural inflows to the system with desired withdrawals and economics.

If the aquifer had no groundwater flow to the wellfield area, the minimum ASR required to supply the city with its desired 306 ac-ft of withdrawals per year and to keep the existing potentiometric surface would be something slightly above the desired 306 ac-ft per year. It would not be prudent to ignore the existing flow of water into the wellfield area. Therefore, it would be to build up the immediately available groundwater for use in times of drought. Similarly, it would be less practical to recharge water back into specific storage as this would require reversing groundwater flow out of the wellfield area and back into the farther reaches of the aquifer and may effectively lower the ASR efficiency. Table B.2.3 outlines the assumed net storage under differing annual operating conditions for ASR where the annual groundwater flow into the wellfield area holds constant at 180 ac-ft per year and annual withdrawals or efficiency losses average 724 ac-ft per year.

Table B.2.3. Water Balance for ASR in the Moorhead Aquifer (Using 1 cfs Withdrawal)

Recharge					Withdrawals	Net Effect	
Rate (cfs)	Recharge days per year	Volume Recharged (ft^3)	Volume Recharged (ac-ft)	*Total Water Supplied to Wellfield *(ac-ft)	**Annual Withdrawal (ac-ft)	Annual +/- (ac-ft)	10 yr gain/loss (ac-ft)
3.0	30	7,776,000	178.5	358.5	724	-365.5	-3654.9
3.0	60	15,552,000	357.0	537.0	724	-187.0	-1869.8
3.0	90	23,328,000	535.5	715.5	724	-8.5	-84.6
3.0	120	31,104,000	714.0	894.0	724	170.0	1700.5
3.0	160	41,472,000	952.1	1132.1	724	408.1	4080.7

* Includes volume recharged and 180 ac-ft of water that is assumed flowing into the wellfield area from adjacent areas with a higher potentiometric surface.
** Annual withdrawal is assumed to average 1.0 cfs over the course of a calendar year.

The Moorhead municipal wells have a pumping capacity of 800 gpm, but it is unclear as to what would be either a sustainable ASR rate in the same wells, or a maximum sustainable rate for withdrawal. Reduction in infiltration rates and unacceptable pumping pressures may require the use of more than one ASR well to implement any of the above scenarios. What can be surmised from the above table is that implementation of ASR for 30 days at 3.0 cfs will exceed recent historical use of the aquifer. Similarly, operational restraint on withdrawals and increasing the duration of recharge closer to 120 days per year allows greater net storage for use in times of sustained drought which is the desired goal.

Existing Conditions Summary

The one thing that is perfectly clear from the above work is that insufficient physical data on the Moorhead Aquifer exist to accurately describe the source(s) of the water withdrawn from the aquifer over the past 90 years. The lack of detectable tritium in the wellfield and the considerable thickness of the overlying clay layer suggest no significant recharge available in the immediate area to replenish long-term aquifer withdrawals. Drawdown and recovery cycles observed in the water levels suggest a limiting boundary condition that restricts water movement into the wellfield from distant portions of the aquifer and this scenario would require intensive fieldwork to verify and quantify. The apparent presence of an artesian potentiometric surface surrounding the wellfield implies the continuation of drainage into the wellfield from storage at distance. This higher potentiometric surface at distance serves as an effective barrier to permanent loss of ASR waters until such time where ASR recharge would overcome the surrounding higher potentiometric surface and result in reversed groundwater flow and losses to the aquifer itself. Given the total volume removed from the aquifer in the past 90 years, this should not be a limiting consideration.

The existing wells and wellfield have limited capacity for ASR and production based upon the described boundary conditions. However, even a limited ASR system could prove beneficial in replenishing some of the water removed over the past 90 years, provide a steady source of groundwater for treatment and temperature considerations, and reserve some of the existing water within the aquifer for use in time of drought.

Conceptual ASR for the Moorhead Aquifer

Several physical constraints apply to a conceptual ASR project for the Moorhead Aquifer. The first constraint that must be considered is the available void space for receiving ASR water. It has been demonstrated that a conservative estimate of 3,840 ac-ft of pore space exists for receiving ASR water. Realistically, this number is probably much greater. However, available void spaces would be at increasingly greater distances and history has shown that it took about 90 years for water drained from these distances to be supplied to the wellfield. The recharging of available pore space several miles from the wellfield would not necessarily be beneficial to the city of Moorhead as recovery of water from this distance would not be immediately available in times of drought.

The next constraint is the source water for recharge. The Red River would be used as the source water. Even during years of severe drought, spring flows typically far exceed demands allowing the withdrawal of 3.0 cfs from the Red River to be treated to meet regulatory and chemical compatibility requirements, and injected into the Moorhead Aquifer. The 3.0 cfs rate was chosen as a reasonable number for infrastructure development that would include three wells, the two existing well locations of Moorhead Public Service Utilities wells 6 and 6B, and one other well up to one half mile away.

The Reclamation hydrologic model incorporates a target level of 3,000 ac-ft of water to be recharged prior to a significant drought event. In order to accomplish this, MPS withdrawals from the aquifer must be kept lower than recharge values for a number of years in order to build the desired reserve capacity. Conceptually, this has been accomplished in the hydrologic model used for the Red River Water Supply Project. Once the initial 3,000 ac-ft are recharged, the model demonstrates that even during a 10 year drought equivalent to the 1930s drought enough ASR could be recharged in the spring to mitigate an increased load on the aquifer; see table B.2.4.

Table B.2.4. Water Balance for ASR in the Moorhead Aquifer (Modeled)

	North Dakota In-Basin Scenario One			North Dakota In-Basin Scenario Two		
Year	Recharge (ac-ft)	Withdrawal (ac-ft)	Net Change (ac-ft)	Recharge (ac-ft)	Withdrawal (ac-ft)	Net Change (ac-ft)
1931	0	60	-60	0	91	-91
1932	60	303	-243	91	303	-212
1933	303	60	243	179	60	119
1934	60	61	-1	179	61	118
1935	179	179	0	184	179	5
1936	61	365	-304	61	389	-328
1937	543	179	364	547	182	365
1938	0	0	0	23	0	23
1939	0	0	0	0	0	0
1940	0	0	0	20	69	-49
Totals	1206	1207	-1	1284	1334	-50

Note: None of the above includes previously discussed natural in-flows to the aquifer.

Conclusions

The stated purpose of ASR in the Moorhead Aquifer was to mitigate drawdown and provide storage for water to be used in a prolonged drought where surface water supplies become scarce.

Aquifer storage and recovery on the Moorhead Aquifer has no apparent physical hurdle that prevents a viable ASR system from being implemented with proper design and operation considerations. Insufficient detail on the geochemistry of the groundwater and the aquifer medium itself does not allow for adequate evaluation of the chemical compatibility of recharge waters and the Moorhead Aquifer. This information must be collected and evaluated in order to prevent undesirable chemical reactions that would deteriorate the utility of this resource as a water supply. However, as a confined system without natural recharge, risks associated with ASR may be preferential to simply doing nothing and watching the continued decline in water available from the aquifer.

Social and economic considerations may prove problematic, but these too should not prevent a well thought out system from serving as a water supply feature to the city of Moorhead.

West Fargo North Aquifer Storage and Recovery

Introduction

The West Fargo Aquifer System is best categorized as a loosely connected series of aquifer units that show varying degrees of connectivity to adjacent water bearing formations within the system. One unit, the West Fargo North Aquifer, provided the vast majority of water for the city of West Fargo prior to 1982. However, about half of the West Fargo municipal water supply has come from the West Fargo South Aquifer since 1984. For the time being, the city of West Fargo will continue to deplete the water held in storage by the WFN and increasingly grow dependent on use of the West Fargo South Aquifer (WFS). Since the WFN is one of the larger units and has undergone considerable development, it is one of the units under consideration for ASR. Successful implementation of an ASR system in the WFN could serve as a model for expanded ASR in other units of the system as they undergo further development and experience water level declines that endanger their usefulness. Figure B.2.7 provides one with a depiction of the WFN boundary and the geographic constraints overlying the aquifer.

Description of the West Fargo North Aquifer

Ripley (2000) provides a detailed description the physical characteristics and historical use of the West Fargo Aquifer system and readers are directed to view his work for specific details. However, the aquifer can generally be described as a very productive sand and gravel formation about 72 feet thick that is buried under an average of 120 feet of till, clay, and silt. Ripley (2000) describes the aquifer as having an areal extent of about 27 square miles and a volume of about 59 billion cubic feet. Using a specific yield of 0.25 implies that when full the aquifer should have about 310,000 ac-ft of water in storage, not including surrounding tills and poorly connected sand and gravel bodies. An important caveat here is that predicting how much of this water is actually available for withdrawal contains much more complexity and could be assumed to be about half of total in storage.

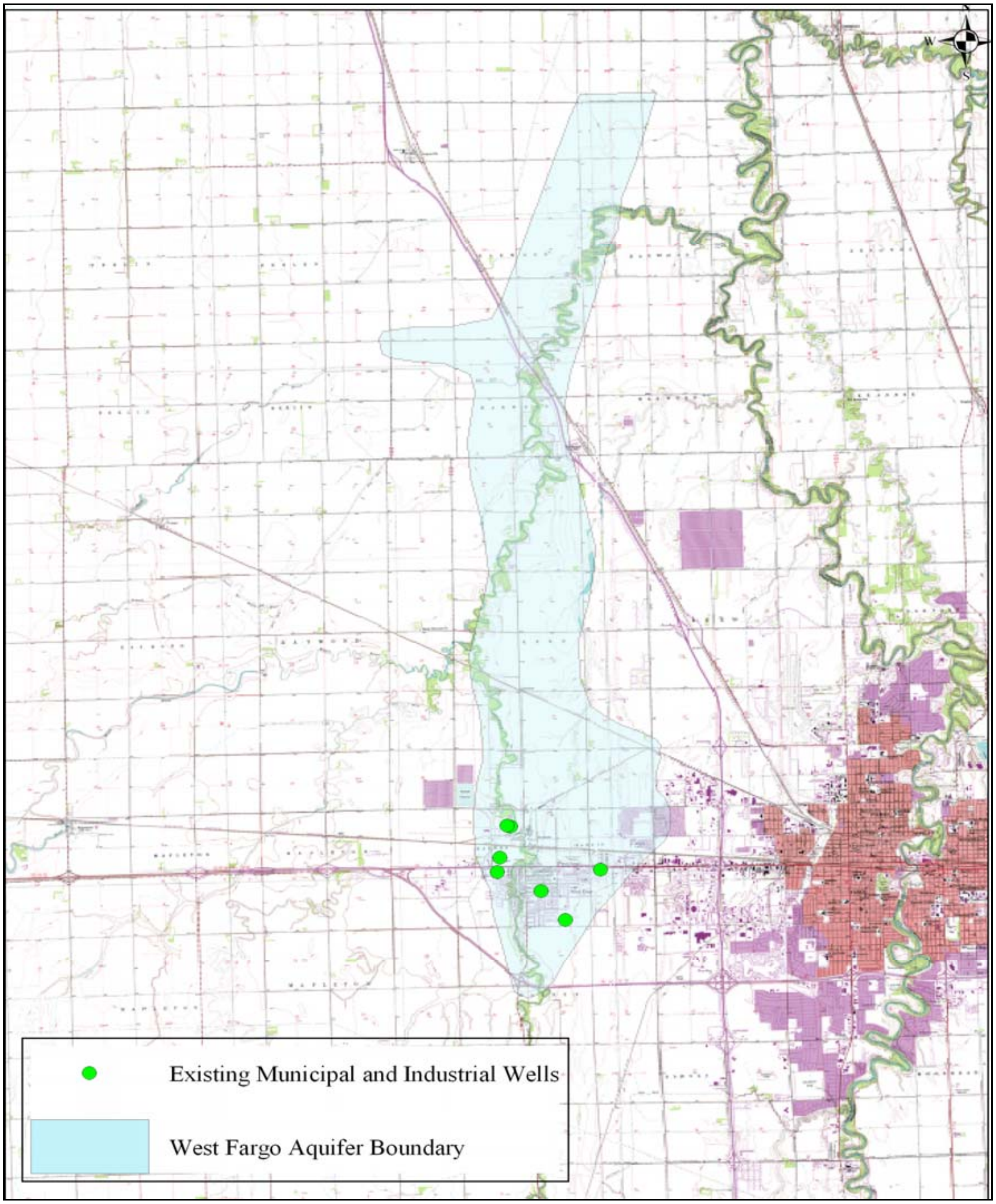


Figure B.2.7. Map showing the accepted boundary of the West Fargo North Aquifer and existing municipal and industrial wells of West Fargo.

Note: Shapefile of the West Fargo North Aquifer was provided by the N.D. State Water Commission with the existing well locations of the West Fargo Municipal system derived from their online database.

Aquifer Storage and Recovery Prospects for WFN

Much of the southern portion of the WFN has experienced water level declines to where the piezometric surface of the aquifer is no longer in contact with the lower surface of the confining unit. This makes this portion of the aquifer behave in an unconfined manner and creates a finite volume of pore space available for ASR purposes, see figure B.2.8. Even though the southern portion of the aquifer tends to be drawn down below the confining unit, the northern extent of the aquifer still provides artesian pressure. Even more importantly, the potentiometric surface appears to be 60 ft greater to the north than it is in the south. Accordingly, Darcy's Law predicts groundwater flow from the north will help replenish depletions in the south, albeit at ever decreasing amounts. The pattern of production wells in the south also help reveal what appears to be at least one zone, and potentially more, of lower hydraulic conductivity based upon the water table depressions. The lower zone(s) of hydraulic conductivity tend to slow drainage enough to be responsible for the presence of some artesian conditions within portions of the southern half of the aquifer.

Ripley (2000) estimates that 33 billion gallons of water (101,000 ac-ft) have been removed from the West Fargo Aquifer System prior to 1995. Simple extrapolation of the 1990-1995 withdrawal data provides another 8 billion gallons (25,000 ac-ft) of withdrawals from the system from 1996-2004, much of this from the WFN and WFS. A GIS analysis used available lithologic and water level data to arrive at an unsaturated volume of 79,600 ac-ft in the WFN (Reclamation 2004). Ripley (2000) used a specific yield value of 0.25 as an estimated average for the West Fargo Aquifer System. Employing this as an acceptable value for the WFN, a conservative estimate of about 19,900 ac-ft of pore space should be available in the WFN for use in an ASR system. These estimates essentially take a snapshot of the aquifer in time and do not take into account the complicating factors of lateral flow between aquifer units, drainage of surrounding aquitards, and possible leakage from underlying bedrock aquifers. The presence of some, or all of these, suggest that the WFN will continue to receive some inflow during the near future. It is impossible to calculate the rate at which any of these contribute to the WFN, but one certainty is that this rate will decrease over time as the surrounding water bearing formations dewater and undergo decreasing pressures.

The WFN tends to be a very permeable formation with transmissivity values between 5,900 and 16,000 feet squared per day with wells capable of producing at least 500 gallons per minute common in the areas drawn down to unconfined conditions. Given the available pore space and high permeability of the aquifer in the southern portion of the aquifer, a series of injection wells matched with recovery wells may be the best prospect for long term ASR.

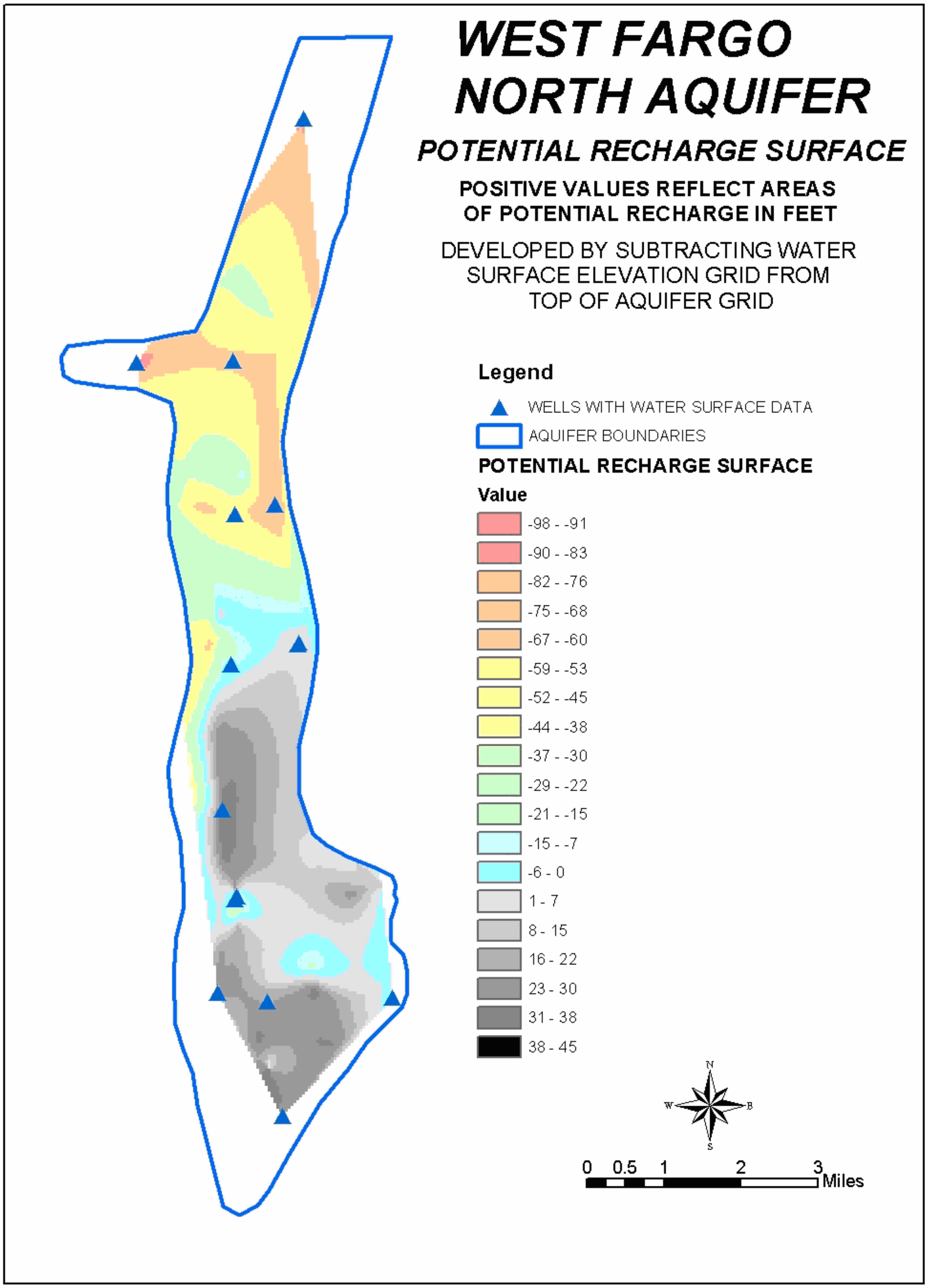


Figure B.2.8. Area of the West Fargo North Aquifer drawn down to unconfined status.

Note: The above figure is an excerpt from Reclamation (2004) where the positive values represent thickness of drained pore space between the water table and the confining unit. The graphical representation of drawdown was clipped to only represent the extent of available data although drawdown is assumed to extend farther towards the aquifer boundary in the southern portion.

Conceptual ASR for the West Fargo North Aquifer

Any aquifer storage and recovery project for the West Fargo North Aquifer will require a major overhaul of the existing regulations and infrastructure that exist for the aquifer. First and foremost, there is no guarantee that existing wells will be serviceable when an ASR system becomes operational. Thus, it is assumed that all existing wells will be redrilled, abandoned, or moved. This will help accommodate changes in the conditions of the aquifer and ever changing geographic constraints associated with the increasing urban development of the land surface. Another major concern is ownership of recharged water. Water placed into the aquifer has economic value and it would be difficult to justify the expense of an ASR system if non-participating entities are allowed to withdraw water from the aquifer.

Since recharge water will need to meet regulatory guidelines and chemical compatibility with the aquifer, it is assumed that water will be withdrawn from the Sheyenne River during times of surplus flow, treated to meet chemical compatibility, and injected into the aquifer. This provides two major constraints on the rate of recharge.

First constraint is that only surplus flows can be used for recharge. The importance of this lies in the assumption that this depends upon a junior water appropriation and all previously existing water users will have seniority over flows in the Sheyenne. The second constraint is probably even more important, namely water treatment plant capacity. Given existing population and industrial projections, West Fargo’s water treatment plant capacity will be for 15 cfs. The envisioned ASR project would allow for a 10 cfs recharge rate and a 10 cfs withdrawal rate with another 5 cfs in peaking capacity. In order to maintain such withdrawals in times of a drought, an ASR project must be in place to store water in the aquifer during times of plenty for use during the drought. However, surface water modeling performed by Reclamation suggests that as long as West Fargo maintains a surface water intake on the Sheyenne River, a maximum withdrawal from the WFN would be around 3,861 ac-ft of water during the worst year. During the same drought of a 1930s magnitude, the most water that could be recharged to the aquifer would be around 3,977 ac-ft in a given year, see table B.2.5. However, the net effect over the 10 year design period has dramatically larger withdrawals than what could be recharged. Clearly, this demonstrates the need to store excess water in the WFN for future use in order to prevent excessive lowering of the water table when surface water is more limited.

It would be best if ASR could be implemented as soon as possible to place between 8,000 and 15,000 ac-ft of water in storage. This water would need to be in excess of annual withdrawals and should be completed prior to the commencement of a significant drought. This could be accomplished by limiting withdrawals during times of plenty to simply peak demand and water quality issues, while recharging the aquifer as conditions allow.

Table B.2.5. Water Balance for ASR in the West Fargo North Aquifer.

	North Dakota In-Basin Scenario One			North Dakota In-Basin Scenario Two		
Year	Recharge (ac-ft)	Withdrawal (ac-ft)	Net Change (ac-ft)	Recharge (ac-ft)	Withdrawal (ac-ft)	Net Change (ac-ft)
1931	1,707	2,996	-1,289	1,139	3,097	-1,958
1932	2,176	2,797	-621	2,399	3,129	-730
1933	1,825	3,677	-1,852	1,825	3,804	-1,979
1934	1,210	3,635	-2,425	595	3,720	-3,125
1935	3,055	2,757	298	1,825	3,237	-1,412
1936	1,765	3,682	-1,917	1,210	4,168	-2,958
1937	2,042	3,785	-1,743	1,783	3,886	-2,103
1938	3,035	2,864	171	2,420	2,949	-529
1939	3,977	2,416	1,561	2,716	2,723	-7
1940	2,360	2,719	-359	2,360	2,820	-460
Totals	23,152	31,328	-8,176	18,272	33,533	-15,261

The physical layout for the WFN requires extensive reworking of the infrastructure in existence. Figure B.2.9 provides a general overview of the recommended spacing of the new ASR system and does not differentiate between replacement wells for existing sites shown in figure B.2.7 and additional wells. New well locations in figure B.2.9 are assumed accurate to within a quarter section to allow for geographic constraints and final site selection. All wells are expected to have the capacity for 500 gpm withdrawal and recharge. It is often easier to develop a well which will take 500 gpm in recharge than it is to develop a well with a production capacity of 500 gpm because a well’s production capacity is limited by gravity driven flow to the wellscreen, whereas it is possible to inject water under much greater pressures than gravity can provide. However, empirical evidence on ASR sites suggests that the efficiency of an injection well tends to decrease with time and successive attempts to redevelop the wells may not achieve original rates.

Given the concern expressed by the North Dakota State Water Commission over the uncertainty involved with the ability to place recharge water into the aquifer at the same rates as withdrawals from a single well, it is possible the sites shown in figure B.2.9 will actually contain multiple wells. A conceptual example of how this would be accomplished is shown in figure B.2.10. Even though it may be possible to inject water under increasingly greater pressure, gravity driven recharge may be considerably slower. To compensate for this and the phenomenon of water mounding, several wells at a designated site may prove beneficial to achieve desirable rates for recharge. Thus, figure B.2.10, is included to provide a rough estimate for well spacing at a particular well site.

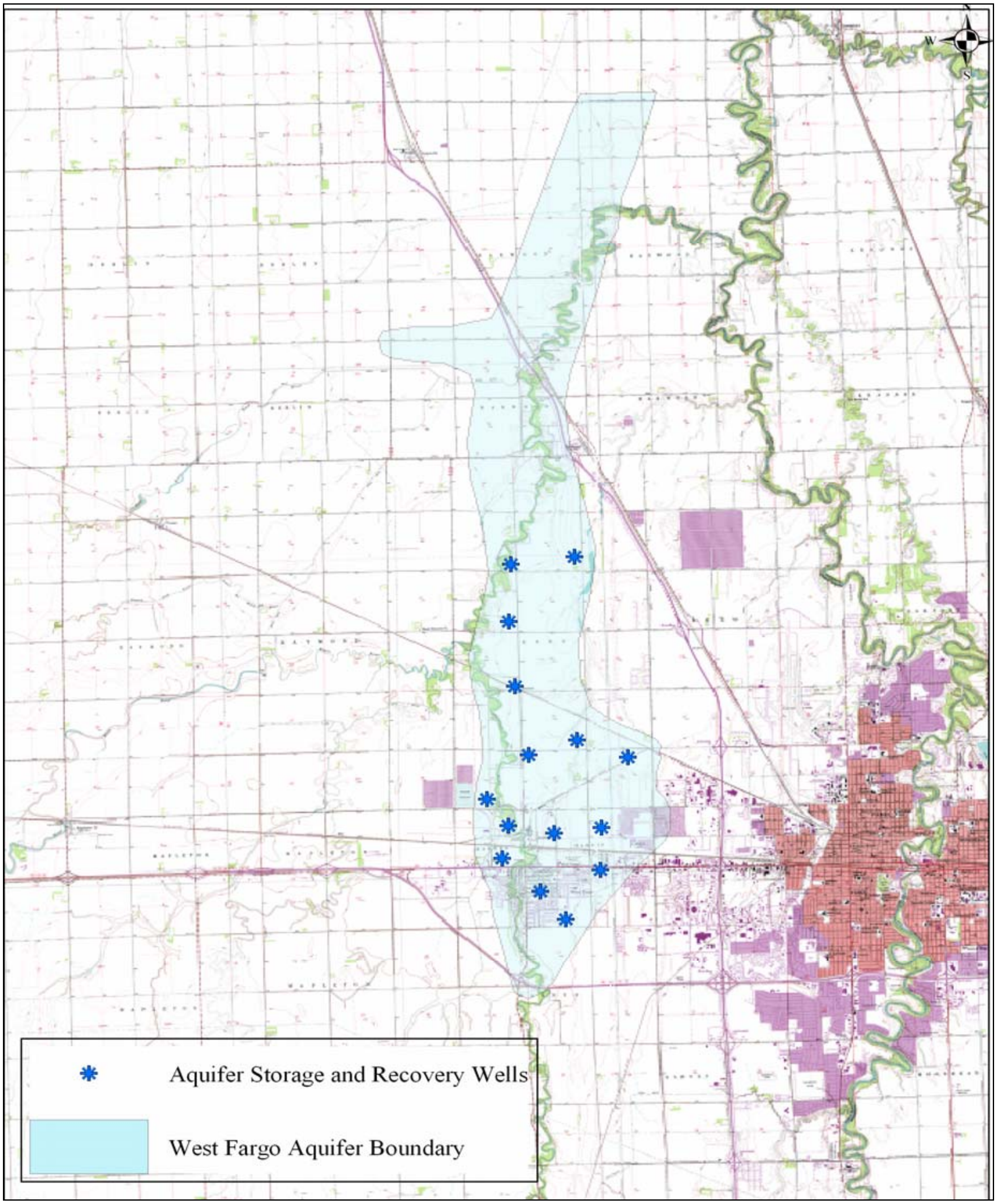


Figure B.2.9. Map of WFN and Associated ASR Well Sites.

Note: ASR wells shown above may contain more than one well per site.

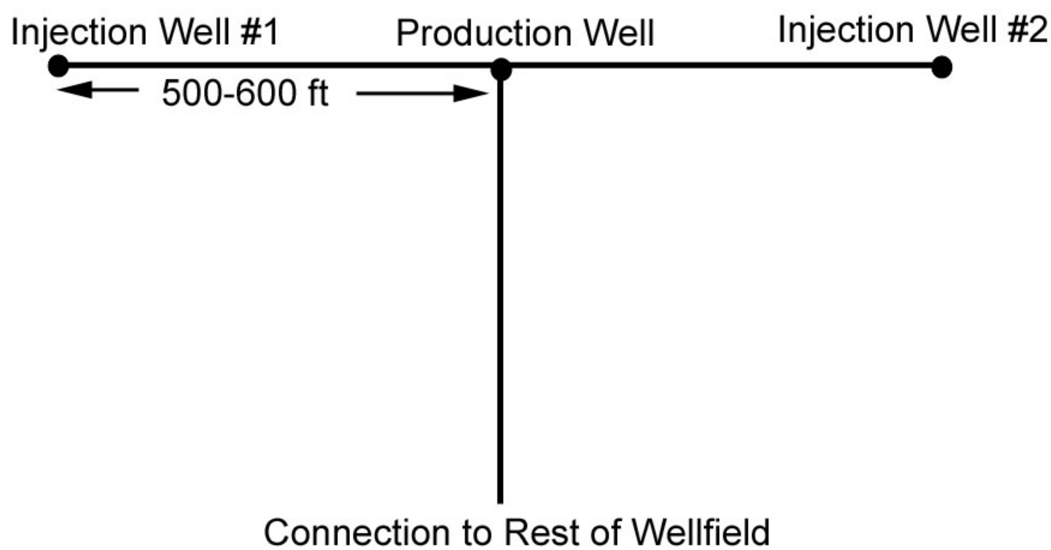


Figure B.2.10. Conceptual Spacing for Injection Wells at Specified Well Sites.

Using two wells dedicated to injection at a well site allows for more rapid injection of water at less pressure than would be required for a single well. A third well, the production well, would be centered between the injection wells and could even be a dual use well capable of both recharge and recovery. Using three wells at a site suggests that plans for ASR in the WFN may require up to 45 wells for full implementation of ASR.

Conclusions

The concept of ASR has become more broadly accepted as larger municipal and industrial systems explore the costs and benefits of ASR compared to more traditional water supply systems. Problems associated with geologic conditions, geochemistry, and economic considerations become more readily solved as work in this area continues. The Red River Valley has potential for ASR in a number of aquifers including the West Fargo Aquifer System as a whole based upon its geographic location and geology. Undesirable geochemical reactions between injected waters and native groundwater are perhaps the largest single concern with ASR in the numerous units of the West Fargo Aquifer System.

B.3 – SURFACE WATER

B.3.1 – Surface Water Model Selection

The model evaluation process began with the development of goals and objectives specific to surface water quantity modeling of the Red River basin. From these goals and objectives, specific model selection criteria were identified. The criteria were used to develop a questionnaire, which was provided to model reviewers who were very familiar with at least one of the models being considered. One reviewer was assigned to complete a questionnaire on each model and the results provided the basis for model comparison. The selection criteria were used to create a matrix which was used to evaluate and highlight each model's capabilities and limitations.

Modeling Objectives

Primary objectives of the monthly water quantity modeling were outlined through questions the modeling needed to answer:

- Will the current surface water sources in the Red River basin used for MR&I purposes provide enough water for these needs in the year 2050 if a 1930s type drought occurred?
- What is the probability of having shortages at the current and probable future MR&I points of interest and if shortages occur, how severe would they be?
- Will the different alternatives evaluated provide enough additional water to eliminate projected MR&I shortages?

The monthly surface water modeling of the Red River basin entailed imposing the basin's projected 2050 MR&I surface water demands on a naturalized (or unregulated) streamflow database. Therefore, the primary purpose of the surface water modeling efforts was to:

- examine water supply conditions to determine any present and potential future water supply shortages and
- assist in the evaluation of alternatives for meeting future water needs.

Model Selection Criteria

As a starting point, Reclamation used criteria developed by a modeling committee that was established for the *Red River Valley Water Needs Assessment, Phase II; Appraisal of Alternatives to Meet Projected Shortages* (Reclamation 2000). This committee included members from Reclamation, Garrison Diversion Conservancy District, ND State Water Commission, U.S. Geological Survey (USGS), North Dakota Department of Health, and the U.S. Army Corps of Engineers (COE). Technical representatives of these same agencies, Minnesota Department of Natural Resource, and Environment Canada participated in a process to refine these criteria for use in this effort. Reclamation also reviewed the model selection process used by the Texas Natural Resource Conservation Commission (TNRCC). Further information about the TNRCC and their efforts including the "An Evaluation of Existing Water Availability Models" can be found at http://www.tnrcc.state.tx.us/permitting/waterperm/wrpa/wam.html#summary).

By identifying user needs, desired functionalities, and ideal model characteristics, the model selection criteria were formulated and arranged into four general categories.

- CATEGORY: Water Rights Criteria
  - Doctrine: Western (Prior Appropriation) & Eastern (Riparian)
  - Use Category: Municipal, Industrial, Irrigation
  - Supplemental Rights: Add on to an original water right
  - Project vs. Non- Project Rights
  - Storage Allocation Rights
  - Monitor instream flow objectives/requirements

- CATEGORY: Functionality Related Criteria
  - Simulate movements of surface water (mass balance accounting not dynamic routing)
  - Model diversions from, and inflows to river and reservoir system at various locations
  - Water quality modeling capabilities
  - Simulate the location and magnitude of water shortages
  - Total water losses
  - Model based on a maximum of a monthly time step
  - Shorter time steps than monthly
  - Simulate and input a number of diverse alternatives
  - Able to use streamflow records and capable of handling large historical or stochastic streamflow databases
  - Model river reaches gains and losses:
  - Reach efficiency
  - Routing
  - Routing and efficiency
  - Losses to deep percolation
  - Ungaged watersheds or minor tributaries
  - Regional scaled model
  - River reach sizes
  - Lagging of return flows

- CATEGORY: Operational Related Criteria
  - Simulate main-stem and off-stream reservoir operations using:
    - Elevation-Area-Capacity Relationships
    - Stage-Discharge (uncontrolled and controlled spillways)
    - Minimum and maximum elevation
    - Elevation, and release targets (normal, flood operations)
    - Evaporation losses
    - Seepage losses
  - Accounting for reservoir multiple use storage allocations
  - Deviate from normal operating plans in low flow periods
- CATEGORY: Information Technology Related Criteria
  - Minimal training
  - Adequate model documentation
  - Graphical User Interface (GUI)

- User support capabilities
- Presently developed, has been used for similar studies elsewhere, and is peer accepted.
- PC compatible with windows, 95, 98, NT, XP, or DOS
- Windows version
- Non-proprietary or one-time fee models are preferred
- Input – Ability for the model to utilize either flat text files or database structures for input/output.
- Output-tabular report, time-series graphs
- Easy method for evaluating model error (sensitivity analysis)
- Reproduce stream flow records based on past demand input
- Model ownership and ability to manipulate code
- GIS capabilities
- Data requirements

Each criteria identified was assigned a ranking of importance or priority (high, medium, or low) and whether the criteria was “Desired” or “Required”. These rankings were assigned by the technical representatives participating in the Technical Team, and were later used when comparing models in the evaluation matrix. The criteria are shown in table B.3.1.

Table B.3.1 – Water Quantity Model Selection Criteria

	Purpose for Study	Importance	Required or Desired?
CATEGORY: Water Rights Criteria			
Doctrine---Western: Appropriation (first in time,first in right) & Eastern: Riparian.	Model needs to account for various operating plans of reservoirs, alternatives and water users--it is not certain that specific water rights modeling is needed.	High	Required
Use Category: Municipal, Industrial, Irrigation.	Model needs to distinguish between sectors of use. Minimum needs are that it be able to segregate Municipal/Industrial and Irrigation	High	Required
Supplemental Rights: Add on to an original water right.	Model needs to be able to split water rights with differing priority dates (I.e. due to additional acreage added to the same diversion.	Medium	Desired
Project vs Non- Project Rights	The model needs to have the ablity to segregate and target individual project water supplies from non-project water supplies, e.g. baseflow, with respect to storage, streamflow, return flow, water rights and imported supply.	High	Required
Storage Allocation Rights	Model needs to be able to allocate storage in a reservoir to specific water rights and priority dates.	High	Desired
Monitor instream flow objectives/requirements (instream flov	Model needs to simulate operating plans that allocate a certain portion of the river flow to instream flow requirements.	High	Required
CATEGORY: Functionality Related Criteria			
Simulate movements of surface water (mass balance accounting not dynamic routing)-	Needed to evaluate past, present and future water management and development effects upon streamflow conditions and alternative water supply solutions.	High	Required
Model diversions from, and inflows to river & res. system @ various locations	Model needs to account for quantity of inflows and outflows at any desired location.	High	Required
Water quality modeling capabilities	It would be beneficial if the model contained a water quality extension to model at least conservative water quality parameters.	High	Desired
Simulate the location and magnitude of water shortages	Need to know the location and magnitude of shortages so alternatives can be evaluated/sized.	High	Required
Total water losses	The user needs to keep track of the total amount of water lost from the system, especially any losses occurring from the rounding of numbers.	High	Desired
Model based on a maximum of a monthly time step.	Monthly time steps may be adequate for analyzing water supply scenarios, longer time steps are less useful.	High	Required
Shoter time steps than monthly.	Monthly time steps may not be adequate for analyzing aquatic impacts or brief shortages. A daily time step could be used.	High	Desired
Simulate & input a number of diverse alternatives(no solution, in-basin, out-of-basin)	The model needs to be capable of simulating alternatives.	High	Required
Able to use streamflow records and capable of handling large historical or stochastic streamflow databases	Modeling will be based upon surface water flow records rather than rainfall-runoff or full water budget methods.	Medium	Desired
Model river reaches gains & losses--	Losses & gains need to be subtracted or added to river quantities to represent the system.	High	Required
Reach Efficiency	Model needs to be capable of generally simulating gains and losses that occurs between various nodes due to groundwater interaction and bank storage.	Medium	Required
Routing	Model needs to be capable of simulating gains and losses that migrate between various nodes.	High	Required
Routing and Efficiency	It would be beneficial if the model allowed routing of losses from canals or conveyance systems, and/or on-farm/site of use losses based on efficiency of use.	Medium	Desired
Losses to deep percolation	The model needs to allow routing of losses to deep percolation that are assumed to be lost from the modeled system.	High	Required
Ungaged watersheds or minor tributaries	Model needs to account for inflow from tributary areas between gaging stations.	High	Required
Regional Scaled model	The model should be one that is generally used to model areas as large as the Red River Basin.	High	Required
River Reach sizes	The model should allow varying degrees of detail, from river reaches that represent several miles all the way up to 100 miles.	High	Required
Lagging of return flows	The model should allow return flows, or parts of return flows, to be returned to the system in the next few months, not just within the month the water was withdrawn.	High	Required

Table B.3.1 – Water Quantity Model Selection Criteria (Continued)

	CATEGORY: Operational Related Criteria			
	Simulate main-stem, & offstream reservoir operations using:	**The model needs to simulate reservoir operation plans so the impacts of reservoir operations can be determined.**	**High**	**Required**
	Elev.-Area-Capacity Relationships	Impacts of reservoir operations.	**High**	**Required**
	Stage-Discharge (uncontrolled & controlled spillways)	Impacts of reservoir operations.	**High**	**Required**
	Min, Max elevation	Impacts of reservoir operations.	**High**	**Required**
	Elev. & release targets (normal, flood operations)	Impacts of reservoir operations.	**High**	**Required**
	Evaporation losses	Losses due to reservoir storage/operations.	**High**	**Required**
	Seppage losses	Routing of losses to deep percolation or other nodes.	**High**	**Required**
	Capacity losses due to sedimentation	Losses of storage over time due to reservoir sedimentation.	**Medium**	**Desired**
	Accounting for reservoir multiple use storage allocations	**Model needs to simulate multiple-use (complex) reservoir operating plans.**	**High**	**Required**
	Deviate from normal operating plans in low flow periods	**The ability to deviate operating plans of reservoirs in low-flow times could be used to simulate any drought contingency plans.**	**High**	**Desired**
	CATEGORY: Information Technology Related Criteria			
	Minimal Training	**Model needs to be user friendly so that excessive learning curves are avoided.**	**High**	**Desired**
	Adequate Model Documentation	**The model should be adequately documented with respect to computational methods used, assumptions, user input requirements, description of the source code, and error checking/troubleshooting methods.**	**High**	**Desired**
	Graphical User Interface	**Input of data to the model needs to be convenient.**	**Medium**	**Desired**
	User support capabilities	**Support for the users is important.**	**High**	**Desired**
	The model is presently developed, has been used for similar studies elsewhere, and is peer accepted.	**Model has successful track record and is generally accepted by professionals for similar work.**	**High**	**Required**
	PC Compatible with windows, 95, 98, NT, XP, or DOS	**PC's are in widely used and universally available…access to other operating systems and mainframe computers is less widespread.**	**High**	**Required**
	Windows version	**The version of windows the model works best in should be a more recent version, otherwise a separate older computer will have to be used, which may be a hassle for the modeler.**	**High**	**Required**
	Non-proprietary or one-time fee models are preferred.	**Fees to use model need to be avoided or minimized.**	**High**	**Desired**
	Input -- Ability for the model to utilize both flat files or database structures for input/output.	**Flexibility of the model to import or use various input formats would add convenience to model set up.**	**Medium**	**Desired**
	Output---tabular report, time-series graphs	**Model output needs to be in a convenient form for presentation and data analysis. The ability to output data in to various formats is integral.**	**High**	**Desired**
	Easy Method for evaluating model error(sensitivity analysis)	**The ability to easily do a sensitivity analysis would be beneficial.**	**High**	**Desired**
	Reproduce stream flow records based on past demand input	**The ability to calibrate the model and reproduce observed results builds confidence in the model results.**	**High**	**Required**
	Model ownership and ability to manipulate code	**The ability for the user to be able to modify the model code for specific conditions or for tailoring the model to a unique component of the basin operations is occasionally important in generally applied "off the shelf" models.**	**Medium**	**Desired**
	GIS Capabilities	**The ability of the model to interface with GIS could allow for better presentation of results and processes.**	**Medium**	**Desired**
	Data requirements	**The model should not require extensive amounts of data beyond that which is currently available. It is understood that some assumptions will have to be made for use of any model, but the amount of data needed to run the model should be investigated to estimate the models applicability.**	**High**	**Required**

Questionnaire

The final model selection criteria were used to develop a questionnaire. This questionnaire was used to identify capabilities and limitations of the models of interest. The questions were answered by experts familiar with each model. Answers received were reviewed and clarification was sought when answers were unclear. Once all responses were understood and compared, the model evaluation matrix was started. The questionnaire was provided to the following:

Model	Reviewer	Agency
StateMod	Ray Bennett	State of Colorado
MODSIM-DSS	Nancy Parker	Bureau of Reclamation
HYDROSS	Thomas Bellinger	Bureau of Reclamation
RiverWare	Don Frevert	Bureau of Reclamation
HEC-5	Marilyn Hurst	U.S. Army Corps of Engineers
WRAP	Lann Bookout	Texas Natural Resource Conservation Commission
MIKE BASIN	Carter Border	Danish Hydraulic Institution

Model Selection Criteria Descriptions Model Review Questions

A detailed description of each model selection criterion and the related questions in the questionnaire are provided in the following discussion. Each description also includes the importance or priority ratings and "desired/required" ratings. The criteria are arranged into four general categories. A complete listing of the questions used in the evaluation is included in table B.3.2.

Water Rights Related Criteria

Doctrine - Western (Prior Appropriation) & Eastern (Riparian). The Red River basin is unique in that a portion of the water rights are adjudicated using Western or Prior Appropriation (North Dakota) and the other half uses Eastern or Riparian Appropriation (Minnesota). The model needs to be able to use some sort of water right appropriation system. Eastern Water Rights could be modeled using a western system by each Minnesota water right being given an older or more senior water right date than the earliest North Dakota water right.

Importance: High

Desired/Required: Required

Related Questions: Is the model able to easily account for water rights from rivers and structures, such as reservoirs? Can the model differentiate water right priorities based on date or a general priority numbering system?

Use Category - Municipal, Industrial, or Irrigation. Easy differentiation between shortages simulated by the different water use categories of municipal, industrial or irrigation water use is needed. This differentiation would be highly useful if project stakeholders deemed shortages experienced by one water use type more important to meet than another diversion type.

Importance: High

Desired/Required: Required

Related Questions: Does the model differentiate between different types of water use (diversions)? Specifically, does the model differentiate between municipal, industrial, and irrigation water use?

Supplemental Rights - Add on to an original water right. In some states, when water rights are reviewed and deemed inadequate for growing population or an increase in irrigation or industry demand, existing water rights are added onto for additional water, rather than making a totally separate water right. For example, Minnesota will increase a water right when it's reviewed rather than give the user a separate water right for the additional amount. It would be beneficial if the model can account for these additional or supplemental water rights, but there are other ways to simulate the addition of such water rights in a water supply model.

Importance: Medium
Desired/Required: Desired
Related Questions: Can the model split out portions of water rights with differing priority dates (e.g., due to additional acreage added to the same diversion at a later time period)?

Project vs. Non- Project Rights. In order to accurately simulate western "Prior Appropriation" water law, the model needs to have the ability to segregate and target individual project water supplies from non-project water supplies. The model should at least be able to separate unappropriated streamflow from appropriated streamflow, but should preferably be able to track streamflow with respect to project storage, return flows, water rights and imported water supply.

Importance: High
Desired/Required: Required
Related Questions: Can the model segregate and target individual project water supplies from non-project water supplies ("color the water")? e.g., separate baseflow from that designated for downstream water users released from upstream storage (reservoir), or water coming from return flows and/or imported supply.

Storage Allocation Rights. The model needs to be able to allocate storage in a reservoir to specific water rights and priority dates in order to perform western water appropriation rules.

Importance: High
Desired/Required: Desired
Related Questions: Can the model allocate storage in a reservoir to specific water rights (owners) with various priority dates?

Monitor Instream Flow Objectives/Requirements. Model needs to simulate operating plans that allocate a certain portion of the river flow to instream flow requirements. It would be beneficial if the model could "watch" a designated instream flow target, identify the number of times and extent to which this target is not met, and attempt to solve any instream flow shortages observed.

Importance: High
*Desired/Required:*_ Required
Related Questions: Does the model monitor instream target flows, in order to identify targets that are not met 100%? Can the model simulate operating plans that allocate a certain portion of the river flow to instream flow requirements?

Functionality Related Criteria

Simulate Movements of Surface Water. This project requires a model capable of simulating past, present, and future surface water management. The model also needs to be capable of simulating development effects upon streamflow conditions and alternative water supply solutions. In particular, the model should perform mass balance accounting of water and should provide an overall water balance of the system.

Importance: High
Desired/Required: Required
Related Questions: Is the model used to evaluate past, present, and future water management and development effects upon streamflow conditions and alternative water supply solutions? Does the model perform mass balance accounting of water or dynamic routing? Does the model provide an overall water balance of the system?

Table B.3.2 - Questionnaire

Name:	Model Name:	Date:
Water Rights Questions		Please Put Answers Here
Doctrine---Western: Appropriation (first in time,first in right) & Eastern: Riparian.	Is the model able to easily account for water rights from rivers and structures, such as reservoirs?	
Doctrine---Western: Appropriation (first in time,first in right) & Eastern: Riparian.	Can the model differentiate water right priorities based on date or a general priority numbering system?	
Doctrine---Western: Appropriation (first in time,first in right) & Eastern: Riparian.	Is the model able to accept and adhere to various operating plans of reservoirs?	
Use Category: Municipal, Industrial, Irrigation.	Does the model differentiate between different types of water use (diversions)? Specifically, does the model differentiate between Municipal, Industiral, and Irrigation water use?	
Supplemental Rights: Add on to an original water right.	Can the model split out portions of water rights with differing priority dates (I.e. due to additional acreage added to the same diversion at a later time period)?	
Project vs Non- Project Rights	Can the model segregate and target individual project water supplies from non-project water supplies ("color the water")? e.g. separate baseflow from that designated for downstream water users realsed from upstream storage(reservoir), or water coming from return flows and or imported supply?	
Storage Allocation Rights	Can the model allocate storage in a reservoir to specific water rights (owners) with various priority dates?	
Monitor instream flow objectives/requirements (instream flow rights)	Can the model monitor instream flow requirements?	
Monitor instream flow objectives/requirements (instream flow rights)	Can the model simulate operating plans that allocate a certain portion of the river flow to instream flow requirements?	
Functionality Related Questions		Please Put Answers Here
Simulate movements of surface water (mass balance accounting not dynamic routing)	Is the model used to evaluate past, present and future water management and development effects upon streamflow conditions and alternative water supply solutions?	
Simulate movements of surface water (mass balance accounting not dynamic routing)-	Does the model perform mass balance accounting of water or dynamic routing?	
Model diversions from, and inflows to river & res. system @ various locations	Does the model allow diversions from and inflows to river systems at any desired location, particularly into reservoirs?	
Water quality modeling capabilities	Does the model have a water quality counterpart or extension that could be used for modeling either conservative or non-conservative water quality parameters, or both?	
Simulate the location and magnitude of water shortages	Does the model track the location and magnitude of shortages?	
Total water losses	Does the model track, or is the user able to track how much water is being lost from the system, either by the users direction (deep percolation) or by rounding off numbers?	
Model based on a maximum of a monthly time step.	Does the model function on a monthly time step?	
Shoter time steps than monthly.	Is the model able to function at a daily time step?	
Simulate & input a number of diverse alternatives(no solution, in-basin, out-of-basin)	Does the model easily allow the user to alter water sources and diversions based on various alternatives for meeting water demands?	
Functionality Related Questions (cont.)		Please Put Answers Here
Able to use streamflow records and capable of handling large historical or stochastic streamflow databases	Does the model depend on gaged surface water records, naturalized streamflow, or "baseflow" inputs? OR does the model require precipitation data or use full water budget calculations?	
Model river reaches gains & losses--	Does the user have to define the coefficients for losses & gains from groundwater? Or does the model create such coefficients based on streamflow at known locations?	
- Reach Efficiency	Is the model capable of simulating gains and losses that occur between various nodes due to groundwater interaction and bank storage?	

Table B.3.2 – Questionnaire (Continued)

Functionality Related Questions (cont.)		Please Put Answers Here
- Routing	Can the model simulate gains and losses that may be returned to another node?	
- Routing and Efficiency	Does the model allow for routing of losses from canals or conveyance systems, and/or on-farm/site of use losses based on efficiency of use?	
- Losses to deep percolation	Does the model allow for routing of losses to deep percolation that are assumed to be lost to the modeled system?	
- Ungaged watersheds or minor tributaries	Does the mode allow inflows from tributary areas between gaging stations?	
Regional scaled model	Is the model used to simulate regional surface water systems, e.g. in a basin totalling about 25 million acres?	
River reach sizes	Does the model allow varying sizes of river reaches between nodes, e.g. ranging from several miles to over 100 miles in length? And is the model generally used in this way?	
Lagging of return flows	Does the model allow return flows, or parts of return flows, to be returned to the system in a future month? If so, how far out can return flows be lagged?	
Operational Related Questions		Please Put Answers Here
Simulate main-stem, & offstream reservoir operations using:	Does the model allow the simulation of various reservoir operation plans?	
- Elev.-Area-Capacity Relationships	Does the model accept area-capacity curve data?	
- Stage-Discharge (uncontrolled & controlled spillways)	Does the model accept stage-discharge information?	
- Min, Max elevation	Does the model use the maximum and minimum elevations for simulating reservoir operations?	
- Elev. & release targets (normal, flood operations)	Does the model accept specified release targets?	
- Evaporation losses	Does the model calculate losses due to reservoir storage/operations?	
- Seepage Losses	Does the model allow for seepage loss estimates from reservoirs and can it route these losses to other areas or remove them from the modeled system, e.g. losses to deep percolation?	
- Capacity losses due to sedimentation	Does the model track and/or accept losses of storage over time due to reservoir sedimentation?	
Accounting for reservoir multiple use storage allocations	Can the model simulate multiple-use (complex) reservoir operating plans?	
Accounting for reservoir multiple use storage allocations	Does the model allow various ownership in reservoirs, e.g. by percentages of total releasable capacity?	
Deviate from normal operating plans in low flow periods	Does the model allow deviations to operating plans of reservoirs in low-flow times, e.g. to simulate drought contingency plans?	
Information Technology Related Questions		Please Put Answers Here
Minimal Training	Is the model considered to be user friendly? Or is there a steep learning curve?	
Adequate Model Documentation	Does the model have adequate documention with respect to computational methods used, assumptions, user input requirements, description of the source code, and error checking/troubleshooting methods?	
Graphical User Interface	Can the input of data be done through using a Windows based Interface?	
User support capabilities	Is there any support for the users?	
The model is presently developed, has been used for similar studies elsewhere, and is peer accepted.	Does the model has successful track record, i.e. have other water supply or water availability projects used the model and been satisfied with the results?	
PC Compatible with windows, 95, 98, 2000, NT, XP, or DOS	Is the model able to be run on a PC, e.g. in DOS, or does it require a UNIX type system to run?	
PC Compatible with windows, 95, 98, 2000, NT, XP, or DOS	Is the model able to be run in any Windows format, or does it work better in particular versions of Windows?	
Non-proprietary or one-time fee models are preferred.	Does the model require any fees for use or support?	
Input -- Ability for the model to utilize both flat files or database structures for input/output.	Can the model accept input data from a database? Or does it only accept flat text files?	
Output---tabular report, time-series graphs	Does the model generate plots or graphs of output data? Or is the output data strictly in tabular format?	
Easy Method for evaluating model error(sensitivity analysis)	Does the model include the ability to evaluate model error, e.g. doing a sensitivity analysis?	
Reproduce stream flow records based on past demand input	Does the model allow the user to "tweak" factors such as reach gains & losses in order to calibrate the model?	
Information Technology Related Questions (cont.)		Please Put Answers Here
Model ownership and ability to manipulate code	Is the user able to modify the model code for specific conditions or for tailoring the model to a unique component of the basin operations?	
GIS Capabilities	Is the model able to interface with a GIS?	
Data requirements	What types of input data is required to evaluate surface water availability for use by water supply? E.g. Naturalized streamflow database, future water demands, crop irrigation requirements.	

Model Evaluation Matrix

A matrix was used to compare the models' strengths and weaknesses in relation to modeling the Red River basin. Completion of the model evaluation matrix was undertaken by one person, so that the comparison minimized subjective opinion that would arise from multiple evaluators. The process of completing the matrix entailed assigning ratings of 1-5 to each model, which was determined by comparing the responses to each question and using general information about the models found in model documentation. Each of these preliminary ratings was then multiplied based on the importance rating each model selection criterion was given, since each question directly related back to a specific criterion.

The required capability that is either necessary or desired. If a particular function was determined "required" in the model selection criteria and the reviewer's comments show that the functionality in question is not included in the model, then the rating would be "0". On the other hand, if the functionality was included, but it was difficult to use or made some inappropriate assumptions, then the rating would was "2" or "3". Once ratings were established for each criterion, the rating numbers were multiplied by the following numbers based on the determined level of importance (high, medium, or low):

- High Importance = Multiplication Factor of 3
- Medium Importance = Multiplication Factor of 2
- Low Importance = Multiplication Factor of 1

After multiplication factors were used, the resultant ratings were summarized to make a total model evaluation number, which was presented in a final matrix. The results of the model evaluation were reviewed by members of the Technical Team and are presented in table B.3.3a.

Table B.3.3a – Red River Valley Computer Models General Description and Functional Evaluation

				WATER QUANTITY MODEL RESULTS						
			Model Name	HYDROSS	HEC-5	MODSIM	RiverWare	WRAP	MIKE BASIN	STATEMOD
			Author	BOR	COE	CSU	CADSWES	Texas	Inst.	Colorado
#	Criterion Description	Importance	Desired or Required?	Surface water supply model to evaluate existing and proposed demands on a river system	Simulation of Flood Control and Conservation Systems (Including Water Quality Analysis)	River Basin Network Simulation Model		Water Rights Analysis Package	River network modeling system for water rights and environmental studies	State of Colorado's Stream Simulation Model
1	**Doctrine---water rights**	**High**	**Required**	30	30	30	18	30	30	30
2	**Doctrine---water rights**	**High**	**Required**	30	30	30	0	30	24	30
3	**Doctrine---water rights**	**High**	**Required**	30	30	30	30	30	30	30
4	**Use Categories: MRI&I**	**High**	**Required**	18	24	12	18	18	18	18
5	**Supplemental Rights**	**Medium**	**Desired**	30	30	30	18	30	30	30
6	**Project vs Non- Project Rights**	**High**	**Required**	30	18	30	30	30	6	30
7	**Storage Allocation Rights**	**High**	**Desired**	24	24	30	0	30	6	30
8	**Monitor instream flow rights**	**High**	**Required**	30	30	30	30	30	30	30
9	**Monitor instream flow rights**	**High**	**Required**	30	30	30	30	30	0	30
10	**Simulate water - past & future alt's**	**High**	**Required**	30	30	30	30	30	30	30
11	**Simulate water - mass balance?**	**High**	**Required**	30	30	30	30	30	30	30
12	**Simulate water-overal water balance**	**High**	**Required**	30	30	30	18	18	30	30
13	**Diversions from, and to river & res.**	**High**	**Required**	30	30	30	30	30	30	30
14	**Water quality modeling capabilities**	**High**	**Desired**	0	30	0	24	6	30	0
15	**Simulate the location and magnitude of water**	**High**	**Required**	30	30	30	30	30	30	30
16	**Simulate natural vs. proj shortages**	**High**	**Required**	30	12	12	30	0	0	30
17	**Total water losses**	**High**	**Desired**	18	18	18	18	0	6	30
18	**Model based on a maximum of a monthly time step.**	**High**	**Required**	30	30	30	30	30	30	30
19	**Shoter time steps than monthly.**	**High**	**Desired**	0	30	30	30	0	30	30
20	**Simulate & input a number of diverse alternatives(no solution, in-basin, out-of-basin)**	**High**	**Required**	30	30	30	30	24	30	30
21	**Use historical streamflow records**	**Medium**	**Desired**	30	30	30	30	30	30	30
22	**Model river reaches gains**	**High**	**Required**	30	30	30	30	30	30	30
22	**Model river reaches losses**	**High**	**Required**	30	30	30	30	30	30	30
23	**Reach Efficiency**	**Medium**	**Required**	24	12	24	30	6	24	24
24	**Routing**	**High**	**Required**	30	12	30	30	30	0	30
25	**Routing and Efficiency**	**Medium**	**Desired**	30	30	30	30	30	30	30
26	**Losses to deep percolation**	**High**	**Required**	30	12	30	30	30	0	30
27	**Ungaged watersheds or minor tributaries**	**High**	**Required**	30	30	30	30	30	30	30
28	**Regional Scaled model**	**High**	**Required**	30	30	30	30	18	30	30
29	**River Reach sizes**	**High**	**Required**	30	30	30	30	30	30	30
30	**Lagging of return flows**	**High**	**Required**	30	30	30	30	18	30	30
31	**Simulate reservoir operations using:**	**High**	**Required**	30	18	30	30	30	18	30
32	Pumping Storage	**High**	**Required**	12	30	30	30	30	0	30
33	Elev.-Area-Capacity Relationships	**High**	**Required**	30	30	30	30	30	30	30
34	Stage-Discharge (uncontrolled & controlled spillways)	**High**	**Required**	6	30	30	30	0	30	0
35	Min, Max elevation	**High**	**Required**	30	30	30	30	18	30	30
36	Elev. & release targets (normal, flood operations)	**High**	**Required**	30	30	30	30	30	30	30
37	Reservoir Spills	**High**	**Required**	30	30	30	30	30	30	30
38	Evaporation losses	**High**	**Required**	30	30	30	30	30	30	30
39	Seppage losses	**High**	**Required**	30	30	30	30	30	30	30
40	Capacity losses due to sedimentation	**Medium**	**Desired**	12	12	12	12	12	12	12
41	**Res. multiple use storage allocations**	**High**	**Required**	18	30	30	30	30	30	30
42	**Res. multiple use storage allocations**	**High**	**Required**	18	18	30	30	30	6	30
43	**Deviate from normal operating plans in low flow periods**	**High**	**Desired**	30	30	30	30	30	30	30
44	**Minimal Training**	**High**	**Desired**	30	6	18	12	6	30	30
45	**Adequate Model Documentation**	**High**	**Desired**	18	30	30	30	30	30	30
46	**Graphical User Interface**	**Medium**	**Desired**	30	0	30	12	30	12	30
47	**User support capabilities**	**High**	**Desired**	18	6	18	12	6	12	30
48	**Presently developed, similar studies elsewhere, peer accepted.**	**High**	**Required**	30	30	30	30	30	30	30
49	**PC Compatible**	**High**	**Required**	30	30	30	30	30	30	30
50	**Windows version**	**High**	**Required**	30	18	30	30	18	30	30
51	**Non-proprietary or one-time fee**	**High**	**Desired**	30	30	30	6	30	6	30
52	**Input -use flat files or database**	**Medium**	**Desired**	18	18	18	24	30	24	18
53	**Output-tabular report, graphs**	**High**	**Desired**	6	18	30	30	6	12	30
54	**Evaluating model error (sensitivity)**	**High**	**Desired**	18	18	18	18	18	12	18
55	**Reproduce flow with past demands**	**High**	**Required**	30	30	30	30	30	30	30
56	**Model and code ownership**	**Medium**	**Desired**	30	0	24	12	30	24	30
57	**GIS Capabilities**	**Medium**	**Desired**	0	6	0	0	18	30	30
58	**Data requirements**	**High**	**Required**	0	0	0	0	0	0	0
				1458	1410	1554	1452	1380	1332	1620

Key

(pink)	= abilities that the model CANNOT do
(yellow)	= abilities that bring the model rating down

The results of the matrix showed StateMod to be the apparent highest scoring software. However, before making a final selection, Reclamation identified the pros and cons (table B.3.3b) of the top three scoring models. These models included HYDROSS, MODSIM, and StateMod.

Hydrologic River Operations Study System (HYDROSS). The Bureau of Reclamation's HYDrologic River Operations Study System (HYDROSS) is a surface hydrologic accounting model developed to assist in planning studies for evaluating existing and proposed demands on a river system. It is intended to operate over a period of record, simulating the effect of the existing and proposed features on the historical pristine flows. HYDROSS was developed to allow the user the flexibility to conduct "what if" studies with ease.

HYDROSS operates on the data in a strict sequential order in time (results from one month depend on the system state at the end of the previous month), space (results at one station depend on what is happening upstream and/or downstream), and priority (earlier water right dates are allowed water before later water right dates). The model only functions at a monthly time step.

A graphical user interface - the PC HYDROSS Simulation System (PCHSS) - is available to assist the user in the development of input files and creation of output reports and graphs. Reclamation has been the prime user of HYDROSS, with recently completed applications in the Taos Valley of New Mexico and Red River Valley of North Dakota. Use of HYDROSS does not require the purchase of a license.

River Basin Network Simulation Model (MODSIM). Colorado State University's River Basin Network Simulation Model (MODSIM) is a generalized water rights planning model capable of assessing past, present, and future water management of river basins. MODSIM allocates water in a manner consistent with the hydrological, physical, and institutional aspects of a river basin. MODSIM was based on modifying and updating the SIMLYDII model.

The model simulates several types of water rights; including direct flow rights, instream flow rights, reservoir storage rights, and exchange and operational priorities. The user assigns relative priorities for meeting diversion, instream flow, and storage targets, as well as lower and upper bounds on flows and storage. A version of MODSIM also includes a stream-aquifer interaction model for analyzing conjunctive use of surface water and groundwater. MODSIM has been enhanced to integrate analysis of water quality and quantity issues.

A network flow programming problem is solved for each individual time interval. The model has the capability to operate in monthly, weekly, or daily time steps, and to calculate channel losses. A GUI was developed for the model; the code is written in FORTRAN95. In addition, MODSIM is well documented and has been used for a wide variety of applications both in the United States and in other countries. At the time of model evaluation, it was being adopted for use in the California Central Valley Project.

Stream Simulation Model, State of Colorado (StateMod). Stream Simulation Model, State of Colorado is derived from an earlier version of Boyle Engineering's BESTSM, which is a general purpose streamflow allocation model developed to simulate surface water and groundwater resources for complex river basins. The StateMod model is capable of simulating very complex physical systems in accordance with prior appropriation doctrine.

The State of Colorado made numerous enhancements to BESTSM to model scenarios unique to the river basins of their state. StateMod supports the priority water rights system and many issues related to water resources planning, including direct diversions and instream flows. StateMod has been applied to all of the Western Slope Basins in Colorado. The model is coded in FORTRAN with GUI capabilities for SGI computers. An updated GUI for PCs using Java is being completed by Colorado. The model supports a daily time step.

StateMod supports complex water rights, exchanges, and importing operations. The model has numerous field applications. StateMod is in the public domain, is free to use, and is maintained by the State of Colorado.

Table B.3.3b – Monthly Water Quantity Model Pros and Cons

Model	*Pros*	*Cons*
HYDROSS	- Already developed for Red River Valley - Links directly with a water quality model - Performs the basic operations needed	- Runs on a monthly time step only - Does not easily simulate complex reservoir operations - Does not give graphical output of data, must use post-processing - Used very little by non-Reclamation modelers - Must be tricked to perform some RRV required operations
MODSIM	- Can perform complex reservoir allocations - Has been applied to areas all over Western U.S. - Described in technical literature/ journals - Runs at daily, weekly or monthly time steps - May represent instream demands in detail	- Code is not available, user makes adaptations using PERL - Customer support is free for small inquiries only - Water use types not used by model, requires post-processing - Flow input is different from other models, requires more work
StateMod	- Performs complex water rights - Some field application - Model summarizes all system water losses for the user - Errors due to arithmetic rounding is documented - Model can show structure locations using GIS - Help with model is free of charge - Updates to model are free of charge - Monthly model can be easily changed into daily time step (conversion usually takes about 1 week of effort) - Highly scrutinized on whether results mimic historical flow - Used to determine Colorado water laws	- Daily reservoir operations may need to be updated

B.3.2 – Model Input

Input data for the StateMod surface water model are extensive and would not fit within the bounds of this document. For that reason, Reclamation has provided a brief overview of the input data. Further detail can be found by accessing them in electronic format on the enclosed CD. These data are contained within a "ModelInput.zip" file.

> NOTE: The ModelInput.zip file is a compressed file requiring the user to use either the program Winzip or other compression software to decompress it into its individual files. In its compressed format, this file is approximately 8 megabyte in size. However, it will decompress to about 76 megabyte. Make provisions for this on your computer before attempting to decompress.

The files contained within "ModelInput.zip" are text based files. Though, they appear with varying filenames and file extensions, they can all be viewed using either a text editor or a generic program such as "Notepad" which comes standard with IBM compatible windows software.

StateMod uses a Response file, denoted by a file with a ***.rsp** extension, to locate all of the data input files used for each modeling application. Each modeling run has its own specific response file. The response files used are included in table B.3.4.

Table B.3.4 – Model Runs and the Response Filenames Used

Base Model Runs	**Scenario One**	**Scenario Two**
Calibr8	Calibr8*	
Baseline	Base171*	
No Action (with Thomas Acker and 28,000 Fish & Wildlife Conservation Pool at Lake Ashtabula)	NA1ID71	NA2ID71
Proposed Alternatives	**Scenario One**	**Scenario Two**
North Dakota In-Basin	Loop171	Loop271
Red River Basin	BF1NGF71	BF2NGF71
Lake of the Woods	BF1W71	BF2W71
GDU Import to Sheyenne River	I1NAWPOP	I2NAWPOP
GDU Import Pipeline	BF1NAW71	BF2NAW71
Missouri River to Red River Valley Import	I1D71	I2D71
GDU Water Supply Replacement Pipeline	N/A	Repl71

* These model runs are based on historic data precluding them from having differing scenarios for range of demands.

Response files give StateMod the names associated with each dataset required to run the model. Table B.3.5 lists the files, the order which they appear, and their type included in the "Current (2005) Water Demand (Base171)" model run. All other response files used to perform model runs include the same number and order of files.

Table B.3.5 – Model Run Base171.rsp Input Files

Input Filename	Type of File
NAmid71.ctl	Control
NAmid.rin	River network
NAmid.res	Reservoir station
NAmid.dds	Direct Diversion station
NAmid.ris	River station
NAmid.ifs	Instream flow station
Base1.wes	Well station
NAmid.ifr	Instream flow rights
NAmid.rer	Reservoir rights
NAmid.ddr	Direct diversion rights
NAmid.opr	Operational rights
Base1.wer	Well rights
calibr8.pre	Precipitation - Monthly
calibr8.eva	Evaporation - Monthly or Average Monthly
NAmid.rim	Streamflow - Monthly
Base1.ddm	Direct diversion demand - Monthly
calibr8.ddo	Direct diversion demand overwrite - Monthly
calibr8.dda	Direct diversion demand - Annual Monthly
NAmid.ifa	Instream flow demand - Average Monthly
Base1.wem	Well demand - Monthly
calibr8.dly	Delay table - Monthly
NAmid.tar	Reservoir target - Monthly
calibr8.eom	Reservoir End of month contents - Monthly
calibr8.rib	Baseflow Parameter
NAmid.rih	Historic Streamflow - Monthly
Base1.ddh	Historic Diversions - Monthly
Base1.weh	Historic Well Pumping - Monthly
Redpractice.gvp	GeoView Project (GIS)
Base171.out	Output Control

A general description of each of these files is included to assist the reader in determining what each file does. Further description and detail of how these files are used by StateMod can be found, and are available for download as part of the "Documentation" for the StateMod Model, at http://cdss.state.co.us/ftp/statemod.asp.

Control File (*.ctl)

This file contains information which controls the model simulation. Information includes years simulated, switches for units used, factors for conversion, and other switches that control the simulation.

- Calibration
  - Period set from 1985 to 1994. This period was originally selected to represent a 10 year period which included a severe drought and included historic record for all required datasets for modeling.
- Simulation.
  - Simulation period set from 1931 to 1941 for initial model runs to optimize pipe sizing (model takes less time to run).
  - Simulation period set from 1931 to 2001 to account for effects over all 71 years (model takes much longer to run).

River Network File (*.rin)

This file is used to describe the river basin of interest. Note, the last downstream node should be blank.

- Calibration
    - The river network file included a structure for every MR&I intake, reservoir, and flow node entered into the model.
    - Irrigation permits were combined into one withdrawal structure for each DEB.
    - Return flows were combined into one return point structure for each DEB.
- Simulation
    - A new node was added for each new permit added to the system.
    - Nodes were added to account for proposed Aquifer Recharge Systems.
    - Nodes were added to be used as "throttles" during the optimization of supply features.

Reservoir Station File (*.res)

This file contains information to describe the physical properties of each reservoir in the system. Reservoirs may be operated such that they will not divert above their target. When a reservoir stores above its target and subsequently releases that water as part of an operating rule, the net result is a paper fill which is charged against the reservoir rights one fill limitation and additional water is available downstream of the reservoir.

- Calibration
    - Lake Ashtabula, Lake Orwell, Lake Traverse, Mud Lake and Red Lake Reservoir were included in this file.
    - Reservoir characteristic including the area capacity curves for each reservoir were entered here.
    - Lake Ashtabula was separated into seven accounts to simulate the Thomas-Acker plan for Fargo, Grand Forks, Valley City, West Fargo, and Lisbon (See Appendix B - Attachment 2). Additionally, the recommended 28,000 acre-foot fish and wildlife conservation pool suggested by the COE was left in tact as a target to maintain. No withdrawals from storage were allowed below this volume.
- Simulation
    - The reservoirs were kept in place from calibration while a fictitious one "MissReservor" was added to simulate an external water source from which imported water would come.
        - MissReservor was incorporated as a reservoir that was almost limitless in size and was not affected by evaporation.
        - This reservoir was used to simulate the Missouri River, Minnesota Groundwater, and Lake of the Woods.
    - WFAquifer and MAquifer were added to simulate ASR for the West Fargo and Moorhead Aquifers.
    - Thomas-Acker Plan was modified and Lake Ashtabula had its accounts limited to three (general storage, fish and wildlife conservation pool, dead pool).
    - Red Lake Reservoir is turned off during simulation in lieu of the historic flow data in the Red Lake River just below the outlet works.

Direct Diversion Station File (*.dds)

This file contains information to describe the physical properties of each direct diversion in the system.

- Calibration
  - Structures for all existing permits were included and were named the same as their corresponding river network node.
- Simulation
  - New structures were added as required for new water users and future permitting to ASR in the proposed alternatives.
  - Also included are nodes that were added into the river station file for use as nodes (throttles) through which water is imported to the system from the reservoir MissReservor.

River Station File (*.ris)

This file is used to describe the name and location of nodes where baseflows are known. Baseflows typically consist of streamflow gages (which have a historical time series in the historical stream flow file (*.rih)) and other nodes which have a base flow estimated using information in the base flow data file (*.rib). The number and order of entries corresponds to the stream flow file.

- Calibration
  - Structures for 37 flow points of which 14 are existing USGS gages located on the Sheyenne and Red rivers.
- Simulation
  - Structures were added to represent return flows which act as tributaries entering into the system at the correct locations toward the end of each DEB.

Instream Flow Station File (*.ifs)

This file contains information to describe the physical properties of each instream flow in the system.

- Calibration
  - No minimum instream flows were added in during calibration as these flows are factored into the historic data.
- Simulation
  - These stations include the Minnesota Q90 minimum instream flows on the tributaries to the Red River and the operational release of 13 cfs on Lake Ashtabula. This instream flow releases water from the lake only when project outflows or natural flow releases drop below 13 cfs.

Well Station File (*.wes)

This file contains information to describe the physical properties of each well structure in the system.

- Calibration
  - No wells were accounted for in the calibration runs.
- Simulation
  - The wells used for Moorhead from the Buffalo Aquifer were added.

  - Return flows were added in as wells with 0% consumptive use that return their full withdrawals to a combined node at the end of each DEB.

Instream Flow Right File (*.ifr)

This file contains data associated with a diversions water rights. This file contains the appropriated amount and priority date given to the minimum instream flow

- Calibration
  - No minimum instream flow rights were assigned during calibration.
- Simulation
  - Rights for volume and priority were assigned to the minimum instream flows provided in the *.ifs file.

Reservoir Right File (*.rer)

The reservoir rights file contains data associated with a reservoir's water rights.

- Calibration
  - Reservoirs were entered in with their priority dates set to the date matching their construction completion.
- Simulation
  - MissReservor is added as an import source.
  - WFAquifer and MAquifer were added and given junior water rights to existing users.
  - Reservoirs are allowed to perform multiple fills throughout each year.

Direct Diversion Rights File (*.ddr)

This file contains data associated with a diversion right.

- Calibration
  - All ND permits within the dataset were given a priority date that corresponded with issuance date. Volume rights were set to match the annual volume shown on the permit.
  - All MN permits were given a priority date of 1800 to account for them being governed by riparian water law.
  - MN cities on the Red River were given priority dates identical to the ND cities directly across the river.
- Simulation
  - The structures controlling flow from ASR are also located here.
  - Although, the flows from import or ASR are set here, they are controlled via entries into the Operation Right File (*.opr).
  - NOTE: This file contains the sizing of all action alternative pipelines. There are “throttle” structures added into both the River Station File and the Direct Demand Station File that are given water allocation rights within this dataset. The water allocations set the max allowable flow that can pass through these structures. The set flow acts as a “throttle” and ultimately sets the sizing of the pipe. The flow was optimized by placing this value just large enough to sustain the 28,000 acre-foot fish and wildlife conservation pool in Lake Ashtabula.

Operation Right File (*.opr)

This file describes unique operating criteria within the basin. The file contains the following standard operating rights. Because the data associated with this file varies based on the type of operational right selected the input description is repeated for each application.

- Calibration
  - No operational rights were required for performing baseflow.
- Simulation
  - Operational rights were entered to allow cities with multiple permits to manifold these together in the correct order.
  - Rights were also given to the Thomas-Acker cities in order to withdraw water from Lake Ashtabula.
  - Permits that were part of the service area and showed shortages that could not be directly served were also given water allocation rights to Lake Ashtabula.
  - Reservoirs were given the right to spill when volume exceeded capacity.
  - Rights were given to the ASR for withdrawing water from the surface when available. Additionally, those cities using the ASR were given rights to extract water when needed.

Well Right File (*.wer)

This file contains data associated with well structures.

- Calibration
  - No wells were included as part of calibration.
- Simulation
  - Wells used in lieu of return flow structures within the model were given priority dates senior to all withdrawal rights.
  - Decreed amounts were set to match the highest monthly return for the well.

Precipitation File - Monthly (*.prm)

This file contains total monthly precipitation for each month of the simulation period.

- This file was not utilized within the model as it was turned off through the control file (*.ctl) in lieu of using the evaporation file (*.evm) reworked to show net evaporation.

Evaporation File - Monthly (*.evm)

This file contains total monthly (12 values per simulation year) evaporation data. The type of data provided is controlled by a variable in the control file.

- This dataset was configured by subtracting the precipitation values from the evaporation values that were provided by the USGS (Vining 2003). This dataset remained unchanged from calibration through the simulation of proposed alternatives.

Stream flow File - Monthly (*.rim or *.xbm)

This file contains total baseflows for each month of the simulation period. When this file is generated outside StateMod or is generated by StateMod and saved for historic purposes, it is commonly named *.rim. When this file is generated by the StateMod baseflow module it is typically named *.xbm.

- Calibration

  - This file contains the naturalized flow database generated by the USGS (Emerson 2005)
  - Running the “Calibr8*”model for baseflow generated the Calibr8.xbm file. This file is baseflow and is typically used as the naturalized flow for calculation during simulation.
- Simulation
  - The Calibr8.xbm file was replaced by the naturalized flow database generated by the USGS (Emerson 2005) once a comparison was performed between the two showing a 0.5% difference over the entire period of comparison.
  - The values within this dataset were unaltered throughout modeling.

Direct Flow Demand File - Monthly (*.ddm)

This file contains demands for direct diversions for each month of the simulation period.

- Calibration
  - The historic demands of all permits within the model were entered on a monthly time step.
  - Return flow were entered in here as a negative number allowing the model to see these as an import to the system which reacts like a return flow.
- Simulation
  - All negative return flow values were replaced with zeros.
  - Irrigation demands were set to full decreed amounts and entered here using the same values for every year 1931 to 2001.
  - MR&I Demands
    - The Current (2005) Water Demand model had the 2005 max month demand for all permits entered using the same values for every year 1931 to 2001.
    - All other alternatives studied have the 2050 max month demand for all permits entered using the same values for every year 1931 to 2001.
    - Those alternatives using peak demand from surface water had their values replaced by those generated for max month with peaking.

Direct Flow Demand Overwrite File - Monthly (*.ddo)

This file contains monthly demands for each year of the study period for selected structures. This file allows a “what if” scenario to be evaluated quickly without revising the direct flow demand file.

- This file was left blank and was not used during this modeling effort.

Direct Flow Demand File - Annual (*.dda)

This file contains twelve constant demands which are repeated for each year of the study period.

- This file was left blank and was not used during this modeling effort.

Instream Flow Demand - Monthly (*.ifm)

This file contains instream flow demands for each month of the simulation period.

- This file was left blank and was not used during this modeling effort.

Instream Flow Demand - Annual (*.ifa)

This file contains 12 monthly instream flow demands for use each year of the simulation.

- Calibration
    - Not required.
- Simulation
    - Monthly volumes consistent with the required Q90's for MN and the 13 cfs operational release from Lake Ashtabula were entered here.

Well Demand File - Monthly (*.wem)

This file contains demands for well structures for each month of the simulation period.

- Calibration
    - Not used.
- Simulation
    - Wells were used to simulate return flows. Fictitious wells were entered into the model and allowed to flow water directly to the surface water without consumptive use.
        - Average values were computed from historic records for each month of each return flow permit. Monthly return flow average values were combined for each DEB within the system. These values were then increased as a direct percent compared to the increase in Scenario One demands for that DEB.
        - Return flows were throttled back in the No Action and Baseline alternatives as a direct relationship to the shortage witnessed within the corresponding DEB.
        - Return flow values calculated for Scenario One were used for Scenario Two without change.
    - A well was included representing Moorhead's water supply system withdrawing water from the Buffalo Aquifer. Actual volumes entered into this file are based on the average historic use data and remain constant for every year of simulation.

Delay (Return Flow) Table - Monthly (*.dly)

The monthly delay table file contains coefficients to lag return flows.

- Since, it was the intent to model the return flows as they historically occurred, the delay entered into this dataset is not used by the model. Nonetheless, the delay entered into this file accounts for return flows at the end of the same month the water was withdrawn.

Reservoir Target File - Monthly (*.tar)

The reservoir target file contains monthly targets for a reservoir's minimum and maximum contents.

- Calibration
    - Not required.
- Simulation
    - Target values were set for Lake Ashtabula that reflect the drawdown for flood parameters listed by the COE in the Baldhill Dam and Lake Ashtabula Sheyenne River Reservoir Regulation Manual.
    - The remainder of the targets set for the other reservoirs were set to mirror maximum pool volume year round.

  - Because of very small inflows, maximum pool targets were modified for Lake Traverse during the 1930s to allow water to spill over into Mud Lake. This was done to mimic what would happen during a drought.

Historic Reservoir EOM File - Monthly (*.eom)

This file contains monthly data for each year of the study period. This data is only used by the Base Flow module to simulate reservoir storage and evaporation impacts on gauged stream flows. It is used by the report module to compare simulated results to gaged observations.

- These data were collected for Lake Ashtabula only as all of the remaining reservoirs within the system either lack this data or operate as flow through structures showing an outflow the same as inflow minus evaporation.
- This dataset is not used during simulation and was considered to be inconsequential as the baseflow generated by the model was replaced by the naturalize flow database generated by the USGS after the calibration process.

Base Flow Data (*.rib)

Base flow data is used by the baseflow module to estimate base flows at river nodes that do not have historic records.

- This file was left blank and was not used.

Historic Streamflow File - Monthly (*.rih)

This file is used by the baseflow module to estimate Base flows at gauged and ungaged locations. The monthly historic streamflow file is also used by the report module to compare simulated results to gaged observations.

- Calibration
  - Flow data were entered directly from this historic flow database generated by the USGS for calculating the naturalized flow database (Emerson 2005).
- Simulation
  - This file was not altered during simulation except to add nodes with zero values to account for return flow nodes that were entered into the system and not used.

Historic Diversion File - Monthly (*.ddh)

This file is used by the baseflow module to estimate Base flows at gauged and ungaged locations. It is used by the report module to compare simulated results to gaged observations.

- Calibration
  - Historic records for withdrawals were entered based on 1979 to 2001 data collected from the North Dakota State Water Commission and the Minnesota Department of Natural Resources.

- Simulation
  - No changes were made to this data as it is used only for comparison purposes outside of the actual model runs.

Historic Well Pumping File - Monthly (*.weh)

This file is used by the baseflow module to estimate Base flows at gauged and ungaged locations. It is used by the report module to compare simulated results to gaged observations.

- Calibration
  - This file is a direct copy of the Well Demand File (*.wem).
- Simulation
  - This file is a direct copy of the Well Demand File (*.wem).

GIS File (*.gvp)

This file contains reference to files which contain GIS data related to structures and maps used by the Graphic User Interface.

- This file is used by the GUI to denote the coverages used for display and allows them to be referenced to datasets and turned on or off.
- This file also contains the reference to the directory that the GIS data are located in.
- Use of this graphical interface outside of this study effort will require the user to change the reference to match the new location of the GIS data directory.

Output Request (*.out)

This file contains data which will limit the extent of selected output file requests. To eliminate the need to type an output request file, one is automatically generated by the check option (-check) for every type of structure in the system.

Figure B.3.1 was included as a general example to assist the reader in understanding the general nomenclature used to name individual structures and permits within the model.

DivPermit749ND
- DivPermit – Diversion Permit
- 749 – Number assigned to this permit by the corresponding state.
- ND – The state the permit was issued.

DM749ND
- DM – Demand point (associated with the actual demands and decreed amounts of a permit).
- 749ND – The permit number used and the state located in.

DVDEB27.50A
- DV – Diversion Structure that is used by a permit as an intake on a stream.
- DEB27.50– is located in DEB 27 subsection .50 (about half way up the DEB).
- A – is listed alphabetically as the first diversion entered into the database for that subsection of that DEB.

IFDEB37.50
- IF – Minimum Instream Flow
- DEB37.50 is located in DEB 37 subsection .50 (about half way up the DEB).

IR27.50
- IR – Irrigation Node – used to reference the location of all irrigation withdrawals for each DEB.
- 27.50 – DEB 27, subsection .50

Rflow
- Return flow structure entered into the river network as a point to route return flows from wells during simulation.

RNDEB27.50
- RN – River Node – Used to designate both gaged structures and the end of each DEB
- DEB27.50 – is located in DEB 27 subsection .50 (about half way up the DEB).

RNDEB23.R1
- RN – River Node (This time used for a reservoir)
- DEB23 – located in DEB 23
- R1 – The first reservoir as you head upstream from the gage located at the end of that DEB.

EVASHTNET – Net Evaporation Station for Lake Ashtabula
EVTRAVNET – Net Evaporation Station for Lake Traverse
EVREDLNET – Net Evaporation Station for Red Lake Reservoir
EVORWLNET – Net Evaporation Station for Lake Orwell
EVMUDLNET – Net Evaporation Station for Mud Lake
EVWFAQNET – Net Evaporation Station for ASR – West Fargo Aquifer (0)
EVMAQNET – Net Evaporation Station for ASR – Moorhead Aquifer (0)

Figure B.3.1 – Nomenclature used by modeler within StateMod

While most files listed in the response file are common between differing model runs, some files are specific to that particular run being performed. For instance, the net evaporation file used during the calibration process (calibr8.eva) is the same one used in all the other model runs. Meanwhile the direct diversion demand file used for calibration is named Calibr8.ddm and the direct diversion demand file used in the "Current (2005) Water Demand (Base171)" model run is named Base1.ddm and is specific to only that modeling run. In most cases, the datasets retained the name given to them during the creation of either the calibration or the No Action modeling runs. Filenames were typically only changed when data within that file were changed to meet the specific need of the model run that it was associated with.

B.3.3 – Model Assumptions

While the assumptions used in modeling have been included in chapter three of the Needs and Options Report, this section is devoted to those items of concern considered to lengthy to include in the report text. Additionally, the reader can refer to Attachment B3 to review the *Surface Water Hydrology Model Configuration and Assumptions* document made available to the

Technical Team mid-way through the modeling effort. This attachment documents the differences between the modeling approach and assumptions used in this effort and those used during *Phase II; Appraisal of Alternatives to Meet Projected Shortages* (Reclamation 2000). There are some differences between this attachment and the documentation presented in chapter three because changes were made to the modeling approach after the release of this information. The assumptions in chapter three reflect the final approach to the modeling effort.

Return Flows

Because of the complexities involved with modeling return flows and their appropriate locations within the system, Reclamation combined the return flow volumes for each DEB. These volumes were returned to the system downstream of all water withdrawals for each DEB, just before its respective downstream gaging station. This approach was considered to be conservative as it does not allow other users within the same DEB to reuse the water before it leaves that DEB. Though conservative, this approach was considered reasonable because most major users are located in differing DEBs.

During the calibration effort, return flows within the model were based directly on historic record. StateMod requires that return flows be modeled as a percent of demand; however, this does not fit the historic trend within the valley where return flows sometimes exceed demands. This led to a negative percentage that the model did not allow for. To mathematically account for this, return flow values were modeled as imports during calibration. Upon recommendation from the StateMod software developer, CDSS (Colorado Decision Support System), return flows were converted to imports by placing them in the demand file as negative numbers. StateMod recognizes these values as an import and properly runs them through the equation to develop baseflow.

This method accurately accounts for the return flows during calibration. However, this method cannot be used during the simulation effort. To account for return flows during simulation, the consumptive use of the demands was set to 100%, meaning that all water taken from the system was used and no water was returned. Next, return flow wells were added to the system that simulated the volume of water that should be returned to the system as a volume taken from the ground and placed back into the surface water at the end of each DEB. These wells have a 0% consumptive use, and all water is passed directly to surface water.

The values used for return flows during the simulation of alternatives were calculated by averaging each month of the historic record. These values were then increased as a direct percent increase as compared to that increase for water demand for the same DEB.

The No Action model runs provided valuable information on the location of shortages within the system and was the base from which all other alternatives began their development. It is important to note that when water demands were not met during the No Action runs, return flows were to be reduced to account for consumptive use differences.

B.3.4 – Model Peer Review

Reclamation worked with the StateMod software developer, CDSS, during the initial setup of the model through running the baseflow for calibration. Ray Bennett (CDSS) was consulted with regularly during this time to ensure the model was set up correctly and the output was reflecting what was historically happening within the Red River Valley. Once baseflow was achieved and it was found to be within 0.5% of the naturalized flow database developed by the USGS (Emerson 2005), Reclamation began reconfiguring the model to perform simulation runs.

Simulation model runs differ from baseflow as they incorporate the use of predictive input, such as future demands, and rely on operation rights to control certain aspects of water routing. Reclamation, through consultation with the USGS, chose a No Action model run as a base from which to start developing all other runs. No Action was chosen because the features and restraints associated with it are also common to all the proposed alternatives. Proposed alternatives were created by adding features and operational rights to the No Action base.

With the No Action model run set as the base from which to develop all of the remaining model runs, Reclamation sought the assistance of the USGS and Ray Bennett (CDSS) during development. The No Action model run was developed, checked, and reviewed internally to verify it was operating correctly. However, because of the importance of this model run to all other modeling and to the outcome of this report, Reclamation contracted with CDSS to perform a peer review of the No Action model run. Results of this peer review are included as Attachment B4.

B.3.5 – Model Output

Introduction

Model output data available directly from StateMod are extremely voluminous in size and variety. When printed, a single "Direct and instream diversion monthly data" file is larger than this report and appendices combined. Additionally, the size of the electronic version of these files does not allow for them to be included on the CD.

Model output can be obtained at any time given the availability of the input files and the modeling software. This allows the model to be somewhat portable as the output data can be generated anywhere as long as the original input data files are available. All the input data used to compile this report have been included on the CD and the StateMod software is available at http://cdss.state.co.us/ftp/statemod.asp.

Given the immense amount of output data, this section provides a general overview of how they are generated with the model and what they include. Additional information regarding how the data are used for this report is also included.

Running the Model to Achieve Output

When StateMod and its GUI software are installed along with the corresponding input dataset files, the user can open a model run by selecting the correct response file from within the GUI. With the exception of the reference for GIS data, all dataset files listed in the response file must be located in the same directory as the response file itself. This allows the user to browse through different datasets from within the GUI in a single session.

It must be clearly understood that there are two distinctively different ways to perform model runs within the StateMod software. The first type of run is listed as "Baseflows." This type of model run is performed using historic data to create baseflow, also known as naturalized flow. This effort is not intended to be predictive and is generally performed before any simulations efforts are undertaken. The second type of run is listed as "Simulate." This type of model run performs calculations based on the naturalized flow dataset along with all of the predictive datasets that have been included to represent an alternative.

Running "Baseflow" produces a number of standard reports. Each of these reports can be used during the setup of the model to determine if it is operating as intended. Upon verifying the baseflow, the simulation model runs were developed based on a "No Action" base.

Output Files

A general description of each output file is included to aid in understanding what each file does. These output files are available for each model run depending on whether it was run for baseflow or for simulation. The format for some of the files has been included to give the reader an idea of how the files are structured.

Baseflow Module Output Files

There are four standard output files from the Base Flow Module; the Base Flow Information File (*.xbi), the Gaged Base Flow Estimate File (*.xbg), the Gaged and ungaged Base Flow Estimate File (*.xbm), and the Log File (*.log).

The **Base Flow Information** file (*.xbi) contains information associated with the base flow estimates but in a spreadsheet format to aid in reviewing the data. It contains the following data:

#	Column	Description
0	Year	Simulation Year
0	Mon	The first month specified in the control file.
0	Days	The number of days in the month.
0	River ID	River station ID
1	Gauged Flow	The streamflow provided in the stream flow file .
2	Import (-)	The total imports (indicated as negative diversion).
3	Divert (+)	The total of diversions upstream of the river ID.
4	Return (-)	The total of current and lagged return flows from upstream diversions and well pumping.
5	Well Dep (+)	The total of current and lagged stream depletions from wells (not adjusted for returns).
6	Delta Sto (+)	The total of upstream reservoir storage changes from data in the End of Month content file.
7	Net Evp (+)	The total of upstream net evaporation occurring at upstream reservoirs which result in a positive adjustment to the gauged flow.
8	Total Base Flow	The estimated base flow W/o(-) Base Flow. The estimated base flow with negative values set to zero.

The **Gaged Base Flow Estimate** file (*.xbg) contains base flow estimates at each gauge location provided in the Stream Station input file. This file is typically used to allow humman impacts to be removed from gaged data prior to filling gaps using a technique such as regression. It contains the following data:

Column	Description
Year	Simulation year

ID	River station ID
Oct	Base flow in Oct (the first month specified in the control file)
Nov - Dec	Same as above for each month of the year
Total	Total annual flow for the year
Repeat	For each River ID and year

The **Base Flow Estimate for Model Input** file (*.xbm) contains gaged and ungaged data in the same format as the gaged base flow estimate file (*.xbg). This file is commonly used as an input file to the Simulate Module.

NOTE: This is the file that was replaced with the USGS naturalized flow database information before beginning simulation model runs.

The **Log** file (*.log) contains a log of the base flow module's operation. Its output file is named *.log.

Simulate Module Output Files

There are seven standard output files from the Simulate Module; (1) the Diversion Summary File, (2) the Instream Flow Summary File, (3) the Well Summary File, (4) the Reservoir Summary File, (5) the Operations Summary File, (6) the Structure Summary File, and (7) the Log File.

The **Demand Summary File (*.xdd)** describes diversion and stream flow data at all river nodes. For nodes with stream gages, only the columns containing hydrology data described below (Upstream Inflow, Reach Gain, Return Flow, River Inflow, River Outflow) have non zero values. Nodes with reservoirs are similar to stream gage nodes but include the column River Divert, which may be positive if the reservoir diverts or negative if the reservoir releases. Instream reach data is printed for the upstream node and represents the minimum diverted within the reach. For detailed analysis, file *.xir, provides detailed data for each node within the instream flow reach.

The header of the Demand Summary File (*.xdd) describes the structure ID, account, name, the administration number, on/off switch, owner, and decreed amount for each water right located at this river node. It also contains a time series for the following:

#	Column	Description
General		
0	Str ID	Structure ID
0	Riv ID	River node ID
0	Year	Year of the simulation
0	Mo	Month of the simulation
Demand		
1	Total Demand	Structure Demand provided in the demand files Note, if demand data are provided as a consumptive value; total demand is adjusted using a surface water efficiency.
2	CU Demand	Consumptive Demand Note, if a consumptive demand file (*.ddc) is provided this value is printed. If a consumptive demand file is not provided this value is calculated from demand and efficiency data.
From River by		
3	Priority	Water Supply from the river by a priority diversion (standard and operation type 11 diverting structure)

4	Storage	Water Supply from the river by a storage release (operation type 1 or 2 diverting structure)
5	Exchange	Water Supply from the river via an exchange (operation type 4)
From Well		
6	From Well	Water Supply from wells to the structure at this river node.
From Carrier by		
7	Priority	Water Supply from a carrier by a priority diversion (operation type 3 or 11 destination structure)
8	Sto_Exc	Water Supply from a carrier by a storage release or exchange (operation type 2 or 6 destination structure if not diverting)
Other		
9	Carried Water	Water Supply diverted for carrier purposes. The source will be presented as a from river by priority, from carrier by priority, or from river by storage.
10	From Soil	Water supplied from the soil zone
11	Total Supply	The sum of all water supplies (does not include Carried Water)
Shortage		
12	Total Short	The difference between total demand and total supply
13	CU Short	The difference between the CU demand and CU
Water Use		
14	CU	Consumptive use of the water supply
15	To Soil	Water diverted to the soil zone.
16	Total Return	Total return flow (note the amount that will return over all return time periods)
17	Loss	Water diverted that is not consumed, to soil or returned. Typically is non zero when the sum of return locations or delays do not equal 100%.
Station In/Out		
18	Upstream Inflow	Inflow from an upstream node to this reach
19	Reach Gain	Inflow from gains to this node as described in stream inflow file
20	Return Flow	Inflow from returns to this node. Note, this term includes returns from both surface and well supplies in the current time step.
21	Well Depletion	Depletion caused by pumping in prior time steps Note, this term impacts the river inflow (water supply) this month.
22	To_From GWS	Inflow or outflow to ground water storage. Note, this term is positive when ground water storage is required to offset pumping depletions in the current month that cause the river to go negative. This term is negative when stream flow is required to offset water originating from groundwater storage in prior months.
Station Balance		
23	River Inflow	The sum of inflows to this node
24	River Divert	The sum of water supplies diverted at this node (does not include From Carrier by Storage or From Carrier by Priority)
25	River by Well	The depletion caused by a well in this month Note, this term is similar to a diversion in the current month.
26	River Outflow	Outflow from this node
27	Avail Flow	Available flow at this river node. This is the amount of water available to a potential user that is the most junior in the basin.

The **Reservoir Summary File (*.xre)** describes diversion, release, storage and stream flow data at river nodes that contain a reservoir. The header describes the reservoir ID, account, name, administration number, on/off switch , owner, and decreed amount for each water right located at this river node. It also contains a time series for the following:

#	Column	Description
General		
0	River ID	River node ID
0	Account	Reservoir account (0 is the total)
0	Year	Year of the simulation

0	Mo	Month of the simulation
1	Initial Storage	Storage at the beginning of month
Water Supply From River by		
2	Priority	Water Supply from the river by a priority diversion (standard and operation type 11 diverting structure)
3	Storage	Water Supply from the river by a storage release (operation type 1 or 2 diverting structure)
4	Exchange	Water Supply from the river by an exchange (operation type 4)
Water Supply From Carrier by		
5	Priority	Water Supply from a carrier by a priority diversion (operation type 30 or 11 destination)
6	Storage	Water Supply from a carrier via a storage release (operation type 2 or 6 destination structure if not diverting)
7	Total Supply	The sum of all water supplies
Water Use from Storage to		
8	River for Use	Releases for downstream use (Operation type 1 and 2)
9	River for Exc.	Releases for exchange (Operation type 4)
10	Carrier for Use	Releases to a carrier canal (Operation type 3)
11	Total Release	Total of all releases
Other		
12	Evap	Net evaporation
13	Seep and Spill	Seepage and spills
14	EOM Content	End of Month Content
15	Target-0	For the total reservoir (account 0) Target Storage Stor-n Limit for accounts (account n) their storage limit
16	BOM Decree Limit	The remaining limit to the one fill rule at the beginning of the month
Station Balance		
17	River Inflow	The sum of inflows to this node
18	Total Release	Total release
19	Total Supply	Total reservoir supplies
20	River by Well	The depletion caused by a well in this month. Note, this term is similar to a diversion in the current month.
21	River Outflow	Outflow from this node

Other Simulation Files

- The **Operation Summary File (*.xop)** provides a matrix of diversion or release activities associated with each operating right. This file is reviewed extensively after simulation to make certain that operational rights are performing as intended. Data from this file can also be used to assist in sizing of features.
- The **Instream Reach Summary File (*.xir)** provides a matrix of total supply for each node associated with an instream flow reach.
- The **Well Reach Summary File (*.xir)** provides a matrix of total supply for each node associated with a well structure.
- The **Log** file (*.log) contains a log of the simulate module's operation. Its output file is named *.log.
- The **Structure Summary File (*.xss)** is a standard output that describes structure data related to area, demand, surface water, ground water, soil storage, consumptive use, and returns.
- The **Well Summary File (*.xwe)** describes the structure data (demand, surface supply, ground supply and shortage), use of water (CU, return, and loss) and source of water (river, groundwater storage, and salvage) for every structure that has a well.

During the modeling analysis this file contained both the well operations for Moorhead and those that were entered into the system to assist in simulating return flows.

- The **Daily Well Station File (*.xwy)** provides the same data as the monthly well station file (.xwe) but on a daily time step.

Reviewing several of the output files allows the modeler to determine if the model run is configured properly. Of particular importance are the *.xdd file showing detailed node accounting, *.xop file showing the routing of water via operational rights, and the *.xre file showing reservoir operating characteristics.

Report Module Output Files

There are multiple standard reports that can be generated by StateMod once simulation has been performed.

- The **Basin Water Balance Report (-xwb)** provides a description of the inflows, outflows, and storage changes.
- The **Water Right Report (-xwr)** provides a sorted list of water rights.
- The **Standard Report (-xst)** produces five files; the Demand Summary File (*.xdd), the Reservoir Summary File (*.xre), the Instream Reach Summary File (*.xir), the Well Summary File (*.xwe), and the Operation Right Summary File (*.xop). These are the same files produced by the simulate option and are described above.
- The **Node Accounting Report (-xn)** produces two files: the Detailed Node Accounting (*.xnm) file and Summary Node Accounting (*.xna) file. Both provide the same results as the standard report but are sorted by the stream order provided in the river network file (*.rin). The detailed node accounting file provided data for every month of the study period while the summary provides an annual average.
- The **Diversion Graph Report (-xdg)** provides the same data presented in the diversion and stream gage summary report but it is formatted for easy graphing by a spreadsheet or other plotting package (e.g. XMGR for the workstation). Its output file is named *.xdg.
- The **Reservoir Graph Report (-xdg)** provides the same data presented in the reservoir summary report but it is formatted for easy graphing by a spreadsheet or other plotting package (e.g. XMGR for the workstation). Its output file is named *.xrg.
- The **Well Graph Report (-xdg)** provides the same data presented in the well summary report but it is formatted for easy graphing by a spreadsheet or other plotting package (e.g. XMGR for the workstation). Its output file is named *.xwg.
- The **Diversion Comparison Report (-xdc)** compares the total diversion estimated by the model to the gauged record if available in the historic diversion file (*.ddh). Its output file is named *.xdc.
- The **Reservoir Comparison Report (-xrc)** compares the end of month contents estimated by the model to the gauged record if available in the historic end of month content file (*.eom). Its output file is named *.xrc.
- The **Well Comparison Report (-xwc)** compares the total well pumping estimated by the model to the gauged record if available in the historic well pumping file (*.weh). Its output file is named *.xwc.

- The **Stream Comparison Report (-xsc)** compares the total diversion estimated by the model to the gauged record if available in the historic streamflow file (*.xsc). Its output file is named *.xcc.
- The **Consumptive Use Water Supply Report (-xcu)** provides four output files; *.xcu, *.xsu, *.xsh, and *.xwd. The CU summary (*.xcu) presents the total diversion by each structure in a special format required by the CRDSS consumptive use model. The supply summary (*.xsu) presents the total supply to each structure. The shortage summary (*.xsh) presents the shortage associated with each structure. The water district summary (*.xwd) presents the total diversion by water district as determined by combining all structures that have the first two digits of each ID the same.
- The **River Data Summary Report (-xrx)** provides a summary of data provided by river node. Its output file is named *.xrx.
- The **Selected Parameter Report (-xsp)** provides a printout of a selected parameter (e.g. Total_Diversion) available to the standard diversion (*.xdd), reservoir (*.xre) and well (*.xwe) output files. It reads the Output Request file (*.out) to determine the type of output (e.g. diversion), parameter (e.g. Total_Diversion), and ID to print. It creates two output files with the same data in a different format. The output formatted into a matrix is named *.xsp while the output formatted into a column is named *.xs2. To get a list of parameters for each data type (diversion, stream, instream flow, reservoir, or well) enter a dummy variable under parameter type (e.g. x) and review the log file.
- The **Daily Selected Parameter Report (-xds)** provides a printout of a selected parameter (e.g., Total_Diversion) available to the standard daily diversion (*.xdy), reservoir (*.xry) and well (*.xwy) output files. It reads the Output Request file (*.out) to determine the type of output (e.g., diversion), parameter (e.g., Total_Diversion), and ID to print. It creates two output files with the same data in a different format. The output formatted into a matrix is named *.xds while the output formatted into a column is named *.xd2. To get a list of parameters for each data type (diversion, stream, instream flow, reservoir, or well) enter a dummy variable under parameter type (e.g. x) and review the log file.
- The **Log** file **(*.log)** contains a log of the report module's operation. Its output file is named *.log.

Data Check Output Files

There are seven standard output files from the Data Check Module; Base Flow File (*.xcb), Direct Demand File (*.xcd), Instream Demand File (*.xci), Well Demand File (*.xcw), Water Right List file (.xwr), Output Request File (*.xou), and Log File (*.log). The first four files are self explanatory and describe the base flow, direct flow demand, instream flow demand, and well demand at each river node. The water right list file is the same as that produced by the Report Module. The Output Request file provides a list of structures which may be used as an input file for data requests by structure. The log file contains a log of the data check module's operation.

Shortages from Model Output

Of particular interest is one of the four Consumptive Use Water Supply Report files (*.xsh) that shows the shortages for each diversion on a monthly time step. This file is used to compile varying shortage statistics that exist when running the Baseline and No Action model runs. It is also used to verify that a model run for a proposed alternative is not shorting demands within the service area.

Baseline Results

At the recommendation of the Technical Team, Reclamation performed a model run that simulated the state of the Red River Valley in its current level of development under conditions similar to a 1930s style drought. Though post processing of the *xsh file, the results of this model run show a shortage for the Red River Valley in North Dakota and Minnesota for each and every year of a 1930s style drought. The worst year results are shown in the table B.3.6.

Table B.3.6 – Baseline Shortages

Location	Worst Year	Drought Duration Total
MR&I Shortage in the Service Area	**7,000 acre-feet** (1936)	42,000 acre-feet
Red River Valley Wide Shortage in North Dakota and Minnesota	67,000 acre-feet (1934)	445,000 acre-feet

The Red River Valley Water Supply Project's primary objective is to meet the MR&I shortages in the service area. Meeting the shortage for entities outside the service area is not authorized by DWRA. The value for valley wide shortages was calculated to provide an understanding of the shortages the valley would encounter as a whole.

The numbers presented show that with the current level of demand the Red River Valley will experience real MR&I shortages, which are overshadowed by the shortage experienced valley wide, if they were to encounter a 1930s style drought in the future. Additionally, these numbers represent worst month shortages and do not show the full impact of shortages seen on a daily time step.

Table B.3.7 Baseline - Percent Short on a Monthly Time Step

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
MR&I in the Service Area	41%	**46%**	38%	0%	5%	6%	12%	20%	26%	33%	33%	40%	**16%**
Red River Valley in North Dakota and Minnesota	47%	53%	**71%**	3%	42%	33%	49%	56%	52%	48%	47%	52%	**40%**

Monthly time step data were developed by comparing the demands to the shortages at a given location. Although as table B.3.7 shows, the service area encounters an averaged 16% yearly shortage of their 2005 needs during the worst year of a 1930s drought, the real concern is the range of shortages on the monthly time step. In February, the MR&I shortage in the service area is 46% of the demand. The lower percentages during the late spring and early summer months are the result of spring runoff and storage in the valley. The percent short grows in the fall and continues to increase over the winter in direct relation to the depletion of storage. A graphical representation of table B.3.7 can be found in figures B.3.2 and B.3.3.

It is also very important to note that these shortages do not take into consideration the effect of daily peaking. Volumetrically, the shortage for each month stays generally the same when looking at a daily time step. However, monthly figures are based on the average day. The percent short would be elevated if values were shown on a daily time step which includes peak day.

It becomes increasingly difficult to reduce these shortages through water conservation and drought contingency measures because they occur during times of the year when reductions to outdoor use and curtailing of lawn watering is difficult at best, given the northern climate in which the service area is located.

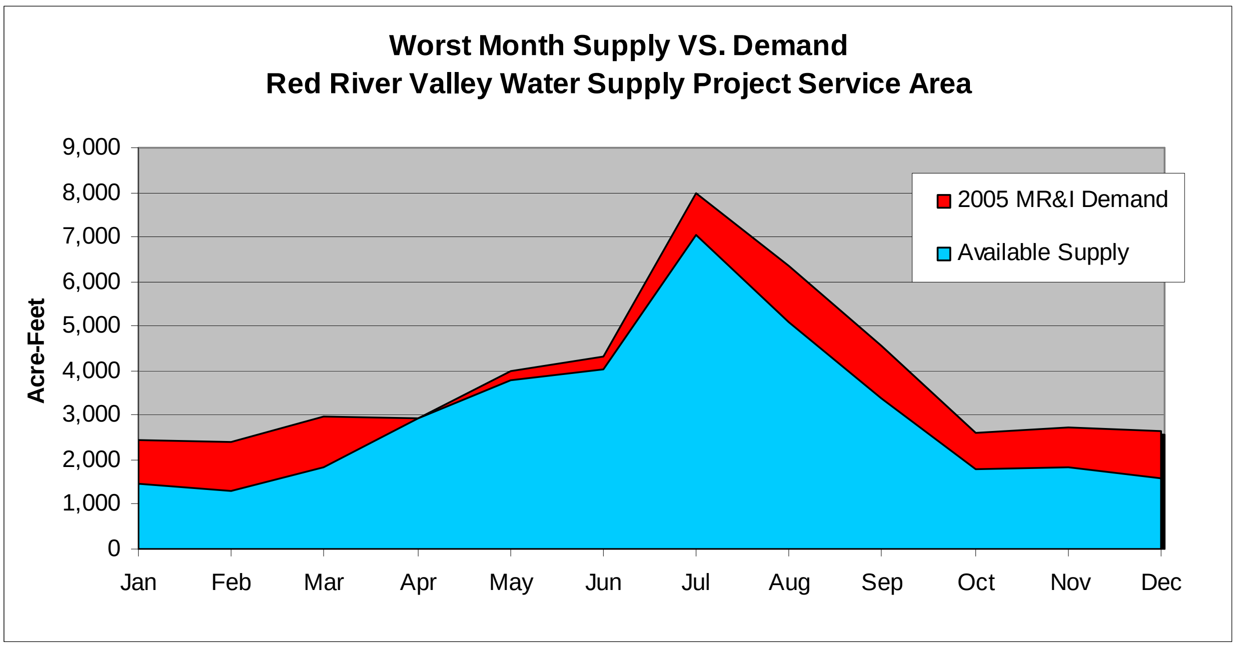


Figure B.3.2 – Baseline - Supply vs. Demand for the Project Service Area

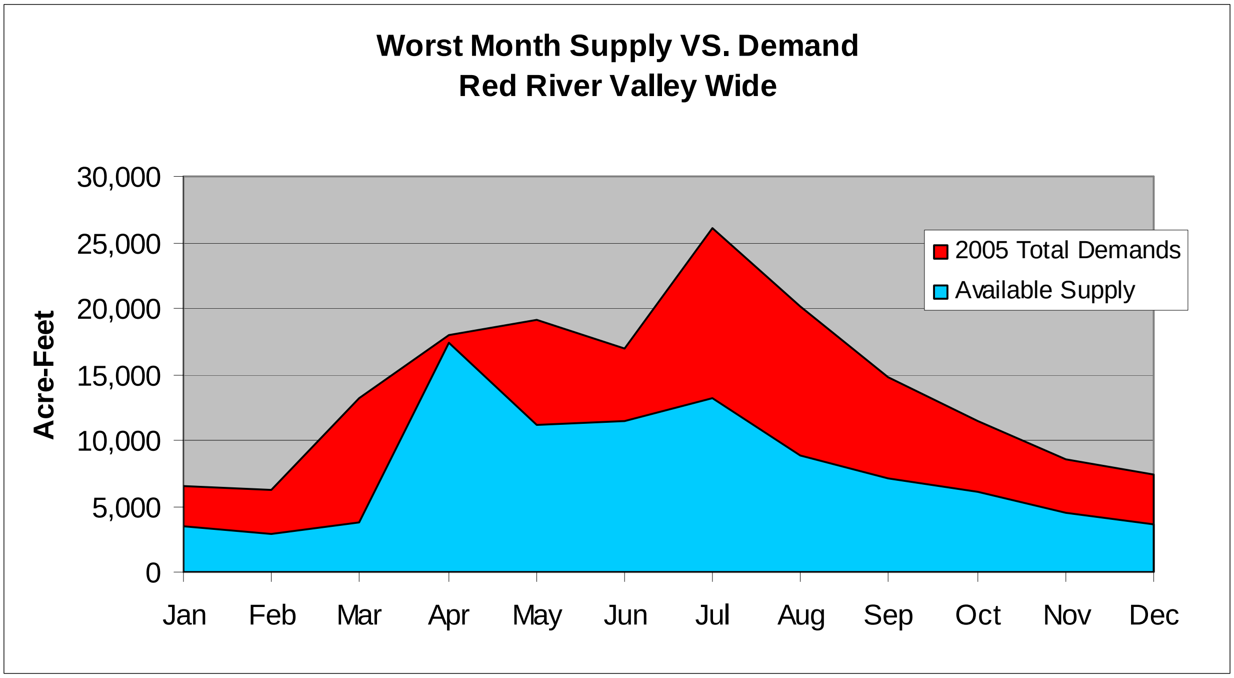


Figure B.3.3 – Baseline – Supply vs. Demand - Red River Valley Wide

No Action Shortage Results

The No Action model runs were not included in this analysis as alternatives. Rather, they are included because they form the base model runs from which all other alternative model runs were constructed. They also provide a good indication of the shortages that would be encountered in the future without a project. This was useful in configuring alternatives that could overcome these shortages.

Table B.3.8 – No Action Shortages – Scenario One

	Location	Worst Year	Drought Duration Total
Scenario One	**MR&I Shortage in the Service Area**	**36,000 acre-feet** (1934)	219,000 acre-feet
	Red River Valley Wide Shortage in North Dakota and Minnesota	98,000 acre-feet (1934)	617,000 acre-feet

Table B.3.9 – No Action Shortages – Scenario Two

	Location	Worst Year	Drought Duration Total
Scenario Two	**MR&I Shortage in the Service Area**	**53,000 acre-feet** (1934)	354,000 acre-feet
	Red River Valley Wide Shortage in North Dakota and Minnesota	115,000 acre-feet (1934)	750,000 acre-feet

Table B.3.10 –Percent Short – Scenario One

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
MR&I in the Service Area	72%	**74%**	67%	0%	8%	9%	52%	57%	67%	68%	69%	72%	**40%**
Red River Valley in North Dakota and Minnesota	67%	72%	**77%**	3%	38%	29%	57%	64%	65%	62%	65%	70%	**40%**

Table B.3.11 –Percent Short – Scenario Two

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
MR&I in the Service Area	72%	73%	**89%**	8%	9%	37%	51%	60%	63%	68%	68%	72%	**41%**
Red River Valley in North Dakota and Minnesota	66%	70%	**86%**	7%	35%	41%	59%	69%	65%	62%	64%	69%	**48%**

At first glance the numbers highlighted in table B.3.11 appear to be inconsistent with Baseline or No Action Scenario One because the highest percent short value for the entire Red River Valley is lower than that for the service area. However, the dynamics of when and how much water the users outside the service area are demanding shifts the shortages to differing times of the year. This is especially true when the demands for irrigation which decline the end of September, are factored in. At this point, the demand is comprised mainly of those from within the service area and those that have senior water rights to natural flows. This forces the percent short to be greater for the service area as compared to the entire valley.

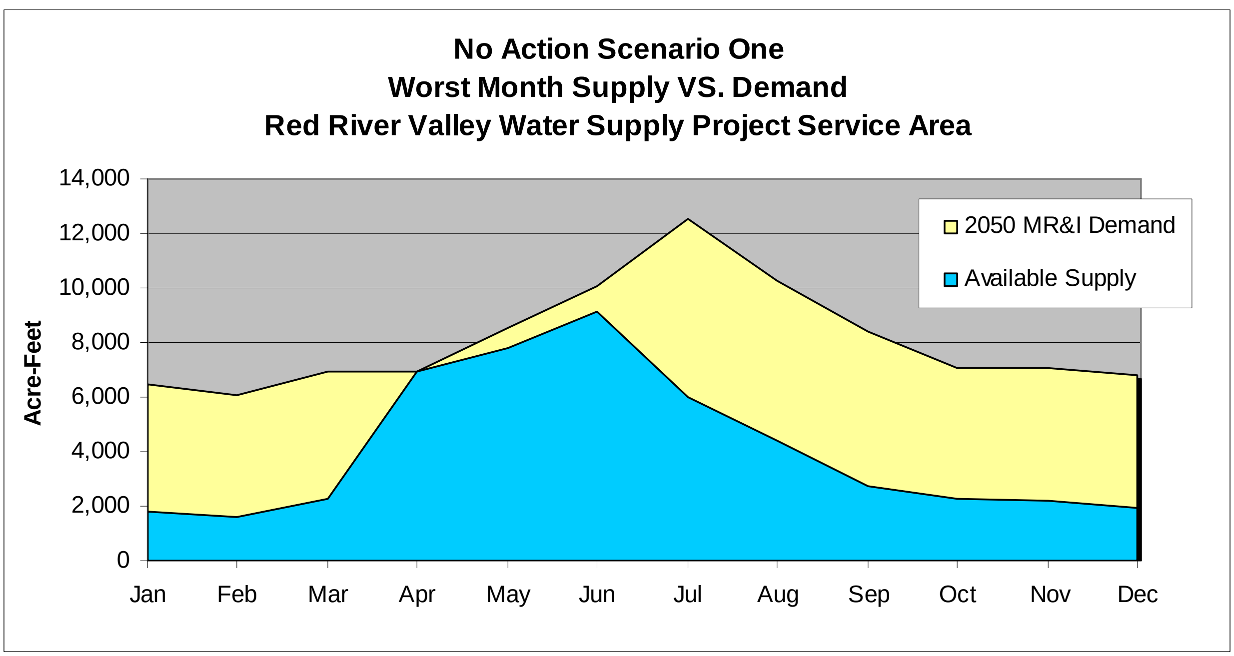


Figure B.3.4 – No Action Supply vs. Demand for the Project Service Area (Scenario One)

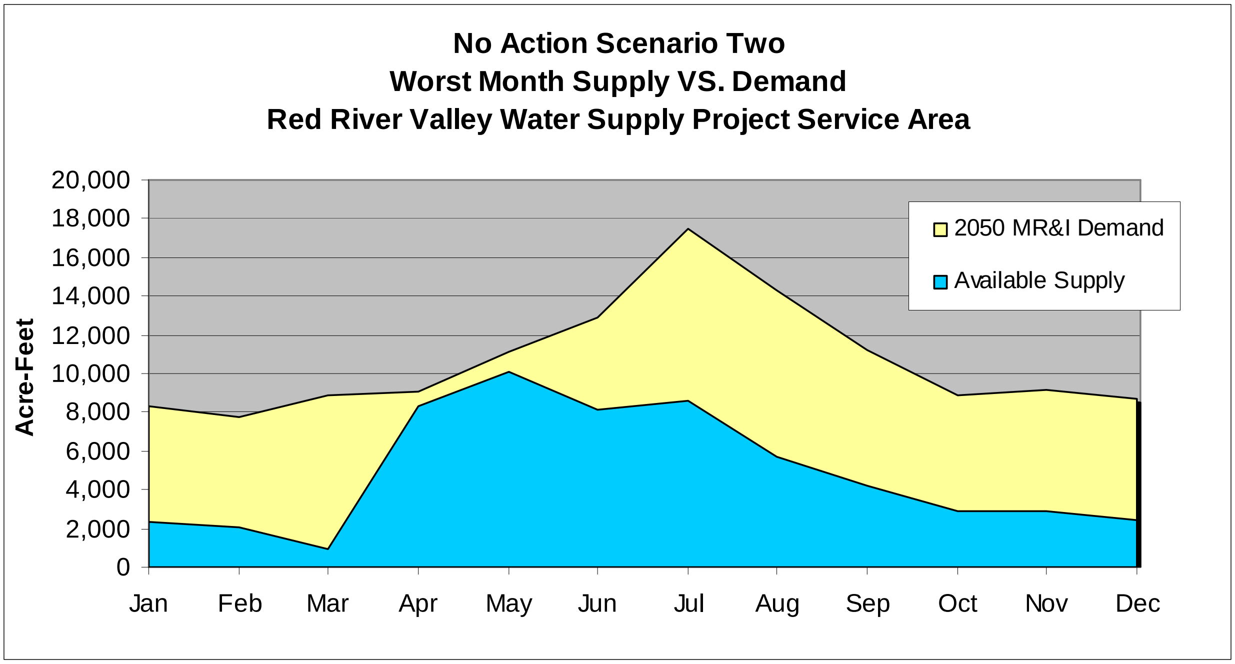


Figure B.3.5 – No Action Supply vs. Demand for the Project Service Area (Scenario Two)

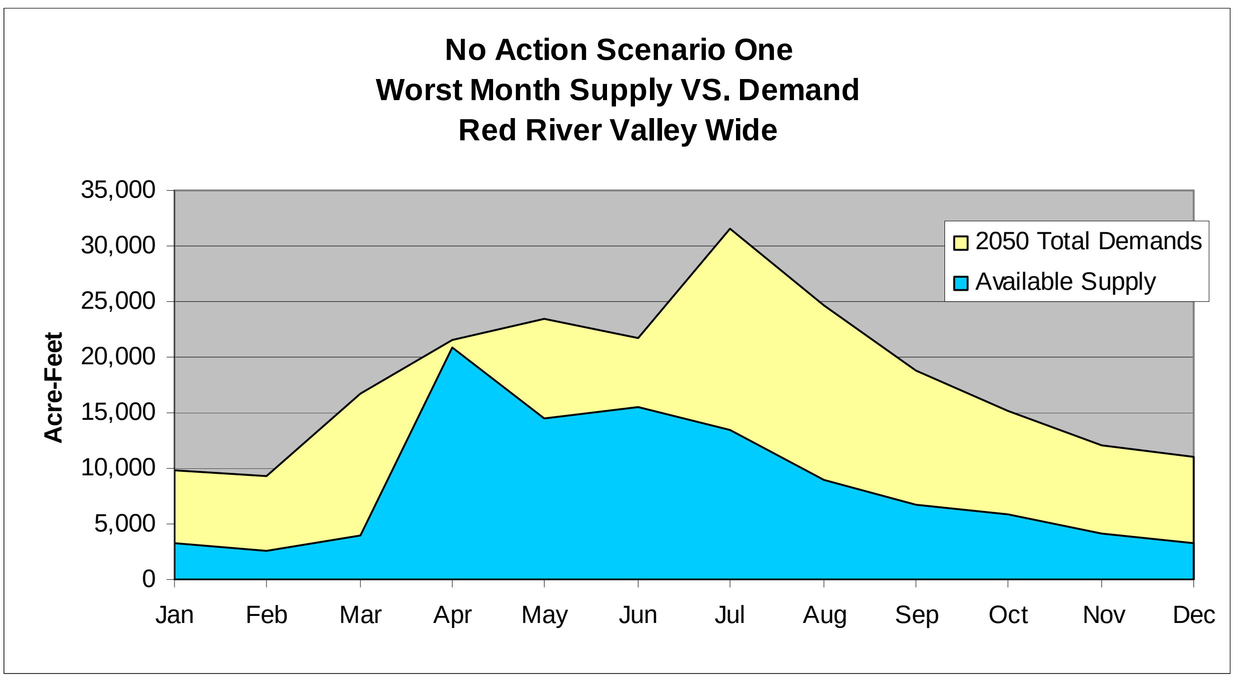


Figure B.3.6 – No Action Supply vs. Demand for the Entire Red River Valley - Scenario One

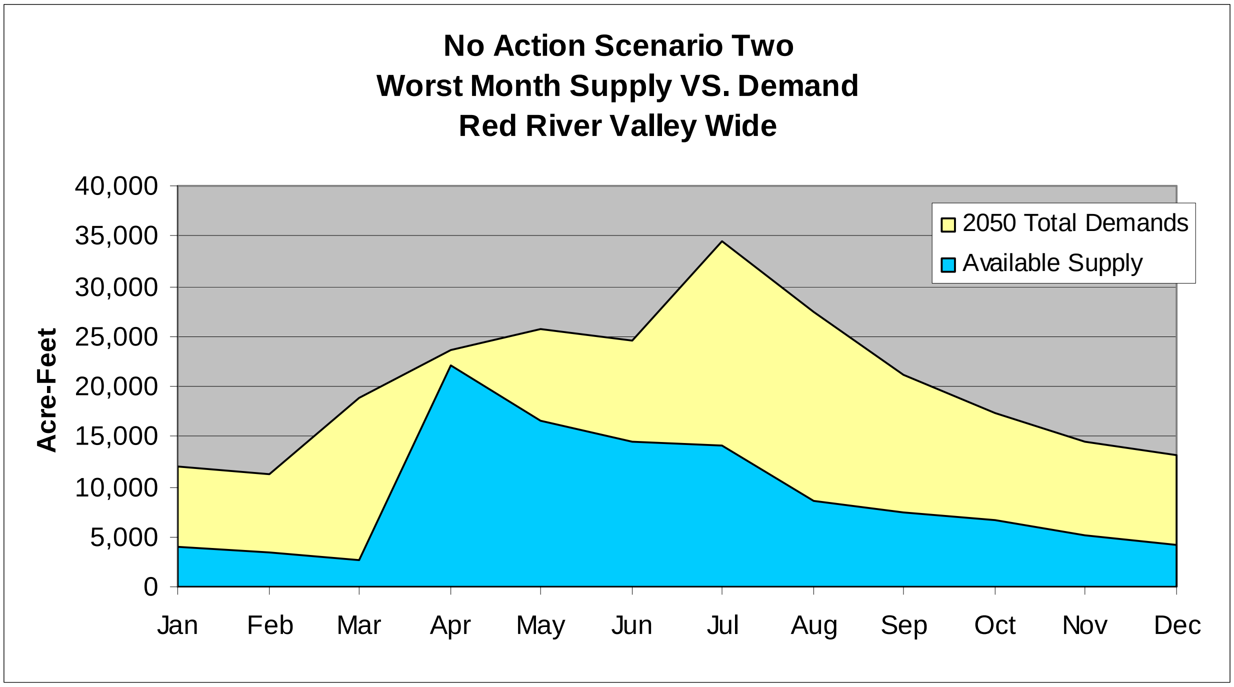


Figure B.3.7 – No Action Supply vs. Demand for the Entire Red River Valley - Scenario Two

Storage Volume

Lake Ashtabula supplies allocated water to the major MR&I users in the North Dakota portion of the Red River Valley. The reservoir volume output data from the model for Lake Ashtabula are key to understanding the dynamic of each model run. Of importance is the 28,000 acre-foot volume of water designated by the COE for the Fish and Wildlife Conservation Pool. As the reservoir begins to reach this volume, storage in the reservoir is depleted and those MR&I systems dependant on the storage begin to show shortages.

During the review of the model output, the 28,000 acre-foot volume became a good indicator as to the health of the water supply in the system. Therefore, this volume became the benchmark from which all action alternatives were optimized and ultimately sized. When this volume was not maintained while modeling an alternative, the system was either reconfigured or the features were resized. Conversely, features were also resized when volumes in the lake were consistently larger than this mark during a drought. Figures B.3.8-B.3.23 were plotted from the model output to show how each alternative affected the volume of Lake Ashtabula.

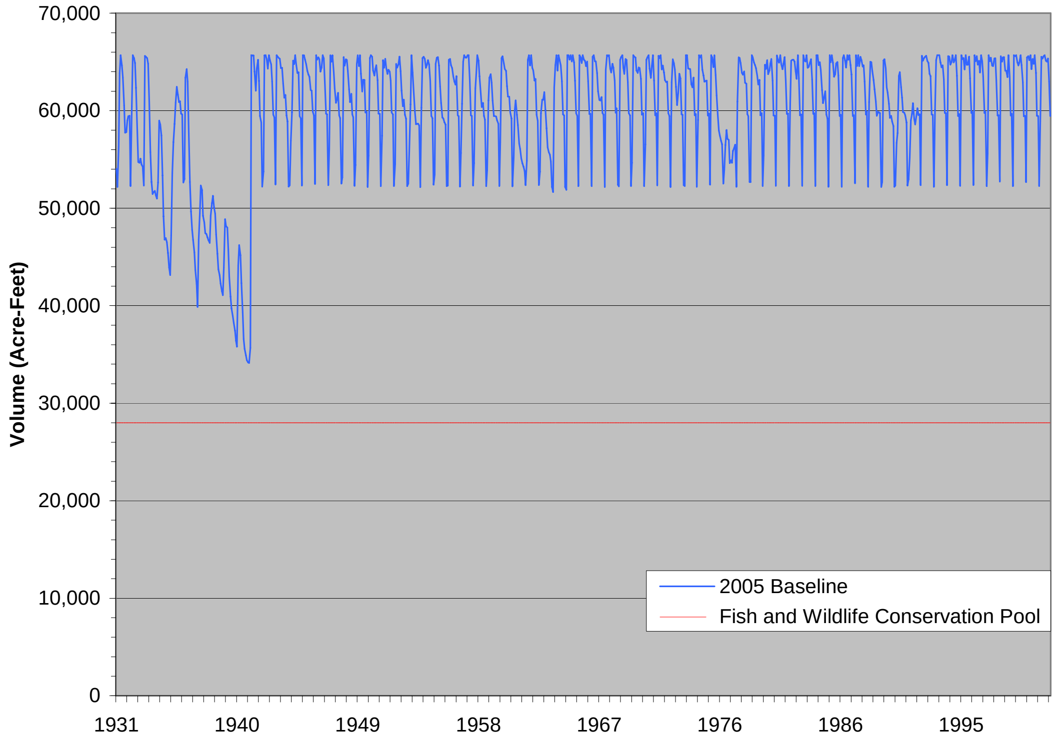


Figure B.3.8 – Baseline End of Month Volumes for Lake Ashtabula

The volume of Lake Ashtabula does not drop below the 28,000 acre-foot pool during the Baseline model run because withdrawals were restricted below the target and Thomas-Acker allocations were enforced. Shortages were encountered.

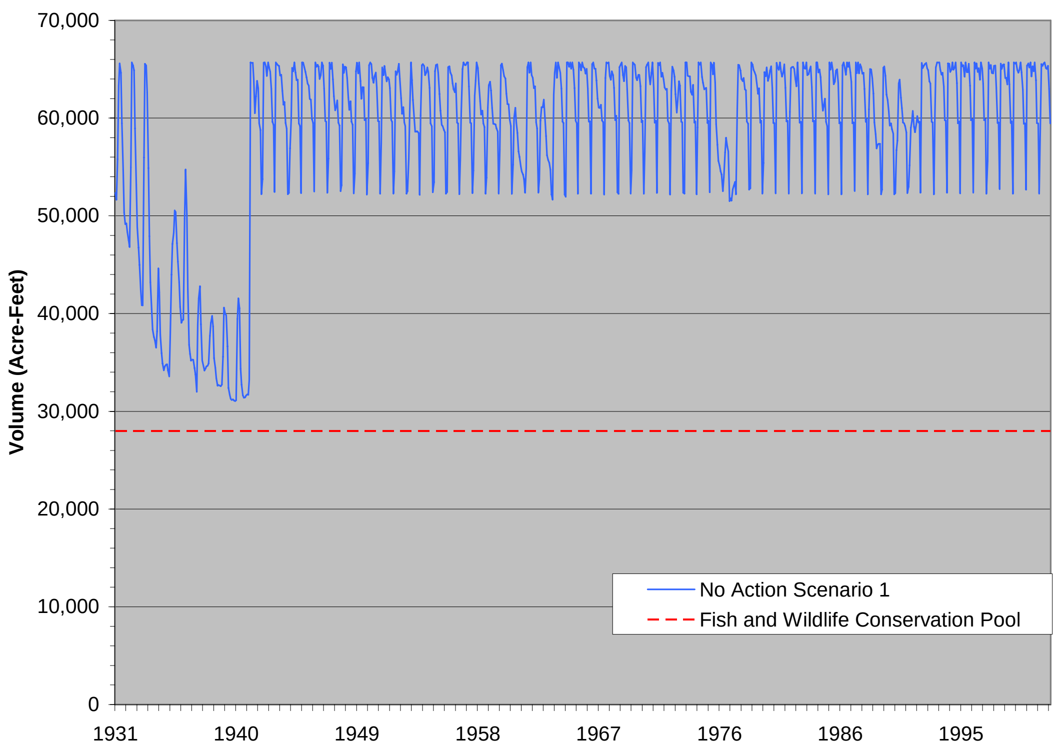


Figure B.3.9 – No Action End of Month Volumes for Lake Ashtabula – Scenario One

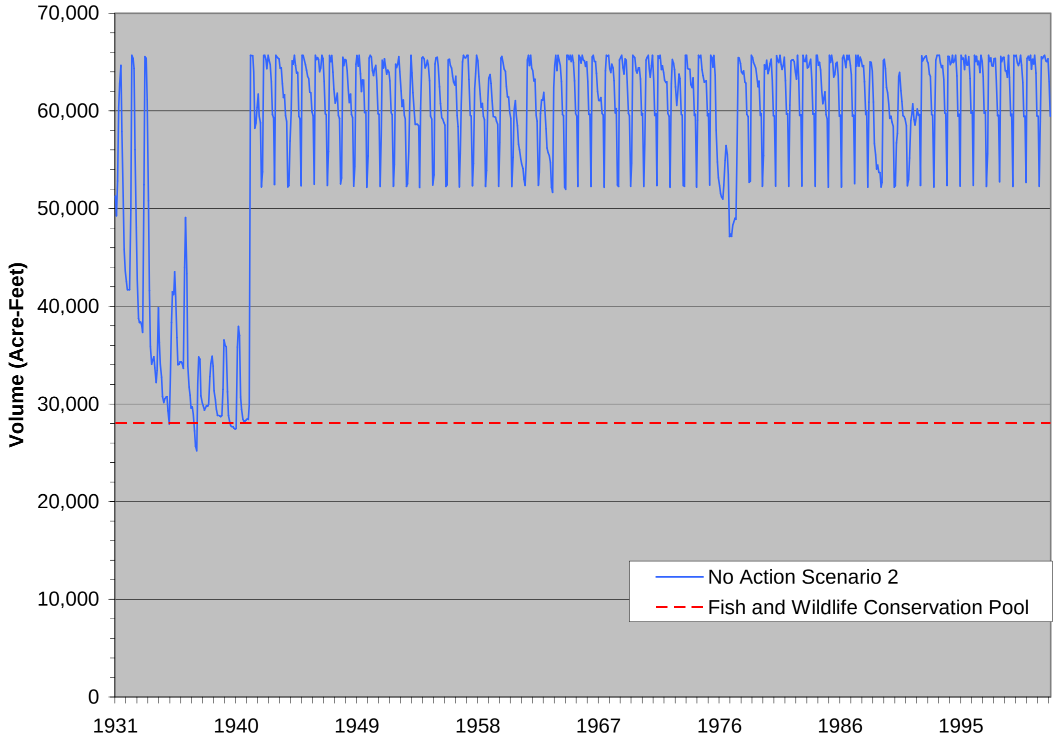


Figure B.3.10 – No Action End of Month Volumes for Lake Ashtabula – Scenario Two

No Action maintains the operational rights associated with Thomas-Acker and does not allow the withdrawal of water by permit below the 28,000 acre-foot target.

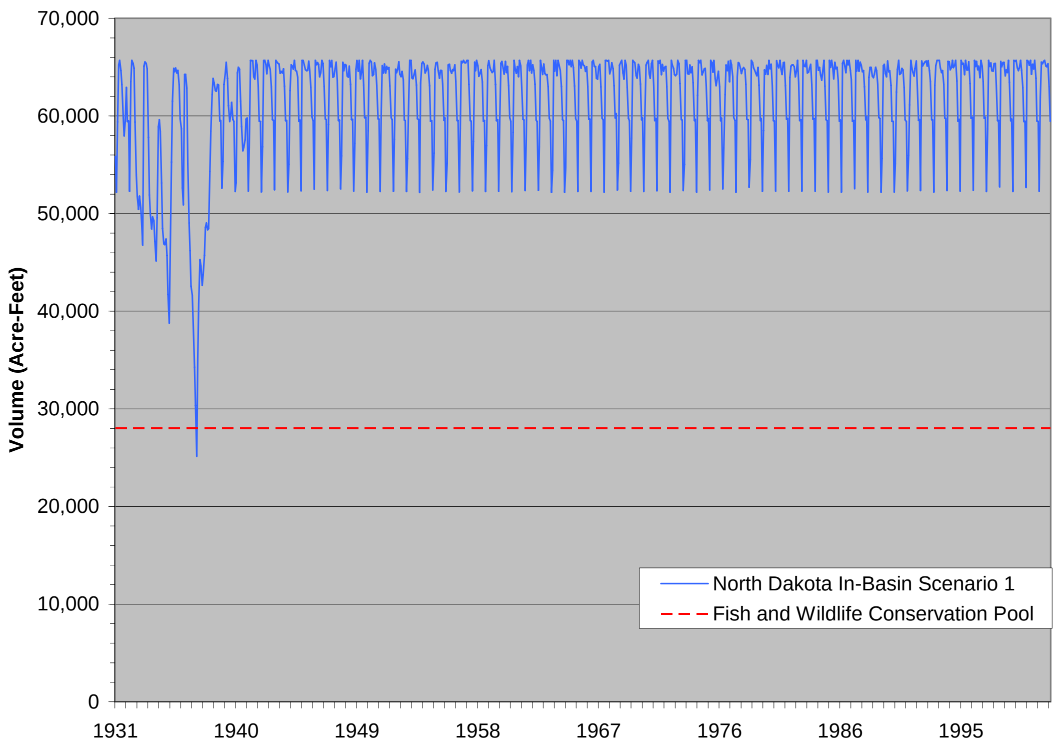


Figure B.3.11 – North Dakota In-Basin End of Month Volumes for Lake Ashtabula – Scenario One

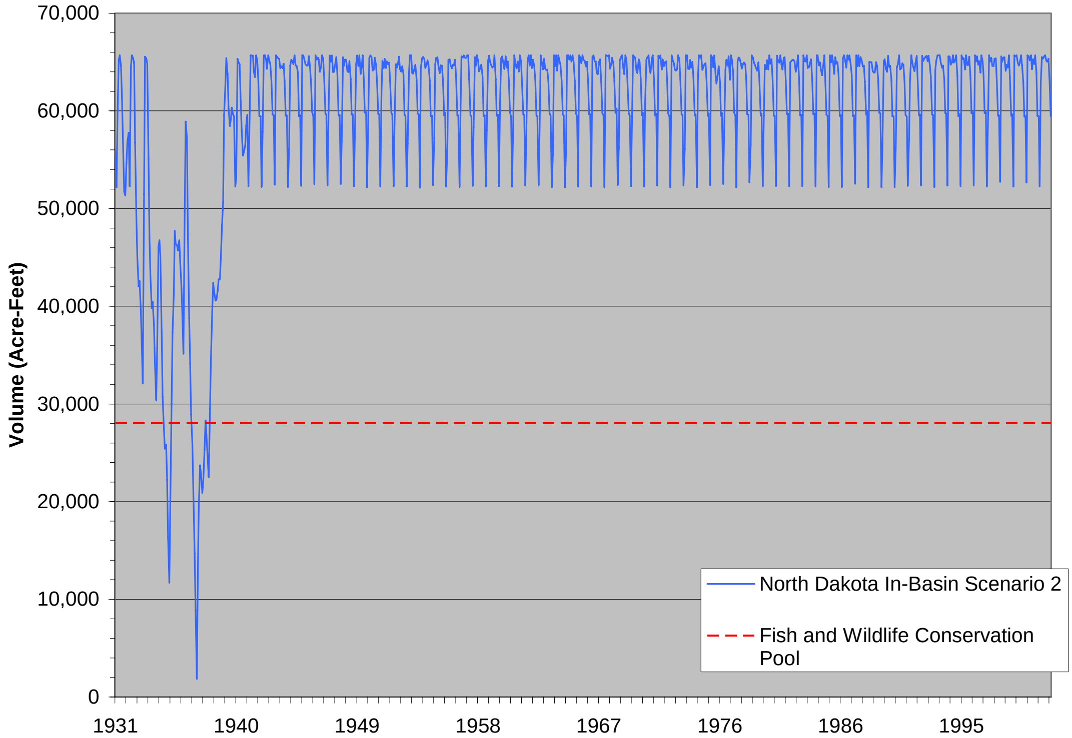


Figure B.3.12 – North Dakota In-Basin End of Month Volumes for Lake Ashtabula – Scenario Two

It is important to note that the action alternatives do not incorporate the Thomas-Acker plan. Additionally the North Dakota In-Basin alternative is not capable of maintaining the 28,000 acre-foot target beyond what is shown even when features were increased in size.

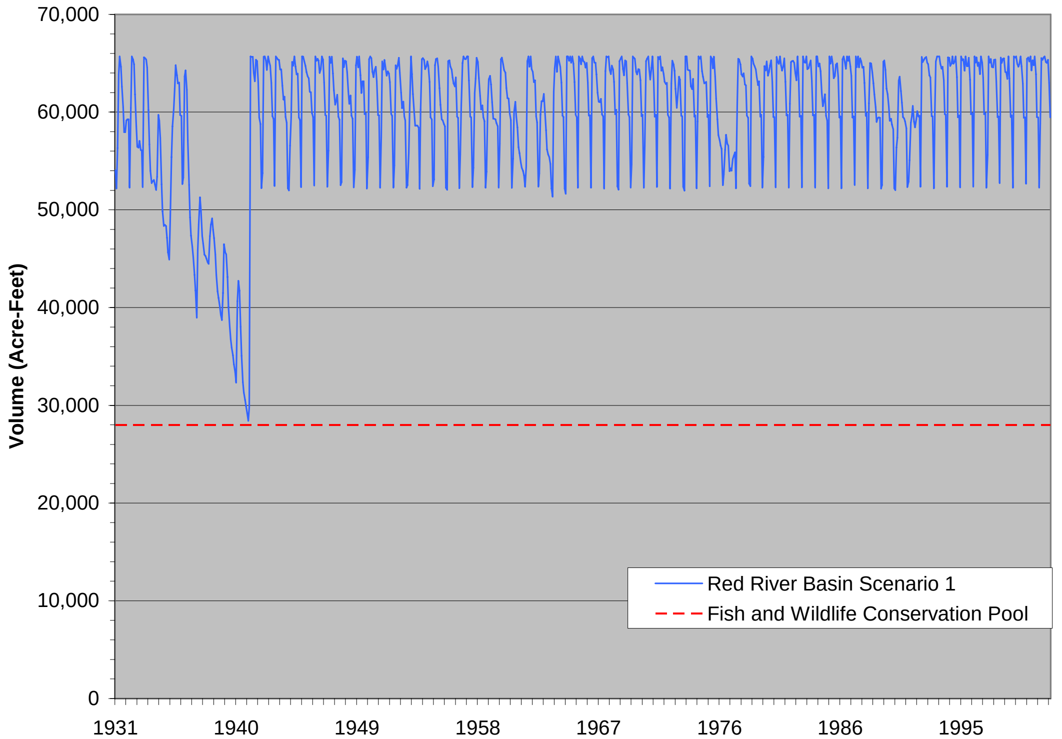


Figure B.3.13 – Red River Basin End of Month Volumes for Lake Ashtabula – Scenario One

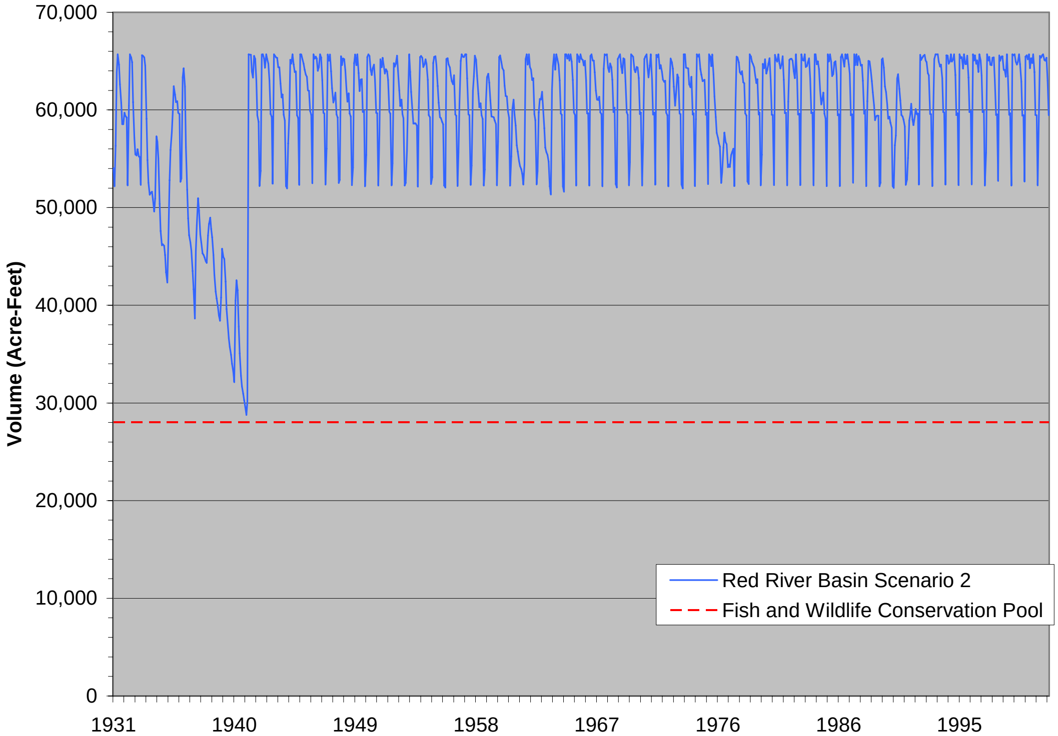


Figure B.3.14 – Red River Basin End of Month Volumes for Lake Ashtabula – Scenario Two

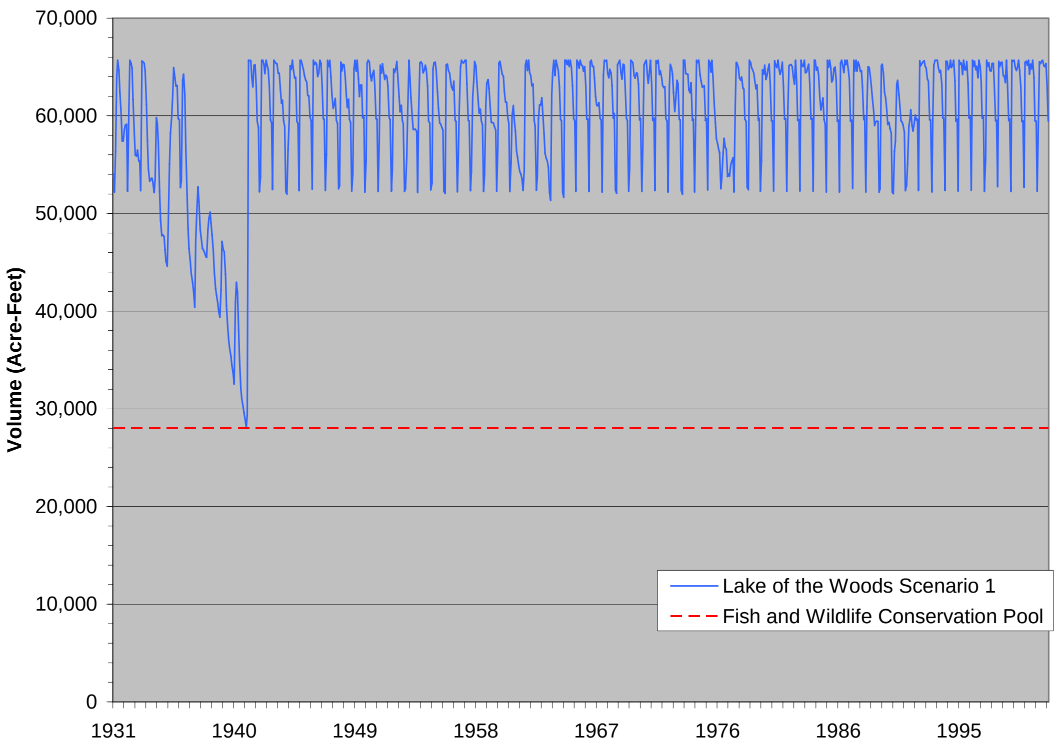


Figure B.3.15 – Lake of the Woods End of Month Volumes for Lake Ashtabula – Scenario One

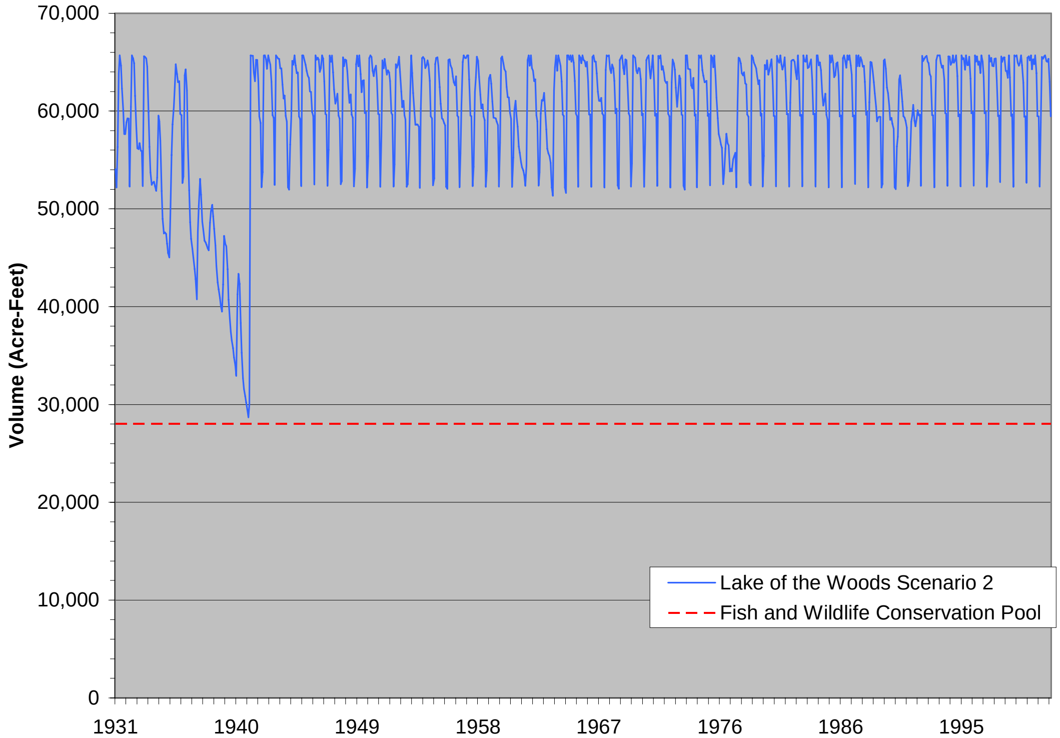


Figure B.3.16 – Lake of the Woods End of Month Volumes for Lake Ashtabula – Scenario Two

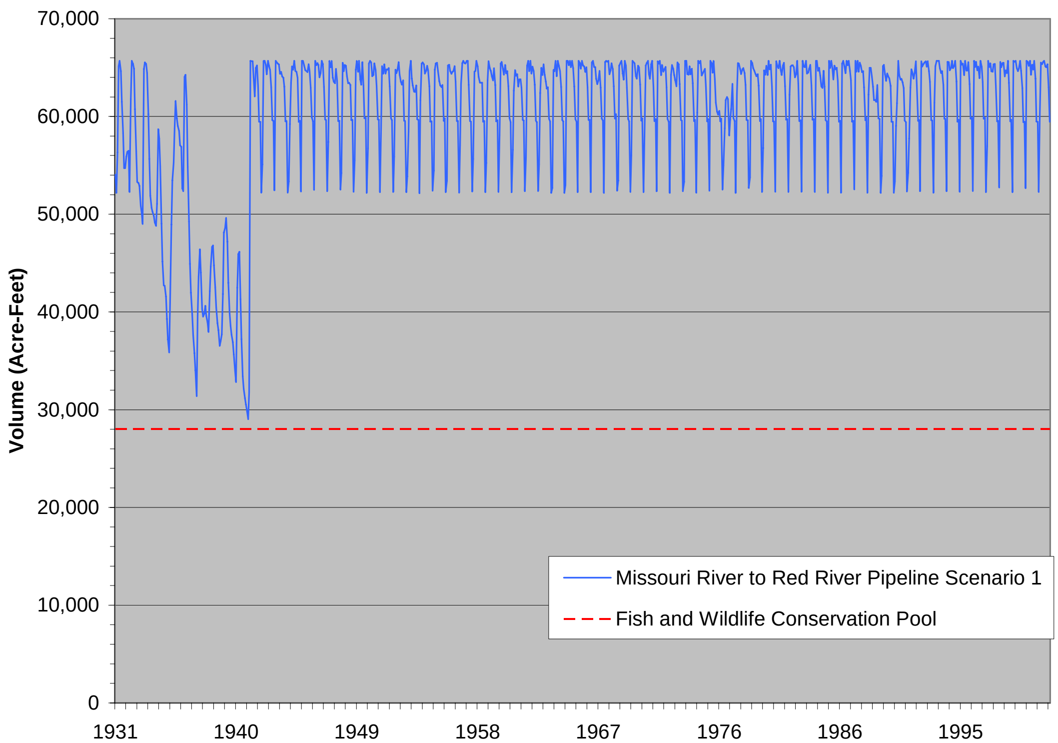


Figure B.3.17 – Missouri River to Red River Pipeline End of Month Volumes for Lake Ashtabula – Scenario One

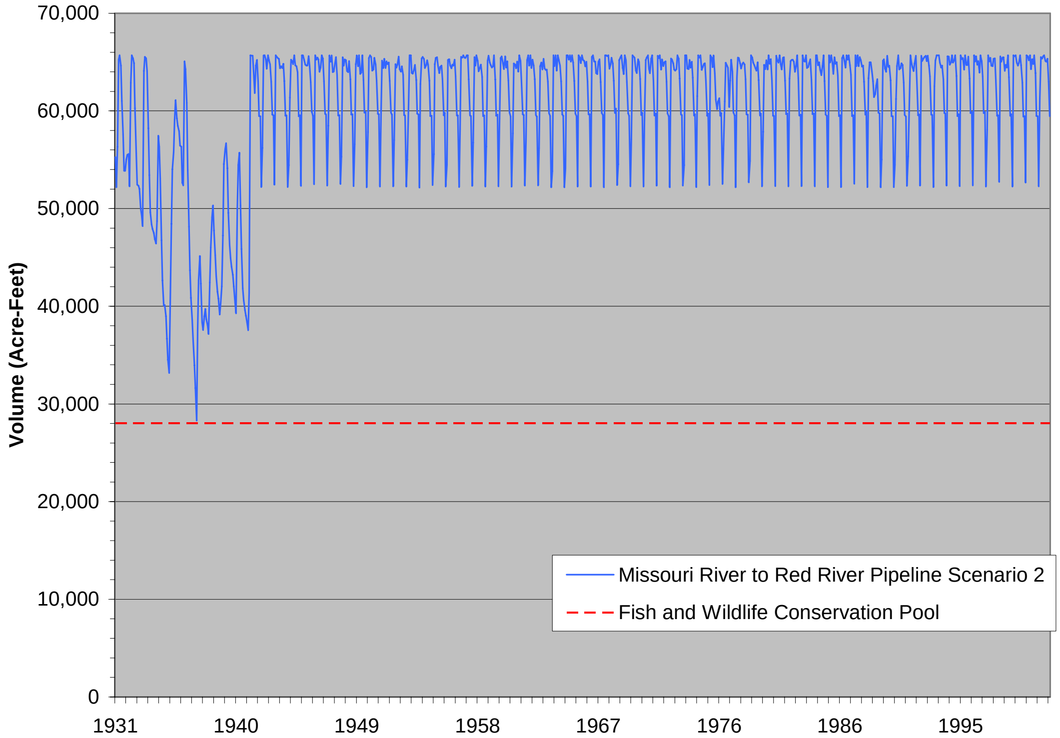


Figure B.3.18 – Missouri River to Red River Pipeline End of Month Volumes for Lake Ashtabula – Scenario Two

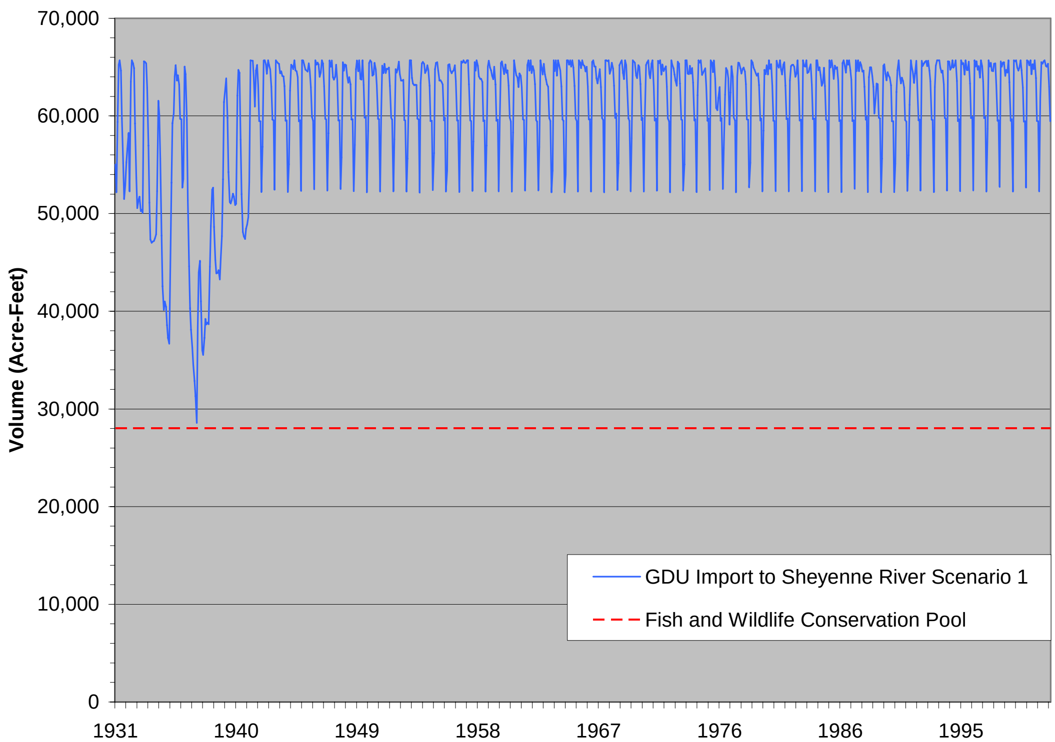


Figure B.3.19 – GDU Import to Sheyenne River End of Month Volumes for Lake Ashtabula – Scenario One

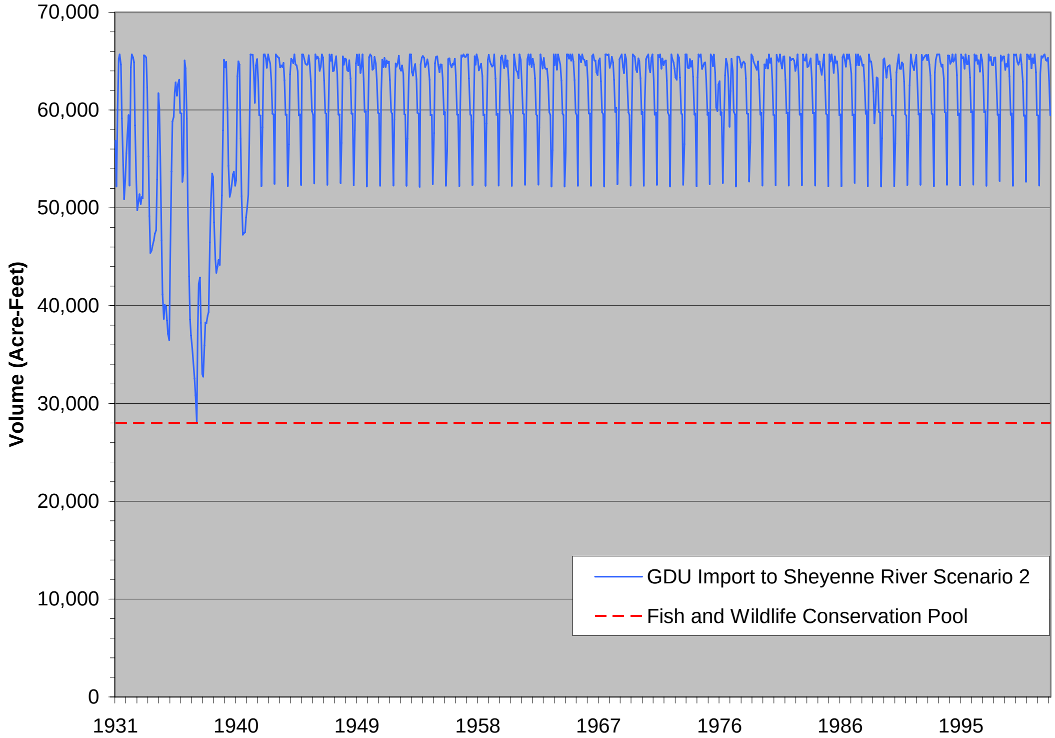


Figure B.3.20 – GDU Import to Sheyenne River End of Month Volumes for Lake Ashtabula – Scenario Two

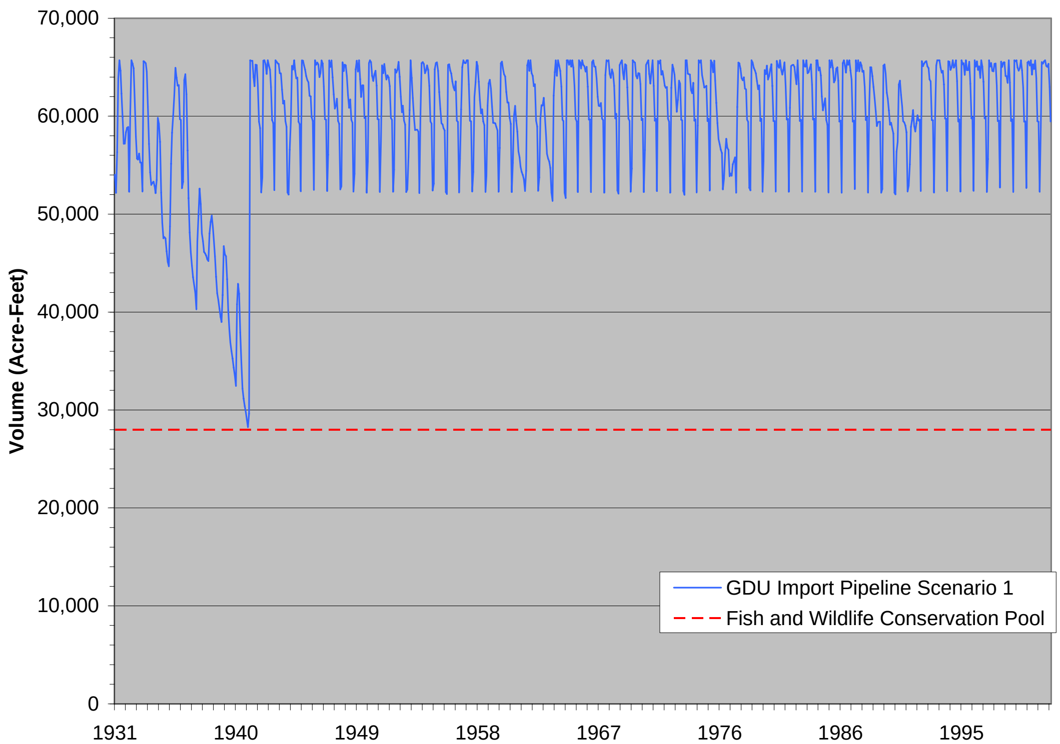


Figure B.3.21 – GDU Import Pipeline End of Month Volumes for Lake Ashtabula – Scenario One

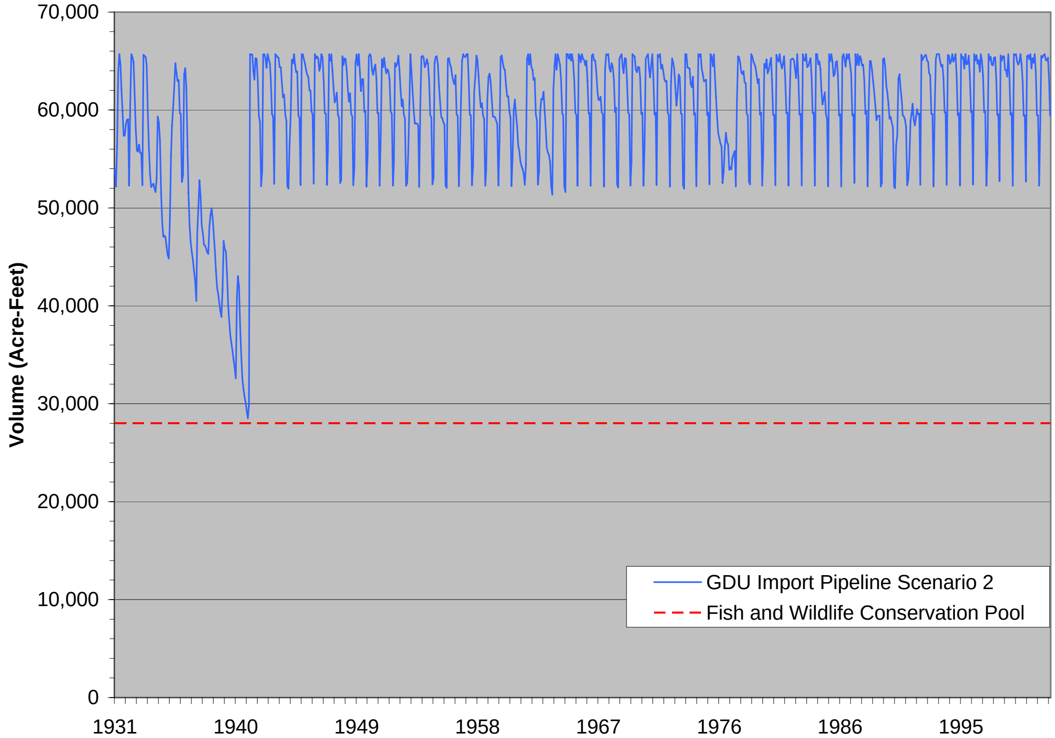


Figure B.3.22 – GDU Import Pipeline End of Month Volumes for Lake Ashtabula – Scenario Two

The GDU Import Pipeline alternative was originally sized to meet peak month and was optimized based on the 28,000 acre-foot target. However this alternative was modified to include peak day demands and figures B.3.21 and B.3.22 show the results including daily peaking.

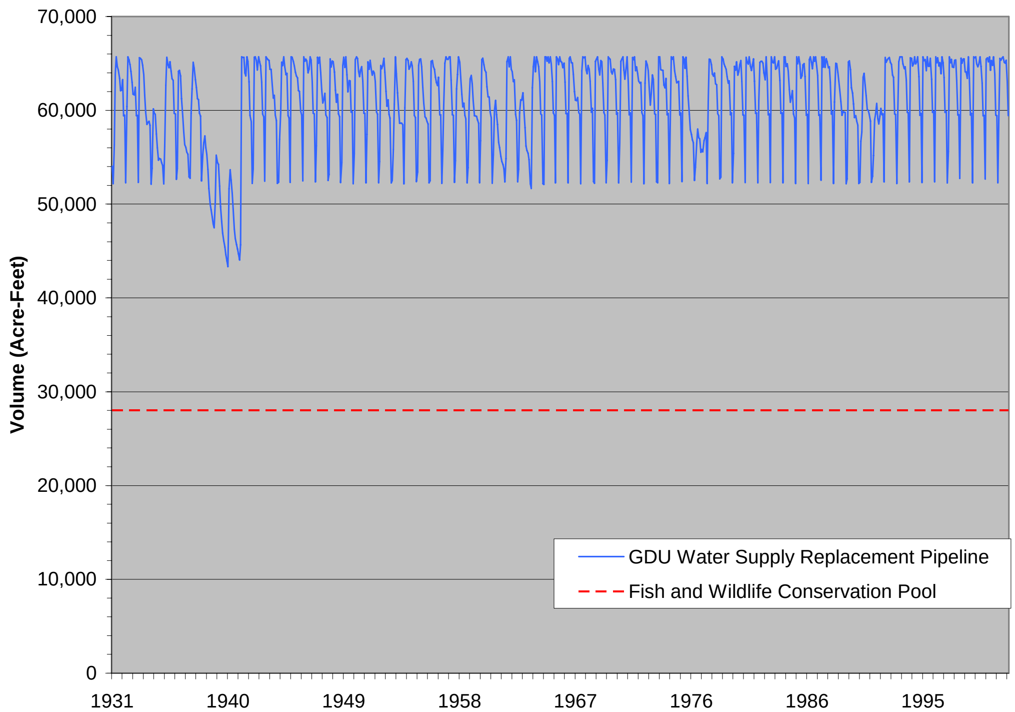


Figure B.3.23 – GDU Water Supply Replacement Pipeline - End of Month Volumes for Lake Ashtabula

Model Alternative Sizing

Each action alternative was sized based on the outcome of the reservoir volume data. Intervening structures within the Operational Rights section of the model were used as throttles. These throttles were set for each supply feature or pipe until the 28,000 acre-foot target could be maintained during a 1930s style drought. The throttle values for the intervening structures are displayed within the “capacity” section of the Direct Diversion Station File (*.dds). Naming intervening structures includes key terms within the title such as: throttle, import, or reoperate. Some structures throttle more than one pipe. Adding up the capacity values for each intervening structure that is turned on within the model run gives the sizing of the pipe required to satisfy the supply. The results of this effort are shown in table B.3.12

Table B.3.12 - Project Alternative Pipe Sizing

Alternative	Scenario One Sizing (cfs)	Scenario Two Sizing (cfs)
North Dakota In-Basin	50	67
Red River Basin	42	68
Lake of the Woods	66	93
GDU Import to Sheyenne River - Peak Day in Pipe	59	92
GDU Import Pipeline - Peak Day in Pipe	160*	202*
Missouri River to Red River Valley Import	42	60
GDU Water Supply Replacement Pipeline*	341**	411**

*These alternatives were sized within the model and then an engineered peak day value was added manually to each pipe size.
**Values for the Replacement Pipeline Alternative were derived from engineering calculations.

The model provides a large amount of detailed output regarding water routing. This includes all routing, volume, and loss data at each node within the model (all intake, reservoir, return flow, and instream flow structures have their own nodes). The following tables have been created to summarize some of this data into a useful format. Further detail can be obtained by running the model and reviewing the output files.

Table B.3.13 shows grouped water source quantity values for each model run performed. Included in each model run are the results of the four largest municipal water users in the service area. Each municipality has between four and six columns assigned to it. The first column shows the demand. The remaining columns show where that demand is being met from.
Also included in the table is a storage depletion section that identifies the volume of water being diverted from Lake Ashtabula storage and from an import to meet the demands in the service area. Some model runs also include an additional column listed as “Import to Lake Ashtabula.” This is provided when an alternative feature delivers water directly to Lake Ashtabula.

Table B.3.14 is very similar to table B.3.13 and it provides water source quantity values for larger industrial users within the service area. Not included in this table are those industries that receive water directly from a municipal system such as Fargo, Grand Forks, Moorhead, or West Fargo.

Table B.3.15 shows the amount of water transferred through project features allowing each model run to eliminate shortages in the service area. This water comes from either the Missouri River, Lake of the Woods, Minnesota groundwater, or is withdrawn from the Red River north or Grand Forks and is rerouted to Lake Ashtabula.

The GDU Water Supply Replacement Pipeline alternative was not included in Tables B.3.14 or B.3.15. This alternative was omitted because all source water for this alternative's industry comes from import and all depletions from source are based directly on engineering results for meeting peak day.

Table B.3.13 – Municipal Water Source Quantity Tables

Base171.rsp: BASELINE MODEL RUN USING 2005 DEMANDS OVER 71 YEARS OF FLOW DATA

	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION	
		Water Source					Water Source					Water Source						Water Source				
Table Statistics	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*2,537*	*2,537*	*1,872*	*2,537*	*0*	*324*	*205*	*324*	*0*	*0*	*772*	*772*	*0*	*0*	*0*	*0*	*1,742*	*1,742*	*1,385*	*0*	*0*	*3,574*
1931-1941 Avg. Month	*1,577*	*945*	*94*	*538*	*0*	*172*	*112*	*40*	*0*	*0*	*534*	*455*	*0*	*0*	*0*	*0*	*1,131*	*1,023*	*108*	*0*	*0*	*686*
1931-1941 Max Year	*18,924*	*16,571*	*3,154*	*12,472*	*0*	*2,062*	*1,828*	*790*	*0*	*0*	*6,410*	*6,410*	*0*	*0*	*0*	*0*	*13,576*	*13,576*	*2,635*	*0*	*0*	*15,723*
1931-1941 Total	*208,164*	*124,762*	*12,437*	*70,967*	*0*	*22,682*	*14,751*	*5,239*	*0*	*0*	*70,510*	*60,002*	*0*	*0*	*0*	*0*	*149,336*	*135,024*	*14,312*	*0*	*0*	*90,518*
71yr Max. Month	*2,537*	*2,537*	*1,872*	*2,537*	*0*	*324*	*205*	*324*	*0*	*0*	*772*	*772*	*0*	*0*	*0*	*0*	*1,742*	*1,742*	*1,385*	*0*	*0*	*3,574*
71yr Avg. Month	*1,577*	*1,477*	*15*	*85*	*0*	*172*	*147*	*22*	*0*	*0*	*534*	*522*	*0*	*0*	*0*	*0*	*1,131*	*1,115*	*17*	*0*	*0*	*124*
71yr Total	*1,343,604*	*1,258,435*	*12,638*	*72,533*	*0*	*146,402*	*125,059*	*18,651*	*0*	*0*	*455,110*	*444,602*	*0*	*0*	*0*	*0*	*963,896*	*949,584*	*14,312*	*0*	*0*	*105,496*

NA1ID71.rsp: NO ACTION RUN SCENARIO 1

	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION	
		Water Source					Water Source					Water Source						Water Source				
Table Statistics	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*5,743*	*5,695*	*2,949*	*5,743*	*0*	*713*	*574*	*528*	*0*	*0*	*1,155*	*1,155*	*0*	*0*	*0*	*0*	*2,742*	*2,742*	*1,750*	*0*	*0*	*7,582*
1931-1941 Avg. Month	*3,812*	*1,558*	*251*	*1,125*	*0*	*399*	*150*	*70*	*0*	*0*	*808*	*697*	*0*	*0*	*0*	*0*	*1,955*	*1,870*	*85*	*0*	*0*	*1,281*
1931-1941 Max Year	*45,740*	*34,763*	*6,412*	*27,137*	*0*	*4,784*	*2,987*	*2,097*	*0*	*0*	*9,696*	*9,696*	*0*	*0*	*0*	*0*	*23,459*	*23,459*	*3,864*	*0*	*0*	*29,474*
1931-1941 Total	*503,140*	*205,683*	*33,143*	*148,546*	*0*	*52,624*	*19,775*	*9,260*	*0*	*0*	*106,656*	*92,049*	*0*	*0*	*0*	*0*	*258,049*	*246,789*	*11,260*	*0*	*0*	*169,066*
71yr Max. Month	*5,743*	*5,743*	*2,949*	*5,743*	*0*	*713*	*574*	*528*	*0*	*0*	*1,155*	*1,155*	*0*	*0*	*0*	*0*	*2,742*	*2,742*	*1,750*	*0*	*0*	*7,582*
71yr Avg. Month	*3,812*	*3,444*	*45*	*187*	*0*	*399*	*208*	*159*	*0*	*0*	*808*	*791*	*0*	*0*	*0*	*0*	*1,955*	*1,942*	*13*	*0*	*0*	*359*
71yr Total	*3,247,540*	*2,934,331*	*38,339*	*159,100*	*0*	*339,664*	*176,894*	*135,308*	*0*	*0*	*688,416*	*673,675*	*0*	*0*	*0*	*0*	*1,665,589*	*1,654,329*	*11,260*	*0*	*0*	*305,668*

NA2ID71.rsp: NO ACTION RUN SCENARIO 2

	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION	
		Water Source					Water Source					Water Source						Water Source				
Table Statistics	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*7,243*	*6,627*	*3,047*	*7,243*	*0*	*729*	*493*	*566*	*0*	*0*	*1,213*	*1,213*	*0*	*0*	*0*	*0*	*3,774*	*3,774*	*2,673*	*0*	*0*	*10,221*
1931-1941 Avg. Month	*4,928*	*1,780*	*310*	*1,169*	*0*	*407*	*142*	*67*	*0*	*0*	*866*	*740*	*0*	*0*	*0*	*0*	*2,775*	*2,535*	*225*	*0*	*0*	*1,460*
1931-1941 Max Year	*59,131*	*42,198*	*7,140*	*31,369*	*0*	*4,885*	*2,734*	*2,160*	*0*	*0*	*10,387*	*10,380*	*0*	*0*	*0*	*0*	*33,304*	*33,304*	*6,469*	*0*	*0*	*33,771*
1931-1941 Total	*650,441*	*234,952*	*40,953*	*154,247*	*0*	*53,735*	*18,711*	*8,784*	*0*	*0*	*114,257*	*97,702*	*0*	*0*	*0*	*0*	*366,344*	*334,665*	*29,752*	*0*	*0*	*192,783*
71yr Max. Month	*7,243*	*7,243*	*3,047*	*7,243*	*0*	*729*	*574*	*566*	*0*	*0*	*1,213*	*1,213*	*0*	*0*	*0*	*0*	*3,774*	*3,774*	*2,673*	*0*	*0*	*10,221*
71yr Avg. Month	*4,928*	*4,396*	*63*	*211*	*0*	*407*	*207*	*163*	*0*	*0*	*866*	*846*	*0*	*0*	*0*	*0*	*2,775*	*2,738*	*35*	*0*	*0*	*409*
71yr Total	*4,198,301*	*3,745,076*	*53,323*	*179,610*	*0*	*346,835*	*176,209*	*139,044*	*0*	*0*	*737,477*	*720,729*	*0*	*0*	*0*	*0*	*2,364,584*	*2,332,905*	*29,752*	*0*	*0*	*348,406*

Table B.3.13 – Municipal Water Source Quantity Tables (Continued)

Loop171.rsp: NORTH DAKOTA IN-BASIN SCENARIO 1

	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION	
		Water Source					Water Source					Water Source						Water Source				
Table Statistics	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*5,743*	*5,743*	*2,949*	*5,743*	*0*	*713*	*205*	*98*	*615*	*0*	*1,269*	*1,155*	*874*	*114*	*61*	*0*	*2,742*	*2,742*	*1,750*	*0*	*0*	*6,145*
1931-1941 Avg. Month	*3,812*	*1,746*	*295*	*1,770*	*0*	*399*	*139*	*3*	*257*	*0*	*922*	*736*	*63*	*114*	*9*	*0*	*1,955*	*1,909*	*46*	*0*	*0*	*1,883*
1931-1941 Max Year	*45,740*	*35,822*	*8,159*	*34,530*	*0*	*4,784*	*2,366*	*98*	*3,785*	*0*	*11,064*	*9,696*	*2,650*	*1,368*	*364*	*0*	*23,459*	*23,459*	*3,339*	*0*	*0*	*37,409*
1931-1941 Total	*503,140*	*230,479*	*38,962*	*233,702*	*0*	*52,624*	*18,322*	*392*	*33,910*	*0*	*121,704*	*97,114*	*8,337*	*15,048*	*1,204*	*0*	*258,049*	*251,922*	*6,127*	*0*	*0*	*248,558*
71yr Max. Month	*5,743*	*5,743*	*2,949*	*5,743*	*0*	*713*	*205*	*98*	*615*	*0*	*1,269*	*1,155*	*874*	*114*	*61*	*0*	*2,742*	*2,742*	*1,750*	*0*	*0*	*6,145*
71yr Avg. Month	*3,812*	*3,476*	*51*	*284*	*0*	*399*	*187*	*0*	*212*	*0*	*922*	*797*	*10*	*114*	*1*	*0*	*1,955*	*1,948*	*7*	*0*	*0*	*302*
71yr Total	*3,247,540*	*2,961,858*	*43,466*	*242,219*	*0*	*339,664*	*158,986*	*392*	*180,286*	*0*	*785,544*	*678,874*	*8,337*	*97,128*	*1,204*	*0*	*1,665,589*	*1,659,462*	*6,127*	*0*	*0*	*257,075*

Loop271.rsp: NORTH DAKOTA IN-BASIN SCENARIO 2

	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION	
		Water Source					Water Source					Water Source						Water Source				
Table Statistics	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*7,243*	*6,627*	*2,949*	*7,243*	*0*	*729*	*205*	*114*	*615*	*0*	*1,327*	*1,213*	*933*	*114*	*61*	*0*	*3,774*	*3,774*	*2,422*	*0*	*0*	*8,847*
1931-1941 Avg. Month	*4,928*	*1,979*	*316*	*2,633*	*0*	*407*	*129*	*3*	*274*	*0*	*980*	*783*	*72*	*114*	*10*	*0*	*2,775*	*2,634*	*141*	*0*	*0*	*2,850*
1931-1941 Max Year	*59,131*	*43,238*	*7,493*	*46,797*	*0*	*4,885*	*2,211*	*114*	*4,168*	*0*	*11,755*	*10,387*	*2,998*	*1,368*	*388*	*0*	*33,304*	*33,304*	*5,594*	*0*	*0*	*52,412*
1931-1941 Total	*650,441*	*261,209*	*41,708*	*347,523*	*0*	*53,735*	*17,066*	*456*	*36,213*	*0*	*129,305*	*103,398*	*9,487*	*15,048*	*1,371*	*0*	*366,344*	*347,674*	*18,670*	*0*	*0*	*376,136*
71yr Max. Month	*7,243*	*7,243*	*2,949*	*7,243*	*0*	*729*	*205*	*114*	*615*	*0*	*1,327*	*1,213*	*933*	*114*	*61*	*0*	*3,774*	*3,774*	*2,422*	*0*	*0*	*8,847*
71yr Avg. Month	*4,928*	*4,435*	*61*	*432*	*0*	*407*	*185*	*1*	*221*	*0*	*980*	*853*	*11*	*114*	*2*	*0*	*2,775*	*2,753*	*22*	*0*	*0*	*466*
71yr Total	*4,198,301*	*3,778,200*	*52,052*	*368,049*	*0*	*346,835*	*157,730*	*456*	*188,649*	*0*	*834,605*	*726,618*	*9,487*	*97,128*	*1,371*	*0*	*2,364,584*	*2,345,914*	*18,670*	*0*	*0*	*396,662*

BF1NGF71.rsp: RED RIVER BASIN SCENARIO 1

	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION	
		Water Source					Water Source					Water Source						Water Source				
Table Statistics	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*5,743*	*5,743*	*2,949*	*3,283*	*2,460*	*713*	*205*	*0*	*615*	*98*	*1,269*	*1,155*	*874*	*114*	*61*	*0*	*2,742*	*2,742*	*1,750*	*0*	*2,558*	*3,743*
1931-1941 Avg. Month	*3,812*	*1,746*	*279*	*420*	*1,367*	*399*	*140*	*0*	*256*	*3*	*922*	*736*	*63*	*114*	*9*	*0*	*1,955*	*1,910*	*44*	*0*	*1,370*	*527*
1931-1941 Max Year	*45,740*	*35,822*	*7,996*	*11,346*	*23,179*	*4,784*	*2,366*	*0*	*3,785*	*98*	*11,064*	*9,696*	*2,650*	*1,368*	*364*	*0*	*23,459*	*23,459*	*3,339*	*0*	*23,277*	*14,127*
1931-1941 Total	*503,140*	*230,479*	*36,792*	*55,396*	*180,488*	*52,624*	*18,491*	*0*	*33,741*	*392*	*121,704*	*97,114*	*8,337*	*15,048*	*1,204*	*0*	*258,049*	*252,179*	*5,870*	*0*	*180,880*	*69,603*
71yr Max. Month	*5,743*	*5,743*	*2,949*	*3,283*	*2,460*	*713*	*205*	*0*	*615*	*98*	*1,269*	*1,155*	*874*	*114*	*61*	*0*	*2,742*	*2,742*	*1,750*	*0*	*2,558*	*3,743*
71yr Avg. Month	*3,812*	*3,476*	*48*	*67*	*220*	*399*	*186*	*0*	*212*	*0*	*922*	*797*	*10*	*114*	*1*	*0*	*1,955*	*1,948*	*7*	*0*	*220*	*84*
71yr Total	*3,247,540*	*2,961,858*	*41,296*	*57,062*	*187,339*	*339,664*	*158,578*	*0*	*180,694*	*392*	*785,544*	*678,874*	*8,337*	*97,128*	*1,204*	*0*	*1,665,589*	*1,659,719*	*5,870*	*0*	*187,731*	*71,269*

BF2NGF71.rsp: RED RIVER BASIN SCENARIO 2

	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION	
		Water Source					Water Source					Water Source						Water Source				
Table Statistics	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*7,243*	*6,627*	*2,949*	*3,185*	*4,058*	*729*	*205*	*0*	*615*	*114*	*1,327*	*1,213*	*933*	*114*	*61*	*339*	*3,774*	*3,774*	*2,432*	*0*	*4,172*	*4,830*
1931-1941 Avg. Month	*4,928*	*1,979*	*341*	*310*	*2,297*	*407*	*132*	*0*	*271*	*3*	*980*	*783*	*67*	*114*	*10*	*5*	*2,775*	*2,640*	*136*	*0*	*2,306*	*513*
1931-1941 Max Year	*59,131*	*43,238*	*8,324*	*8,214*	*38,014*	*4,885*	*2,211*	*0*	*3,886*	*114*	*11,755*	*10,387*	*2,998*	*1,368*	*388*	*441*	*33,304*	*33,304*	*5,594*	*0*	*38,128*	*13,294*
1931-1941 Total	*650,441*	*261,209*	*45,052*	*40,949*	*303,225*	*53,735*	*17,468*	*0*	*35,811*	*456*	*129,305*	*103,398*	*8,894*	*15,048*	*1,286*	*676*	*366,344*	*348,452*	*17,892*	*0*	*304,357*	*67,735*
71yr Max. Month	*7,243*	*7,243*	*2,949*	*3,185*	*4,058*	*729*	*205*	*0*	*615*	*114*	*1,327*	*1,213*	*933*	*114*	*61*	*339*	*3,774*	*3,774*	*2,432*	*0*	*4,172*	*4,830*
71yr Avg. Month	*4,928*	*4,435*	*64*	*50*	*379*	*407*	*185*	*0*	*222*	*1*	*980*	*853*	*10*	*114*	*2*	*1*	*2,775*	*2,754*	*21*	*0*	*381*	*81*
71yr Total	*4,198,301*	*3,778,200*	*54,620*	*42,353*	*323,123*	*346,835*	*157,555*	*0*	*188,824*	*456*	*834,605*	*726,618*	*8,894*	*97,128*	*1,286*	*676*	*2,364,584*	*2,346,692*	*17,892*	*0*	*324,255*	*69,139*

Table B.3.13 – Municipal Water Source Quantity Tables (Continued)

BF1W71.rsp: LAKE OF THE WOODS SCENARIO 1

Table Statistics	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION	
		Water Source					Water Source					Water Source						Water Source				
	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	5,743	5,743	2,949	3,468	2,275	713	205	98	615	0	1,269	1,155	874	114	61	0	2,742	1,512	520	1,230	4,017	3,590
1931-1941 Avg. Month	3,812	1,747	278	487	1,300	399	142	3	254	0	922	739	60	114	9	0	1,955	744	5	1,207	2,872	555
1931-1941 Max Year	45,740	35,822	7,778	12,830	21,694	4,784	2,366	98	3,785	0	11,064	9,696	2,650	1,368	364	0	23,459	8,978	520	14,481	41,421	15,578
1931-1941 Total	503,140	230,540	36,699	64,327	171,580	52,624	18,685	392	33,547	0	121,704	97,566	7,884	15,048	1,204	0	258,049	98,164	595	159,291	379,118	73,198
71yr Max. Month	5,743	5,743	2,949	3,468	2,275	713	205	98	615	0	1,269	1,155	874	114	61	0	2,742	1,512	520	1,230	4,017	3,590
71yr Avg. Month	3,812	3,476	48	78	209	399	186	0	212	0	922	797	9	114	1	0	1,955	747	1	1,207	1,479	88
71yr Total	3,247,540	2,961,919	41,203	66,178	178,246	339,664	158,772	392	180,500	0	785,544	679,326	7,884	97,128	1,204	0	1,665,589	636,844	595	1,028,151	1,259,849	75,049

BF2W71.rsp: LAKE OF THE WOODS SCENARIO 2

Table Statistics	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION	
		Water Source					Water Source					Water Source						Water Source				
	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	7,243	6,627	2,949	3,492	3,751	729	205	114	615	0	1,327	1,213	933	114	61	0	3,774	2,544	1,203	1,230	5,718	4,022
1931-1941 Avg. Month	4,928	1,979	364	393	2,192	407	141	3	262	0	980	784	71	114	10	0	2,775	1,543	26	1,207	3,968	494
1931-1941 Max Year	59,131	43,238	9,240	10,506	35,344	4,885	2,366	114	3,886	0	11,755	10,387	2,998	1,368	388	0	33,304	18,823	2,024	14,481	57,658	13,618
1931-1941 Total	650,441	261,209	48,019	51,914	289,308	53,735	18,671	456	34,608	0	129,305	103,489	9,364	15,048	1,340	0	366,344	203,641	3,415	159,291	523,825	65,149
71yr Max. Month	7,243	7,243	2,949	3,492	3,751	729	205	114	615	0	1,327	1,213	933	114	61	0	3,774	2,544	1,203	1,230	5,718	4,022
71yr Avg. Month	4,928	4,435	68	63	363	407	186	1	220	0	980	853	11	114	2	0	2,775	1,565	4	1,207	1,681	78
71yr Total	4,198,301	3,778,200	57,587	53,625	308,899	346,835	158,758	456	187,621	0	834,605	726,709	9,364	97,128	1,340	0	2,364,584	1,333,021	3,415	1,028,151	1,432,461	66,860

I1NAWPOP.rsp: GDU IMPORT TO SHEYENNE RIVER SCENARIO 1 with Peak Day in the River

Table Statistics	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION		
		Water Source					Water Source					Water Source						Water Source					
	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula	Import to Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	5,743	5,743	2,949	5,743	0	1,019	205	1,019	0	0	1,269	1,155	935	114	0	0	4,193	4,193	2,173	0	3,586	7,320	3,586
1931-1941 Avg. Month	3,812	1,749	90	1,973	0	535	60	475	0	0	922	739	69	114	0	0	2,755	2,725	46	0	2,863	2,563	2,863
1931-1941 Max Year	45,740	35,822	4,724	36,279	0	6,424	1,417	6,020	0	0	11,064	9,696	2,986	1,368	0	0	33,060	33,060	3,730	0	41,525	45,530	41,525
1931-1941 Total	503,140	230,849	11,817	260,476	0	70,664	7,974	62,690	0	0	121,704	97,589	9,067	15,048	0	0	363,660	359,695	6,022	0	377,898	338,255	377,898
71yr Max. Month	5,743	5,743	2,949	5,743	0	1,019	205	1,019	0	0	1,269	1,155	935	114	0	0	4,193	4,193	2,173	0	3,586	7,320	3,586
71yr Avg. Month	3,812	3,477	14	321	0	535	157	378	0	0	922	797	11	114	0	0	2,755	2,750	20	0	859	730	859
71yr Total	3,247,540	2,962,228	12,187	273,128	0	456,104	133,707	322,397	0	0	785,544	679,349	9,067	97,128	0	0	2,347,260	2,343,295	17,242	0	731,979	621,834	731,979

I2NAWPOP.rsp: GDU IMPORT TO SHEYENNE RIVER SCENARIO 2 with Peak Day in the River

Table Statistics	City of Fargo					City of West Fargo					City of Moorhead						City of Grand Forks				STORAGE DEPLETION		
		Water Source					Water Source					Water Source						Water Source					
	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula	Import to Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	7,243	6,627	2,949	7,175	0	1,042	205	1,042	0	0	1,327	1,213	994	114	0	0	5,340	5,340	2,079	0	5,657	8,347	5,657
1931-1941 Avg. Month	4,928	1,989	426	2,512	0	547	174	373	0	0	980	788	77	114	0	0	3,643	3,592	139	0	4,655	3,102	4,655
1931-1941 Max Year	59,131	43,238	9,343	44,773	0	6,565	2,407	5,134	0	0	11,755	10,387	3,358	1,368	0	0	43,711	43,711	5,500	0	65,752	54,978	65,752
1931-1941 Total	650,441	262,545	56,256	331,640	0	72,215	22,945	49,246	0	0	129,305	104,036	10,221	15,048	0	0	480,821	474,159	18,320	0	614,510	409,427	614,510
71yr Max. Month	7,243	7,243	2,949	7,175	0	1,042	205	1,042	0	0	1,327	1,213	994	114	0	0	5,340	5,340	2,079	0	5,657	8,347	5,657
71yr Avg. Month	4,928	4,436	81	411	0	547	193	353	0	0	980	854	12	114	0	0	3,643	3,635	96	0	1,677	872	1,677
71yr Total	4,198,301	3,779,536	68,673	350,091	0	466,115	164,830	301,088	0	0	834,605	727,256	10,221	97,128	0	0	3,103,481	3,096,819	81,920	0	1,428,422	743,320	1,428,422

Table B.3.13 – Municipal Water Source Quantity Tables (Continued)

BF1NAW71.rsp: GDU IMPORT PIPELINE SCENARIO 1

Table Statistics	City of Fargo: Demand	Fargo Water Source: Red River	Fargo Water Source: Natural Flows on Sheyenne River	Fargo Water Source: Lake Ashtabula Storage	Fargo Water Source: Import Pipeline	City of West Fargo: Demand	West Fargo Water Source: Natural Flows on Sheyenne River	West Fargo Water Source: Lake Ashtabula Storage	West Fargo Water Source: West Fargo Aquifer Recharge	West Fargo Water Source: Import Pipeline	City of Moorhead: Demand	Moorhead Water Source: Red River	Moorhead Water Source: Lake Ashtabula Storage	Moorhead Water Source: Buffalo Aquifer	Moorhead Water Source: Moorhead Aquifer Recharge	Moorhead Water Source: Import Pipeline	City of Grand Forks: Demand	Grand Forks Water Source: Red & Red Lake Rivers	Grand Forks Water Source: Lake Ashtabula Storage	Grand Forks Water Source: Import Pipeline	STORAGE DEPLETION: Import	STORAGE DEPLETION: Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*5,743*	*5,743*	*2,949*	*3,038*	*2,705*	*713*	*205*	*713*	*0*	*508*	*1,269*	*1,155*	*935*	*114*	*0*	*7*	*2,742*	*1,512*	*520*	*1,230*	*4,447*	*3,837*
1931-1941 Avg. Month	*3,812*	*1,747*	*275*	*332*	*1,458*	*399*	*142*	*135*	*0*	*123*	*922*	*739*	*69*	*114*	*0*	*0*	*1,955*	*744*	*5*	*1,207*	*3,271*	*540*
1931-1941 Max Year	*45,740*	*35,822*	*7,543*	*9,408*	*25,118*	*4,784*	*2,366*	*3,287*	*0*	*2,229*	*11,064*	*9,696*	*3,016*	*1,368*	*0*	*7*	*23,459*	*8,978*	*520*	*14,481*	*45,904*	*15,711*
1931-1941 Total	*503,140*	*230,540*	*36,290*	*43,854*	*192,452*	*52,624*	*18,685*	*17,766*	*0*	*16,172*	*121,704*	*97,566*	*9,083*	*15,048*	*0*	*7*	*258,049*	*98,164*	*595*	*159,291*	*431,834*	*71,298*
71yr Max. Month	*5,743*	*5,743*	*2,949*	*3,038*	*2,705*	*713*	*205*	*713*	*0*	*549*	*1,269*	*1,155*	*935*	*114*	*0*	*7*	*2,742*	*1,512*	*520*	*1,230*	*4,447*	*3,837*
71yr Avg. Month	*3,812*	*3,476*	*48*	*53*	*234*	*399*	*186*	*21*	*0*	*191*	*922*	*797*	*11*	*114*	*0*	*0*	*1,955*	*747*	*1*	*1,207*	*2,116*	*86*
71yr Total	*3,247,540*	*2,961,919*	*40,794*	*45,274*	*199,548*	*339,664*	*158,802*	*18,110*	*0*	*162,751*	*785,544*	*679,326*	*9,083*	*97,128*	*0*	*7*	*1,665,589*	*636,844*	*595*	*1,028,151*	*1,802,758*	*73,062*

BF2NAW71.rsp: GDU IMPORT PIPELINE SCENARIO 2

Table Statistics	City of Fargo: Demand	Fargo Water Source: Red River	Fargo Water Source: Natural Flows on Sheyenne River	Fargo Water Source: Lake Ashtabula Storage	Fargo Water Source: Import Pipeline	City of West Fargo: Demand	West Fargo Water Source: Natural Flows on Sheyenne River	West Fargo Water Source: Lake Ashtabula Storage	West Fargo Water Source: West Fargo Aquifer Recharge	West Fargo Water Source: Import Pipeline	City of Moorhead: Demand	Moorhead Water Source: Red River	Moorhead Water Source: Lake Ashtabula Storage	Moorhead Water Source: Buffalo Aquifer	Moorhead Water Source: Moorhead Aquifer Recharge	Moorhead Water Source: Import Pipeline	City of Grand Forks: Demand	Grand Forks Water Source: Red & Red Lake Rivers	Grand Forks Water Source: Lake Ashtabula Storage	Grand Forks Water Source: Import Pipeline	STORAGE DEPLETION: Import	STORAGE DEPLETION: Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*7,243*	*6,627*	*2,949*	*3,062*	*4,181*	*729*	*205*	*729*	*0*	*524*	*1,327*	*1,213*	*994*	*114*	*0*	*385*	*3,774*	*2,544*	*1,203*	*1,230*	*6,149*	*4,207*
1931-1941 Avg. Month	*4,928*	*1,979*	*358*	*273*	*2,318*	*407*	*140*	*121*	*0*	*146*	*980*	*784*	*72*	*114*	*0*	*9*	*2,775*	*1,543*	*26*	*1,207*	*4,249*	*492*
1931-1941 Max Year	*59,131*	*43,238*	*8,988*	*7,368*	*38,480*	*4,885*	*2,366*	*3,096*	*0*	*2,335*	*11,755*	*10,387*	*3,388*	*1,368*	*0*	*647*	*33,304*	*18,823*	*2,024*	*14,481*	*61,580*	*13,852*
1931-1941 Total	*650,441*	*261,209*	*47,288*	*35,992*	*305,950*	*53,735*	*18,491*	*15,986*	*0*	*19,257*	*129,305*	*103,489*	*9,515*	*15,048*	*0*	*1,252*	*366,344*	*203,641*	*3,415*	*159,291*	*560,854*	*64,908*
71yr Max. Month	*7,243*	*7,243*	*2,949*	*3,062*	*4,181*	*729*	*205*	*729*	*0*	*561*	*1,327*	*1,213*	*994*	*114*	*0*	*385*	*3,774*	*2,544*	*1,203*	*1,230*	*6,149*	*4,207*
71yr Avg. Month	*4,928*	*4,435*	*67*	*44*	*383*	*407*	*186*	*19*	*0*	*202*	*980*	*853*	*11*	*114*	*0*	*1*	*2,775*	*1,565*	*4*	*1,207*	*1,904*	*78*
71yr Total	*4,198,301*	*3,778,200*	*56,856*	*37,273*	*325,971*	*346,835*	*158,578*	*16,342*	*0*	*171,914*	*834,605*	*726,709*	*9,515*	*97,128*	*0*	*1,252*	*2,364,584*	*1,333,021*	*3,415*	*1,028,151*	*1,622,141*	*66,545*

I1D71.rsp: MISSOURI RIVER TO RED RIVER VALLEY IMPORT SCENARIO 1

Table Statistics	City of Fargo: Demand	Fargo Water Source: Red River	Fargo Water Source: Natural Flows on Sheyenne River	Fargo Water Source: Lake Ashtabula Storage	Fargo Water Source: Import Pipeline	City of West Fargo: Demand	West Fargo Water Source: Natural Flows on Sheyenne River	West Fargo Water Source: Lake Ashtabula Storage	West Fargo Water Source: West Fargo Aquifer Recharge	West Fargo Water Source: Import Pipeline	City of Moorhead: Demand	Moorhead Water Source: Red River	Moorhead Water Source: Lake Ashtabula Storage	Moorhead Water Source: Buffalo Aquifer	Moorhead Water Source: Moorhead Aquifer Recharge	Moorhead Water Source: Import Pipeline	City of Grand Forks: Demand	Grand Forks Water Source: Red & Red Lake Rivers	Grand Forks Water Source: Lake Ashtabula Storage	Grand Forks Water Source: Import Pipeline	STORAGE DEPLETION: Import	STORAGE DEPLETION: Lake Ashtabula	Import to Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*5,743*	*5,743*	*2,949*	*4,390*	*1,353*	*713*	*205*	*98*	*615*	*0*	*1,269*	*1,155*	*874*	*114*	*61*	*0*	*2,742*	*1,512*	*520*	*1,230*	*2,583*	*4,512*	*1,353*
1931-1941 Avg. Month	*3,812*	*1,747*	*185*	*950*	*930*	*399*	*136*	*3*	*260*	*0*	*922*	*739*	*60*	*114*	*9*	*0*	*1,955*	*744*	*5*	*1,207*	*2,412*	*1,017*	*275*
1931-1941 Max Year	*45,740*	*35,822*	*5,259*	*21,666*	*13,726*	*4,784*	*2,366*	*98*	*3,862*	*0*	*11,064*	*9,696*	*2,650*	*1,368*	*364*	*0*	*23,459*	*8,978*	*520*	*14,481*	*30,410*	*24,414*	*7,816*
1931-1941 Total	*503,140*	*230,540*	*24,432*	*125,427*	*122,759*	*52,624*	*17,978*	*392*	*34,254*	*0*	*121,704*	*97,566*	*7,884*	*15,048*	*1,204*	*0*	*258,049*	*98,164*	*595*	*159,291*	*318,330*	*134,298*	*36,284*
71yr Max. Month	*5,743*	*5,743*	*2,949*	*4,390*	*1,353*	*713*	*205*	*98*	*615*	*0*	*1,269*	*1,155*	*874*	*114*	*61*	*0*	*2,742*	*1,512*	*520*	*1,230*	*2,583*	*4,512*	*1,353*
71yr Avg. Month	*3,812*	*3,476*	*31*	*151*	*153*	*399*	*186*	*0*	*212*	*0*	*922*	*797*	*9*	*114*	*1*	*0*	*1,955*	*747*	*1*	*1,207*	*1,638*	*162*	*278*
71yr Total	*3,247,540*	*2,961,919*	*26,220*	*129,031*	*130,390*	*339,664*	*158,642*	*392*	*180,630*	*0*	*785,544*	*679,326*	*7,884*	*97,128*	*1,204*	*0*	*1,665,589*	*636,844*	*595*	*1,028,151*	*1,395,340*	*137,902*	*237,055*

I2D71.rsp: MISSOURI RIVER TO RED RIVER VALLEY IMPORT SCENARIO 2

Table Statistics	City of Fargo: Demand	Fargo Water Source: Red River	Fargo Water Source: Natural Flows on Sheyenne River	Fargo Water Source: Lake Ashtabula Storage	Fargo Water Source: Import Pipeline	City of West Fargo: Demand	West Fargo Water Source: Natural Flows on Sheyenne River	West Fargo Water Source: Lake Ashtabula Storage	West Fargo Water Source: West Fargo Aquifer Recharge	West Fargo Water Source: Import Pipeline	City of Moorhead: Demand	Moorhead Water Source: Red River	Moorhead Water Source: Lake Ashtabula Storage	Moorhead Water Source: Buffalo Aquifer	Moorhead Water Source: Moorhead Aquifer Recharge	Moorhead Water Source: Import Pipeline	City of Grand Forks: Demand	Grand Forks Water Source: Red & Red Lake Rivers	Grand Forks Water Source: Lake Ashtabula Storage	Grand Forks Water Source: Import Pipeline	STORAGE DEPLETION: Import	STORAGE DEPLETION: Lake Ashtabula	Import to Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*7,243*	*6,627*	*2,949*	*4,783*	*2,460*	*729*	*205*	*114*	*615*	*0*	*1,327*	*1,213*	*933*	*114*	*61*	*0*	*3,774*	*2,544*	*1,203*	*1,230*	*3,689*	*5,314*	*2,460*
1931-1941 Avg. Month	*4,928*	*1,979*	*185*	*1,000*	*1,764*	*407*	*136*	*3*	*268*	*0*	*980*	*783*	*72*	*114*	*10*	*0*	*2,775*	*1,541*	*27*	*1,207*	*3,419*	*1,102*	*449*
1931-1941 Max Year	*59,131*	*43,238*	*5,423*	*22,146*	*25,636*	*4,885*	*2,366*	*114*	*3,947*	*0*	*11,755*	*10,387*	*2,998*	*1,368*	*388*	*0*	*33,304*	*18,823*	*2,024*	*14,481*	*43,435*	*25,258*	*12,402*
1931-1941 Total	*650,441*	*261,209*	*24,443*	*131,975*	*232,843*	*53,735*	*17,969*	*456*	*35,310*	*0*	*129,305*	*103,398*	*9,487*	*15,048*	*1,371*	*0*	*366,344*	*203,476*	*3,581*	*159,291*	*451,365*	*145,499*	*59,312*
71yr Max. Month	*7,243*	*7,243*	*2,949*	*4,783*	*2,460*	*729*	*205*	*114*	*615*	*0*	*1,327*	*1,213*	*933*	*114*	*61*	*0*	*3,774*	*2,544*	*1,203*	*1,230*	*3,689*	*5,314*	*2,460*
71yr Avg. Month	*4,928*	*4,435*	*32*	*160*	*301*	*407*	*186*	*1*	*220*	*0*	*980*	*853*	*11*	*114*	*2*	*0*	*2,775*	*1,564*	*4*	*1,207*	*1,900*	*176*	*392*
71yr Total	*4,198,301*	*3,778,200*	*27,133*	*136,266*	*256,733*	*346,835*	*158,633*	*456*	*187,746*	*0*	*834,605*	*726,618*	*9,487*	*97,128*	*1,371*	*0*	*2,364,584*	*1,332,856*	*3,581*	*1,028,151*	*1,618,663*	*149,790*	*334,167*

Table B.3.13 – Municipal Water Source Quantity Tables (Continued)

Repl71.rsp: GDU WATER SUPPLY REPLACEMENT PIPELINE

	City of Fargo					**City of West Fargo**					**City of Moorhead**						**City of Grand Forks**				**STORAGE DEPLETION**	
		Water Source					Water Source					Water Source						Water Source				
Table Statistics	Demand	Red River	Natural Flows on Sheyenne River	Lake Ashtabula Storage	Import Pipeline	Demand	Natural Flows on Sheyenne River	Lake Ashtabula Storage	West Fargo Aquifer Recharge	Import Pipeline	Demand	Red River	Lake Ashtabula Storage	Buffalo Aquifer	Moorhead Aquifer Recharge	Import Pipeline	Demand	Red & Red Lake Rivers	Lake Ashtabula Storage	Import Pipeline	Import	Lake Ashtabula
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*7,243*	*0*	*0*	*0*	*7,243*	*729*	*0*	*0*	*0*	*729*	*1,213*	*0*	*0*	*0*	*0*	*1,213*	*3,774*	*0*	*0*	*3,774*	*14,480*	*0*
1931-1941 Avg. Month	*4,928*	*0*	*0*	*0*	*4,928*	*407*	*0*	*0*	*0*	*407*	*866*	*0*	*0*	*0*	*0*	*866*	*2,775*	*0*	*0*	*2,775*	*10,789*	*0*
1931-1941 Max Year	*59,131*	*0*	*0*	*0*	*59,131*	*4,885*	*0*	*0*	*0*	*4,885*	*10,387*	*0*	*0*	*0*	*0*	*10,387*	*33,304*	*0*	*0*	*33,304*	*129,469*	*0*
1931-1941 Total	*650,441*	*0*	*0*	*0*	*650,441*	*53,735*	*0*	*0*	*0*	*53,735*	*114,257*	*0*	*0*	*0*	*0*	*114,257*	*366,344*	*0*	*0*	*366,344*	*1,424,159*	*0*
71yr Max. Month	*7,243*	*0*	*0*	*0*	*7,243*	*729*	*0*	*0*	*0*	*729*	*1,213*	*0*	*0*	*0*	*0*	*1,213*	*3,774*	*0*	*0*	*3,774*	*14,480*	*0*
71yr Avg. Month	*4,928*	*0*	*0*	*0*	*4,928*	*407*	*0*	*0*	*0*	*407*	*866*	*0*	*0*	*0*	*0*	*866*	*2,775*	*0*	*0*	*2,775*	*10,789*	*0*
71yr Total	*4,198,301*	*0*	*0*	*0*	*4,198,301*	*346,835*	*0*	*0*	*0*	*346,835*	*737,477*	*0*	*0*	*0*	*0*	*737,477*	*2,364,584*	*0*	*0*	*2,364,584*	*9,192,299*	*0*

Table B.3.14 - Industrial Water Source Quantity Tables

Base171.rsp: BASELINE MODEL RUN USING 2005 DEMANDS OVER 71 YEARS OF FLOW DATA

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*519*	*519*	*0*	*319*	*319*	*0*	*54*	*54*	*0*	*215*	*215*	*0*	*197*	*197*	*0*	*248*	*248*	*0*	*692*	*692*	*0*	*25*	*25*	*0*	*0*	*0*	*0*
1931-1941 Avg. Month	*96*	*88*	*0*	*61*	*47*	*0*	*9*	*9*	*0*	*53*	*48*	*0*	*175*	*76*	*0*	*38*	*38*	*0*	*251*	*251*	*0*	*25*	*14*	*0*	*0*	*0*	*0*
1931-1941 Max Year	*1,156*	*1,156*	*0*	*732*	*732*	*0*	*104*	*104*	*0*	*637*	*637*	*0*	*2,105*	*1,768*	*0*	*450*	*450*	*0*	*3,011*	*3,011*	*0*	*300*	*225*	*0*	*0*	*0*	*0*
1931-1941 Total	*12,716*	*11,630*	*0*	*8,052*	*6,214*	*0*	*1,144*	*1,129*	*0*	*7,007*	*6,335*	*0*	*23,155*	*9,999*	*0*	*4,950*	*4,950*	*0*	*33,121*	*33,121*	*0*	*3,300*	*1,816*	*0*	*0*	*0*	*0*
71yr Max. Month	*519*	*519*	*0*	*319*	*319*	*0*	*54*	*54*	*0*	*215*	*215*	*0*	*197*	*197*	*0*	*248*	*248*	*0*	*692*	*692*	*0*	*25*	*25*	*0*	*0*	*0*	*0*
71yr Avg. Month	*96*	*95*	*0*	*61*	*53*	*0*	*9*	*9*	*0*	*53*	*52*	*0*	*175*	*160*	*0*	*38*	*38*	*0*	*251*	*251*	*0*	*25*	*22*	*0*	*0*	*0*	*0*
71yr Total	*82,076*	*80,990*	*0*	*51,972*	*45,408*	*0*	*7,384*	*7,369*	*0*	*45,227*	*44,555*	*0*	*149,455*	*136,117*	*0*	*31,950*	*31,950*	*0*	*213,781*	*213,781*	*0*	*21,300*	*18,732*	*0*	*0*	*0*	*0*

NO ACTION RUN SCENARIO 1

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*519*	*519*	*0*	*319*	*319*	*0*	*54*	*54*	*0*	*215*	*215*	*0*	*197*	*194*	*0*	*248*	*248*	*0*	*692*	*692*	*0*	*25*	*25*	*0*	*315*	*315*	*0*
1931-1941 Avg. Month	*96*	*96*	*0*	*61*	*47*	*0*	*9*	*9*	*0*	*53*	*48*	*0*	*175*	*41*	*0*	*38*	*37*	*0*	*251*	*251*	*0*	*25*	*14*	*0*	*309*	*70*	*0*
1931-1941 Max Year	*1,156*	*1,156*	*0*	*732*	*732*	*0*	*104*	*104*	*0*	*637*	*637*	*0*	*2,105*	*1,226*	*0*	*450*	*450*	*0*	*3,011*	*3,011*	*0*	*300*	*250*	*0*	*3,709*	*2,175*	*0*
1931-1941 Total	*12,716*	*12,716*	*0*	*8,052*	*6,214*	*0*	*1,144*	*1,144*	*0*	*7,007*	*6,352*	*0*	*23,155*	*5,380*	*0*	*4,950*	*4,941*	*0*	*33,121*	*33,121*	*0*	*3,300*	*1,841*	*0*	*40,799*	*9,176*	*0*
71yr Max. Month	*519*	*519*	*0*	*319*	*319*	*0*	*54*	*54*	*0*	*215*	*215*	*0*	*197*	*197*	*0*	*248*	*248*	*0*	*692*	*692*	*0*	*25*	*25*	*0*	*315*	*315*	*0*
71yr Avg. Month	*96*	*96*	*0*	*61*	*53*	*0*	*9*	*9*	*0*	*53*	*52*	*0*	*175*	*152*	*0*	*38*	*37*	*0*	*251*	*251*	*0*	*25*	*22*	*0*	*309*	*266*	*0*
71yr Total	*82,076*	*82,076*	*0*	*51,972*	*45,408*	*0*	*7,384*	*7,384*	*0*	*45,227*	*44,572*	*0*	*149,455*	*129,519*	*0*	*31,950*	*31,941*	*0*	*213,781*	*213,781*	*0*	*21,300*	*18,757*	*0*	*263,339*	*227,046*	*0*

NO ACTION RUN SCENARIO 2

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	*519*	*519*	*0*	*319*	*319*	*0*	*54*	*54*	*0*	*215*	*215*	*0*	*197*	*194*	*0*	*248*	*248*	*0*	*692*	*692*	*0*	*25*	*25*	*0*	*548*	*548*	*0*
1931-1941 Avg. Month	*96*	*96*	*0*	*61*	*45*	*0*	*9*	*9*	*0*	*53*	*48*	*0*	*175*	*34*	*0*	*38*	*37*	*0*	*251*	*251*	*0*	*25*	*14*	*0*	*538*	*99*	*0*
1931-1941 Max Year	*1,156*	*1,156*	*0*	*732*	*732*	*0*	*104*	*104*	*0*	*637*	*637*	*0*	*2,105*	*1,131*	*0*	*450*	*450*	*0*	*3,011*	*3,011*	*0*	*300*	*250*	*0*	*6,451*	*3,100*	*0*
1931-1941 Total	*12,716*	*12,716*	*0*	*8,052*	*5,895*	*0*	*1,144*	*1,144*	*0*	*7,007*	*6,383*	*0*	*23,155*	*4,534*	*0*	*4,950*	*4,937*	*0*	*33,121*	*33,121*	*0*	*3,300*	*1,829*	*0*	*70,961*	*13,122*	*0*
71yr Max. Month	*519*	*519*	*0*	*319*	*319*	*0*	*54*	*54*	*0*	*215*	*215*	*0*	*197*	*197*	*0*	*248*	*248*	*0*	*692*	*692*	*0*	*25*	*25*	*0*	*548*	*548*	*0*
71yr Avg. Month	*96*	*96*	*0*	*61*	*53*	*0*	*9*	*9*	*0*	*53*	*52*	*0*	*175*	*148*	*0*	*38*	*37*	*0*	*251*	*251*	*0*	*25*	*22*	*0*	*538*	*447*	*0*
71yr Total	*82,076*	*82,076*	*0*	*51,972*	*45,089*	*0*	*7,384*	*7,384*	*0*	*45,227*	*44,603*	*0*	*149,455*	*125,963*	*0*	*31,950*	*31,937*	*0*	*213,781*	*213,781*	*0*	*21,300*	*18,715*	*0*	*458,021*	*380,447*	*0*

Table B.3.14 – Industrial Water Source Quantity Tables (Continued)

NORTH DAKOTA IN-BASIN SCENARIO 1

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	315	315	315
1931-1941 Avg. Month	96	96	0	61	47	14	9	9	0	53	53	0	175	44	131	38	37	0	251	251	0	25	14	11	309	72	237
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	1,926	450	450	0	3,011	3,011	0	300	250	225	3,709	2,175	3,404
1931-1941 Total	12,716	12,716	0	8,052	6,214	1,838	1,144	1,144	0	7,007	6,954	53	23,155	5,845	17,310	4,950	4,941	0	33,121	33,121	0	3,300	1,841	1,459	40,799	9,543	31,256
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	315	315	315
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	153	22	38	37	0	251	251	0	25	22	3	309	268	41
71yr Total	82,076	82,076	0	51,972	45,408	6,564	7,384	7,384	0	45,227	45,174	53	149,455	130,514	18,941	31,950	31,941	0	213,781	213,781	0	21,300	18,757	2,543	263,339	228,506	34,833

NORTH DAKOTA IN-BASIN SCENARIO 2

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	548	548	548
1931-1941 Avg. Month	96	96	0	61	45	16	9	9	0	53	53	0	175	37	139	38	37	0	251	251	0	25	14	11	538	104	434
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	2,065	450	450	0	3,011	3,011	0	300	250	225	6,451	3,514	6,451
1931-1941 Total	12,716	12,716	0	8,052	5,895	2,157	1,144	1,144	0	7,007	6,954	53	23,155	4,819	18,336	4,950	4,937	0	33,121	33,121	0	3,300	1,829	1,471	70,961	13,703	57,258
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	548	548	548
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	149	26	38	37	0	251	251	0	25	22	3	538	452	86
71yr Total	82,076	82,076	0	51,972	45,089	6,883	7,384	7,384	0	45,227	45,174	53	149,455	126,940	22,515	31,950	31,937	0	213,781	213,781	0	21,300	18,715	2,585	458,021	384,701	73,320

RED RIVER BASIN SCENARIO 1

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	315	315	315
1931-1941 Avg. Month	96	96	0	61	47	14	9	9	0	53	53	0	175	44	131	38	37	0	251	251	0	25	14	11	309	72	237
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	1,926	450	450	0	3,011	3,011	0	300	250	225	3,709	2,175	3,404
1931-1941 Total	12,716	12,716	0	8,052	6,214	1,838	1,144	1,144	0	7,007	6,954	53	23,155	5,845	17,310	4,950	4,941	0	33,121	33,121	0	3,300	1,841	1,459	40,799	9,543	31,256
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	315	315	315
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	153	22	38	37	0	251	251	0	25	22	3	309	268	41
71yr Total	82,076	82,076	0	51,972	45,408	6,564	7,384	7,384	0	45,227	45,174	53	149,455	130,514	18,941	31,950	31,941	0	213,781	213,781	0	21,300	18,757	2,543	263,339	228,506	34,833

RED RIVER BASIN SCENARIO 2

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	548	548	548
1931-1941 Avg. Month	96	96	0	61	45	16	9	9	0	53	53	0	175	37	139	38	37	0	251	251	0	25	14	11	538	104	434
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	2,065	450	450	0	3,011	3,011	0	300	250	225	6,451	3,514	6,451
1931-1941 Total	12,716	12,716	0	8,052	5,895	2,157	1,144	1,144	0	7,007	6,954	53	23,155	4,819	18,336	4,950	4,937	0	33,121	33,121	0	3,300	1,829	1,471	70,961	13,703	57,258
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	548	548	548
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	149	26	38	37	0	251	251	0	25	22	3	538	452	86
71yr Total	82,076	82,076	0	51,972	45,089	6,883	7,384	7,384	0	45,227	45,174	53	149,455	126,940	22,515	31,950	31,937	0	213,781	213,781	0	21,300	18,715	2,585	458,021	384,701	73,320

Table B.3.14 – Industrial Water Source Quantity Tables (Continued)

LAKE OF THE WOODS SCENARIO 1

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	315	315	315
1931-1941 Avg. Month	96	96	0	61	47	14	9	9	0	53	53	0	175	44	131	38	37	0	251	251	0	25	14	11	309	75	234
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	1,926	450	450	0	3,011	3,011	0	300	250	225	3,709	2,175	3,404
1931-1941 Total	12,716	12,716	0	8,052	6,214	1,838	1,144	1,144	0	7,007	6,954	53	23,155	5,845	17,310	4,950	4,941	0	33,121	33,121	0	3,300	1,866	1,434	40,799	9,858	30,941
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	315	315	315
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	153	22	38	37	0	251	251	0	25	22	3	309	269	41
71yr Total	82,076	82,076	0	51,972	45,408	6,564	7,384	7,384	0	45,227	45,174	53	149,455	130,514	18,941	31,950	31,941	0	213,781	213,781	0	21,300	18,782	2,518	263,339	228,821	34,518

LAKE OF THE WOODS SCENARIO 2

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	548	548	548
1931-1941 Avg. Month	96	96	0	61	47	14	9	9	0	53	53	0	175	37	138	38	37	0	251	251	0	25	14	11	538	105	432
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	2,065	450	450	0	3,011	3,011	0	300	250	225	6,451	3,514	6,440
1931-1941 Total	12,716	12,716	0	8,052	6,214	1,838	1,144	1,144	0	7,007	6,954	53	23,155	4,932	18,223	4,950	4,937	0	33,121	33,121	0	3,300	1,829	1,471	70,961	13,884	56,960
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	548	548	548
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	149	26	38	37	0	251	251	0	25	22	3	538	452	86
71yr Total	82,076	82,076	0	51,972	45,408	6,564	7,384	7,384	0	45,227	45,174	53	149,455	127,053	22,402	31,950	31,937	0	213,781	213,781	0	21,300	18,715	2,585	458,021	384,882	72,977

GDU IMPORT TO SHEYENNE RIVER SCENARIO 1 with Peak Day in the River

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	315	315	315
1931-1941 Avg. Month	96	96	0	61	45	16	9	9	0	53	53	0	175	36	139	38	37	0	251	251	0	25	14	11	309	59	250
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	2,105	450	450	0	3,011	3,011	0	300	250	225	3,709	2,175	3,709
1931-1941 Total	12,716	12,716	0	8,052	5,895	2,157	1,144	1,144	0	7,007	6,954	53	23,155	4,779	18,376	4,950	4,931	0	33,121	33,121	0	3,300	1,825	1,475	40,799	7,832	32,967
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	315	315	315
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	149	27	38	37	0	251	251	0	25	22	3	309	260	49
71yr Total	82,076	82,076	0	51,972	45,089	6,883	7,384	7,384	0	45,227	45,174	53	149,455	126,640	22,815	31,950	31,931	0	213,781	213,781	0	21,300	18,685	2,615	263,339	221,297	42,042

GDU IMPORT TO SHEYENNE RIVER SCENARIO 2 with Peak Day in the River

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpe			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	184	197	248	248	0	692	692	0	25	25	25	548	548	548
1931-1941 Avg. Month	96	96	0	61	45	16	9	9	0	53	53	0	175	29	147	38	37	0	251	251	0	25	13	12	538	84	452
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	882	2,105	450	450	0	3,011	3,011	0	300	225	225	6,451	2,538	6,440
1931-1941 Total	12,716	12,716	0	8,052	5,895	2,157	1,144	1,144	0	7,007	6,954	53	23,155	3,789	19,366	4,950	4,823	0	33,121	33,121	0	3,300	1,775	1,525	70,961	11,144	59,696
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	548	548	548
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	143	33	38	37	0	251	251	0	25	22	3	538	434	104
71yr Total	82,076	82,076	0	51,972	45,089	6,883	7,384	7,384	0	45,227	45,174	53	149,455	121,503	27,952	31,950	31,823	0	213,781	213,781	0	21,300	18,596	2,704	458,021	369,586	88,235

Table B.3.14 – Industrial Water Source Quantity Tables (Continued)

GDU IMPORT PIPELINE SCENARIO 1 WITH PEAK DAY ADDED TO SIZE OF PIPE

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpeton			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	315	315	315
1931-1941 Avg. Month	96	96	0	61	47	14	9	9	0	53	53	0	175	44	131	38	37	0	251	251	0	25	14	11	309	75	234
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	1,926	450	450	0	3,011	3,011	0	300	250	225	3,709	2,175	3,404
1931-1941 Total	12,716	12,716	0	8,052	6,214	1,838	1,144	1,144	0	7,007	6,954	53	23,155	5,845	17,310	4,950	4,941	0	33,121	33,121	0	3,300	1,866	1,434	40,799	9,858	30,941
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	315	315	315
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	153	22	38	37	0	251	251	0	25	22	3	309	269	41
71yr Total	82,076	82,076	0	51,972	45,408	6,564	7,384	7,384	0	45,227	45,174	53	149,455	130,514	18,941	31,950	31,941	0	213,781	213,781	0	21,300	18,782	2,518	263,339	228,821	34,518

GDU IMPORT PIPELINE SCENARIO 2 WITH PEAK DAY ADDED TO SIZE OF PIPE

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpeton			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Import
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	548	548	548
1931-1941 Avg. Month	96	96	0	61	47	14	9	9	0	53	53	0	175	37	138	38	37	0	251	251	0	25	14	11	538	106	431
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	2,065	450	450	0	3,011	3,011	0	300	250	225	6,451	3,553	6,440
1931-1941 Total	12,716	12,716	0	8,052	6,214	1,838	1,144	1,144	0	7,007	6,954	53	23,155	4,932	18,223	4,950	4,937	0	33,121	33,121	0	3,300	1,854	1,446	70,961	13,927	56,917
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	548	548	548
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	149	26	38	37	0	251	251	0	25	22	3	538	452	86
71yr Total	82,076	82,076	0	51,972	45,408	6,564	7,384	7,384	0	45,227	45,174	53	149,455	127,053	22,402	31,950	31,937	0	213,781	213,781	0	21,300	18,740	2,560	458,021	384,925	72,934

MISSOURI RIVER TO RED RIVER VALLEY IMPORT SCENARIO 1

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpeton			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	315	315	315
1931-1941 Avg. Month	96	96	0	61	47	14	9	9	0	53	53	0	175	44	131	38	37	0	251	251	0	25	14	11	309	75	234
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	1,926	450	450	0	3,011	3,011	0	300	250	225	3,709	2,175	3,404
1931-1941 Total	12,716	12,716	0	8,052	6,214	1,838	1,144	1,144	0	7,007	6,954	53	23,155	5,845	17,310	4,950	4,941	0	33,121	33,121	0	3,300	1,866	1,434	40,799	9,858	30,941
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	315	315	315
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	153	22	38	37	0	251	251	0	25	22	3	309	269	41
71yr Total	82,076	82,076	0	51,972	45,408	6,564	7,384	7,384	0	45,227	45,174	53	149,455	130,514	18,941	31,950	31,941	0	213,781	213,781	0	21,300	18,782	2,518	263,339	228,821	34,518

MISSOURI RIVER TO RED RIVER VALLEY IMPORT SCENARIO 2

	American Crystal Sugar 1076			American Crystal Sugar 1917			American Crystal Sugar 251			American Crystal Sugar 450008			Cargill Incorporated - Wahpeton			American Crystal Sugar 520039			American Crystal Sugar 630213			ADM Corn Processing - Wallhalla			New Industry at Wahpeton		
		Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source			Water Source	
	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Goose River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundw	Demand	Natural Flows on Red Lake River	From Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	Lake Ashtabula Storage	Demand	Natural Flows on Red River	From Groundwater
Control Period	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft
1931-1941 Max Month	519	519	0	319	319	319	54	54	0	215	215	53	197	194	197	248	248	0	692	692	0	25	25	25	548	548	548
1931-1941 Avg. Month	96	96	0	61	47	14	9	9	0	53	53	0	175	37	138	38	37	0	251	251	0	25	14	11	538	104	434
1931-1941 Max Year	1,156	1,156	0	732	732	447	104	104	0	637	637	53	2,105	1,226	2,065	450	450	0	3,011	3,011	0	300	250	225	6,451	3,514	6,451
1931-1941 Total	12,716	12,716	0	8,052	6,214	1,838	1,144	1,144	0	7,007	6,954	53	23,155	4,932	18,223	4,950	4,937	0	33,121	33,121	0	3,300	1,829	1,471	70,961	13,703	57,258
71yr Max. Month	519	519	0	319	319	319	54	54	0	215	215	53	197	197	197	248	248	0	692	692	0	25	25	25	548	548	548
71yr Avg. Month	96	96	0	61	53	8	9	9	0	53	53	0	175	149	26	38	37	0	251	251	0	25	22	3	538	452	86
71yr Total	82,076	82,076	0	51,972	45,408	6,564	7,384	7,384	0	45,227	45,174	53	149,455	127,053	22,402	31,950	31,937	0	213,781	213,781	0	21,300	18,715	2,585	458,021	384,701	73,320

Table B.3.15 - Depletion from Water Source Table
(Additional volume of water required from project features to supply demand)

OPTION		North Dakota In-Basin Scenario One	North Dakota In-Basin Scenario Two	Red River Basin Scenario One	Red River Basin Scenario Two	Lake of the Woods Scenario One	Lake of the Woods Scenario Two	GDU Import to Sheyenne River Scenario One (*Peak Day in River*)	GDU Import to Sheyenne River Scenario Two (*Peak Day in River*)	GDU Import to Red River Valley Scenario One (*Peak Day in Pipe*)	GDU Import to Red River Valley Scenario Two (*Peak Day in Pipe*)	Missouri River to Red River Valley Import Scenario One	Missouri River to Red River Valley Import Scenario Two
	Filename	*Loop171*	*Loop271*	*BF1NGF71*	*BF2NGF71*	*BF1W71*	*BF2W71*	*I1NAWPOP*	*I2NAWPOP*	*BF1NAW71*	*BF2NAW71*	*I1D71*	*I2D71*
		ac-ft	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*
1931 to 1940	Min Year	11,606	12,986	10,594	18,745	28,135	38,958	29,163	49,700	30,817	41,724	27,748	39,325
	Max Year	29,566	42,669	23,277	38,128	41,421	57,658	41,525	65,752	45,337	61,580	30,410	43,435
	Avg. Year	20,385	27,487	17,487	29,363	35,640	49,511	36,042	58,445	39,076	52,943	29,612	42,245
	Total	203,850	274,866	174,867	293,625	356,395	495,109	360,419	584,453	390,755	529,434	296,124	422,445
1941 to 2001	Min Year	12	12	0	0	14,481	14,481	6	2	16,841	16,942	14,488	14,488
	Max Year	15,554	19,000	6,013	10,732	22,723	28,716	22,108	39,403	25,377	31,420	27,069	33,488
	Avg. Year	5,127	5,964	211	502	14,811	15,366	6,091	13,836	17,257	17,913	18,020	19,610
	Total	312,765	363,801	12,864	30,630	903,454	937,352	371,560	843,969	1,052,700	1,092,707	1,099,216	1,196,218
1931 to 2001	Average	7,276	8,995	2,644	4,567	17,744	20,176	10,310	20,119	20,330	22,847	19,653	22,798

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Appendix B - Attachment 1

West Fargo North Aquifer Potential Recharge Volume Analysis with GIS

West Fargo North Aquifer Potential Recharge Volume Analysis with GIS

Bureau of Reclamation
Technical Service Center
Denver, CO

Background

The West Fargo North Aquifer is a confined aquifer that is used for residential, municipal, and industrial water. Over time there has been enough withdraw of water from the aquifer to lower the piezometeric head in part of the aquifer where it is now below the upper confining layer. The upper confining layer has an irregular shape and is difficult to map as a topographic surface. The space between the water surface (the currently lowered water surface) and the upper confining layer, provides a good opportunity for use as storage space in an aquifer recharge and recovery program. In order to develop an estimate of the volume of storage available between this irregular shaped upper confining layer and the current water level, a "map" is needed where the volume of this space can be computed. Creating a 3-D representation of this space, using existing data with ArcGIS, has been completed. The completion of this 3-D can now be used as a first estimate in the amount of available storage, or can be used to point out where data gaps exist and provide guidance on future planning for additional exploration.

Roger Burnett, an engineer in Reclamation's Ground Water and Drainage Group, D-8550, asked Bruce Whitesell and Patrick Wright, from the Remote Sensing and Geographic Information Group, D-8260, to assist in estimating the potential available recharge volume for North Dakota's West Fargo North aquifer using the modeling tools available within the ArcGIS Geographic Information System environment. This document is a brief summary of the methodology used and results achieved to this point the project.

When this work was originally completed in June, 2003, an incorrect grid cell size was used in calculating the recharge area and volume. This error has been corrected. All grids now use a 10 meter by 10 meter cell size. The figures have been recompiled and the potential recharge volume recalculated. Only wells within the boundary of the West Fargo North Aquifer were used to define the Top of Aquifer surface, the Water Surface Elevation, and the Potential Recharge surface.

Data

The three primary data sets used in this work covered all of Cass County, North Dakota and were acquired from Mr. Chris Bader at the North Dakota State Water Commission. These data were provided as Microsoft Access data tables that are related by a common site index field. Tables include:

1. Site data (well sites) – This table contains geographic locations of well sites and other tabular information. Each of the 311 wells in the county has a unique site index number. The Mp_elev field contains a value which is the elevation in feet above Mean Sea Level for the top of the well. The "Top_screen" and "Bottom_screen" fields provide the depths for the screened interval from which the well draws water.

2. Lithology - This table shows the down hole stratigraphy for the 158 wells in the county which were logged and had the lithology recorded. Of these, only 79 wells fall within the boundary of the West Fargo North Aquifer.

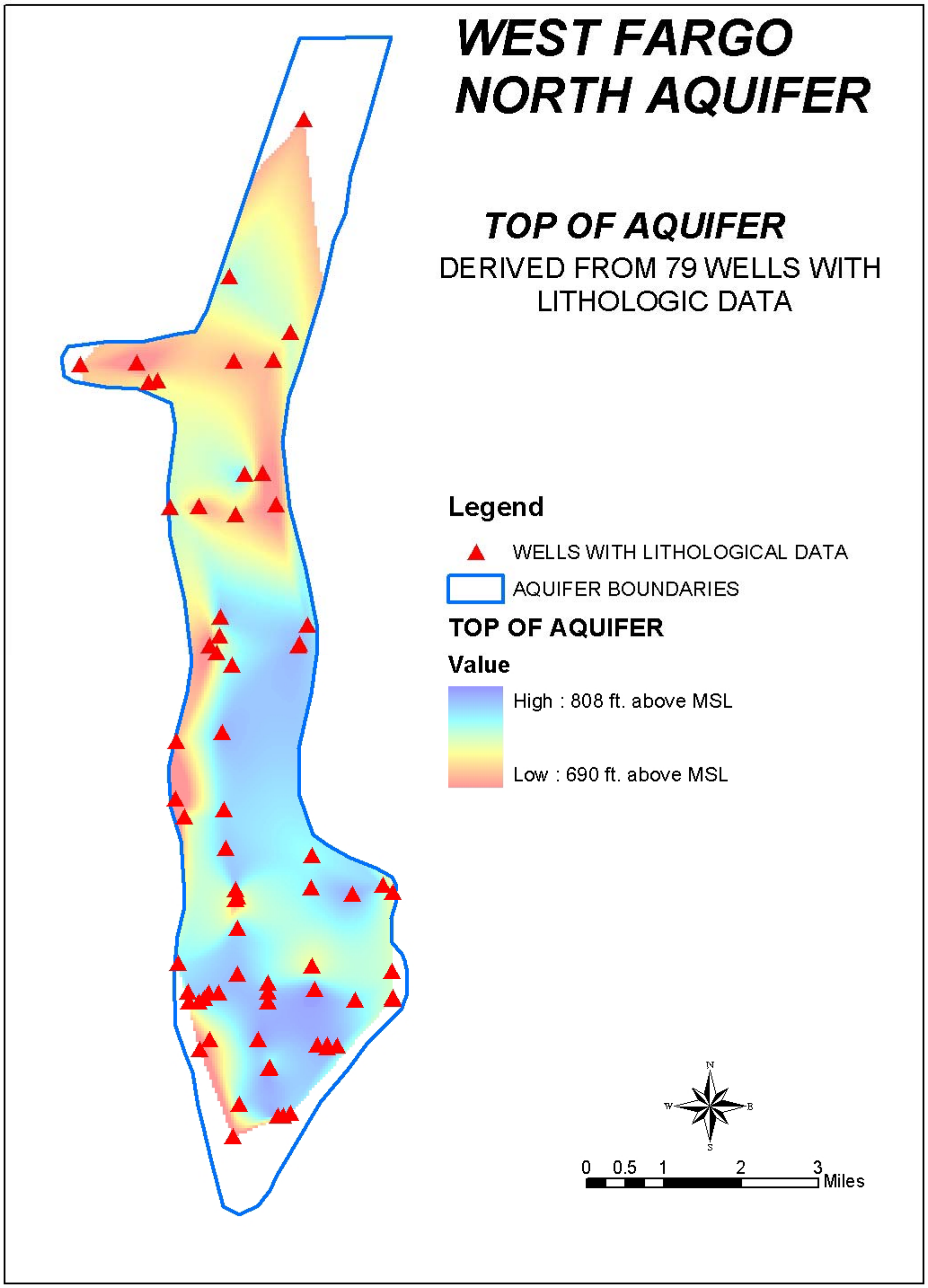
3. Water elevation – This table contains measurements of depth to water for various wells and the date the measurement was made. Some wells have many water depth readings and others have only one. While this data table contains more than 80,000 records, only 47 readings are more recent than January 1, 1999. Of those 47 records, there are only 17 that fall within the West Fargo North Aquifer boundary. The depth to water reading for the most recent date in these 17 wells was used for this study.

Mr. Bader also provided aquifer boundary data in ArcGIS compatible shapefile format.

Methodology

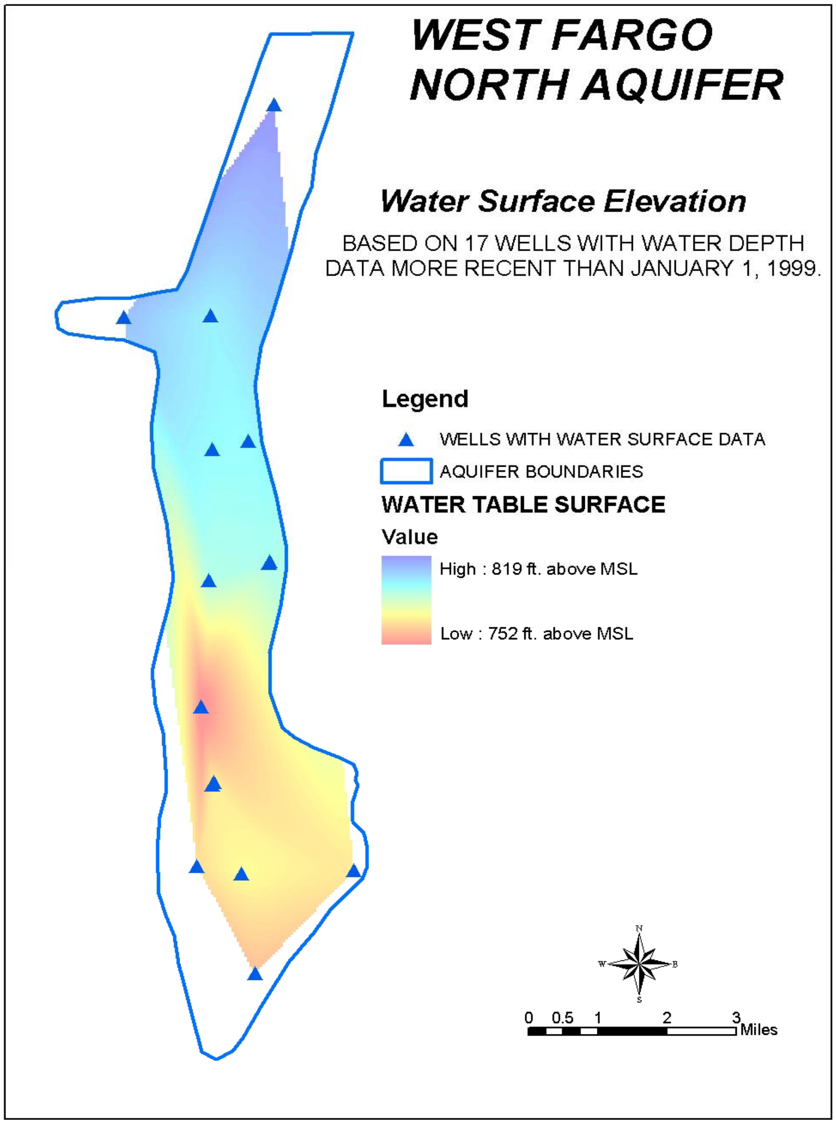
The methodology to derive potential recharge volume was relatively simplistic and made use of ESRI's ArcGIS 8.3 and Arcview 3.3 software. The top of aquifer values were generated by examining the lithology for the wells in association with the screened interval depth. The lithology logs usually indicated sands or gravels for the depths where the site table showed the screened interval of the well. The lithology was followed back up the hole to a depth where it changed from sand or gravel to a clay or till confining layer. The depth value from the lithology table's "Begin_inte" field was used to define this interface. The "Begin_inte" depth values were subtracted from the "Mp_Elev" value, a measurement of the Mean Sea Level Elevation for the top of the well, to calculate the top of the aquifer for each well. These 79 points were then run through the "Natural Neighbors" algorithm creating a raster file representing the interpolated surface elevation of the top of the aquifer. This algorithm was selected because of the distribution and uneven density of the data points. Figure 1 shows this surface with 10m x 10m pixels.

Figure 1 – Top of Aquifer



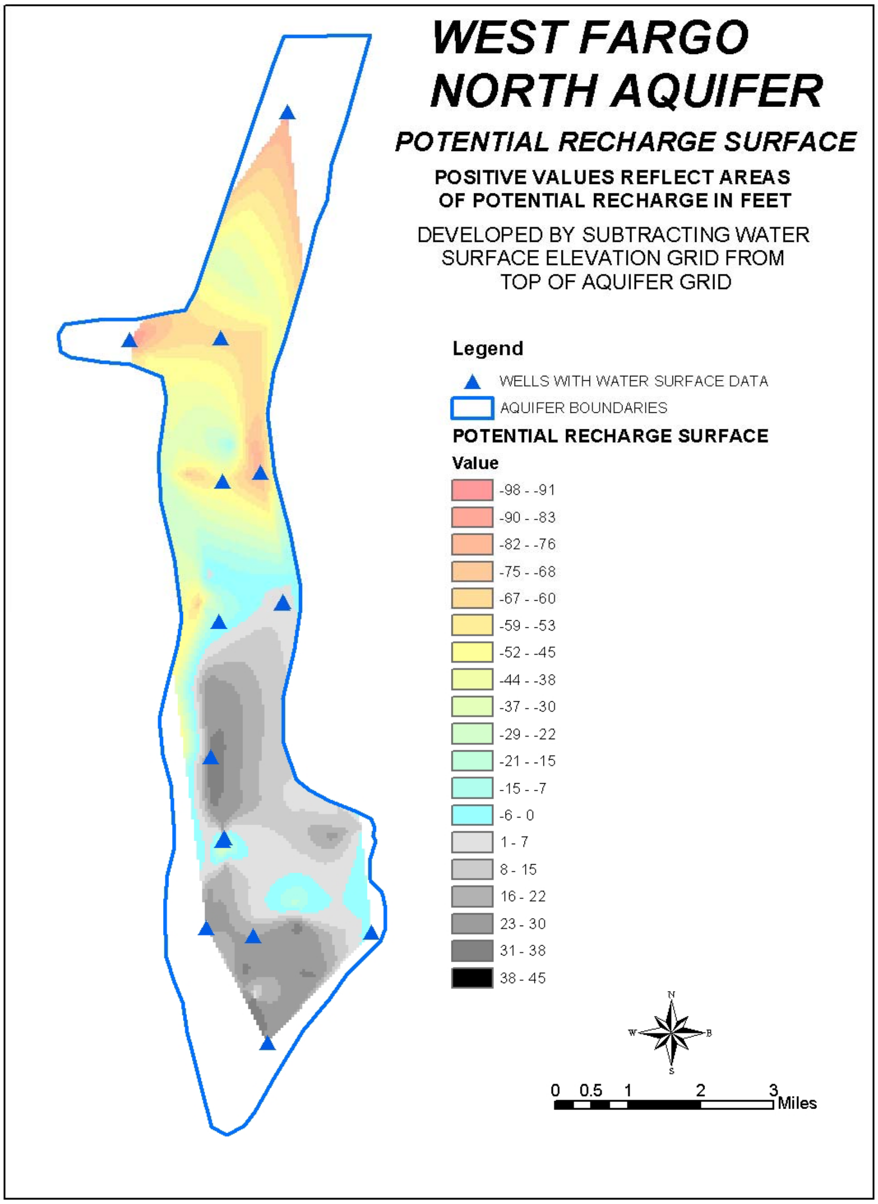
The water surface elevation was derived using the most current depth to water value for the 17 wells within the West Fargo North Aquifer. The depths to water values were subtracted from the “Mp_Elev” value, a measurement of the Mean Sea Level Elevation for the top of the well, to calculate a top of water surface elevation. These 17 points were run through the “Natural Neighbors” algorithm to produce a raster file with 10m X 10m grid cells representing the surface elevation of the water table surface. See figure 2. The investigators recognize that there were only a limited number of measurements and they are spread across more than 3 years. However, these are the only data that were available for this study.

Figure 2 – Water Surface Elevation



Using the grid algebra functions within ArcGIS, the Water Surface Elevation grid was subtracted from the Top of Aquifer grid to produce a third 10m x 10m raster data set, the Potential Recharge Surface grid. See figure 3. Positive values in this raster grid represent space between the upper confining layer and the current water surface that is potentially suitable for artificial recharge while negative values show areas where the piezometric surface elevation is already greater than the top of the aquifer elevation.

Figure 3 – Potential Recharge Surface



Results
The total potential recharge volume was calculated by multiplying the 100 square meter cell size for each cell representing a void by the distance to the top of the aquifer for that cell. A value of 98,186,764 cubic meters, or 79,601 acre feet was calculated. Because of concerns about the interconnectivity with other aquifers, only the 17 points that fall inside the West Fargo North

Aquifer were used in this calculation. Limiting the potential recharge surface to these points leaves large blank areas area around the southern tip of the aquifer boundary. Therefore, the 79,601 acre feet should be considered a conservative estimate until the water levels at the boundary of the aquifer can be defined and included.

These calculations provide a limited use view of the spatial characteristics of the West Fargo North Aquifer because:
There were only 17 wells with depth to water values more recent than January 1, 1999. Because these wells were sampled over a 3 year period, they do not provide an accurate representation of the water surface for the aquifer.
No estimates of porosity were available for the various lithologies. Therefore, the potential recharge volume calculations do not account for the sediment porosity.

Future efforts
Following discussions with Roger Burnett, D-8550, it was decided that in order to have good data from which to generate the depth to water and potential recharge surfaces, future efforts must concentrate on gathering new depth to water readings for a large number of wells that are more evenly distributed across the aquifer than the 17 wells used here. If the wells were measured during the same time period, a much more accurate picture of the aquifer could be developed. Because the potential recharge zone appears to be concentrated at the southern end of aquifer, additional wells might be considered in this area.

The second issue that needs to be addressed is development of a porosity data. A fourth raster layer representing porosity should be used to calculate a more accurate measurement of the potential recharge volume. D-8550 and DKAO staff should review the lithologic data and obtain or develop porosity values for each pertinent sediment type. Upon receipt of these data, D-8260 staff can develop the porosity data set and recalculate the total potential recharge volume.

Appendix B - Attachment 2

North Dakota State Water Commission Internal Memo Regarding Thompson-Acker

OFFICE OF THE NORTH DAKOTA STATE ENGINEER

MEMO TO: Dave Ripley, Director, Water Appropriation Division
FROM: Robert R. White, Water Resource Engineer
SUBJECT: Baldhill Dam Review
DATE: March 17, 2005

This memo is intended to provide you with a summary of the results of a review of the Baldhill Dam project files.

Senate Document No. 193 authorized the construction of Baldhill Dam. The Board of Engineers for Rivers and Harbors recommended the construction of Baldhill Dam for "…flood control and water conservation…”. The Corps of Engineers, District Engineer, recommended the construction of "…a dual-purpose reservoir for flood control and the alleviation of low-water conditions downstream… ".

The document also contains a description of the project and the project area along with a cost/benefit analysis. The analysis showed that for flood control alone, the project would not be justified, however, a dual-purpose reservoir for flood control and water supply would be justified. The benefits to the downstream municipalities were estimated and benefits to the downstream rural areas were addressed. In addressing the benefits to the downstream rural areas they mainly addressed the benefits that would accrue due to a more reliable supply of stock water. The locals were asked to estimate the benefits of a live stream throughout the summer and they were asked not to consider the possibility of irrigation.

The authorizing senate document did not address the allocation of the stored waters. It did, however, state that the project would not be constructed until the local interests gave certain assurances. These assurances were made in a document signed by Fred G. Aandahl, then the Governor of North Dakota, on May 23, 1947. One of these assurances was that the local interests would make a cash contribution of $208,000 toward the construction cost. The collection of this money was the responsibility of the Eastern North Dakota Water Resource Development Association.

When Baldhill Dam was constructed, questions arose regarding the apportionment of the stored water. A statement presented at a special meeting of the State Water Commission by the Corps of Engineers stated:

"Although the reservoir will be operated by the Corps of Engineers, the assigning of water rights and the determination of priorities of water use, consistent with the intent of Congress, should be handled by the North Dakota State Water Conservation Commission under existing state law."

A plan for apportioning the water in Lake Ashtabula (Thompson-Acker plan) was developed by Sivert Thompson, Vice Chairman of the State Water Commission, and I. A. Acker, Counsel for the State Water Commission. This plan apportioned the water based in part on the amount of money contributed and in part on the populations of the municipalities at that time. 75% of the 69,000 acre-feet stored at full pool was apportioned based on the population of the municipalities. The remaining 25% of the stored water was apportioned based on the amount of money contributed.

When this plan was presented to the Commission at the same special meeting, Mr. Thompson noted that the plan "could not be set up on a permanent basis, but was merely a trial proposition". He went on to explain that, "Whether there will be such a thing as demand for irrigation of farms along the river we can not tell. Dry years and the advent of the sprinkler systems would have to be considered." It is this plan that has served as the basis for the granting of water rights for the water stored in Lake Ashtabula.

The construction of Baldhill Dam was cost shared by the State of North Dakota and several municipalities and industries. The cities of Grand Forks, West Fargo, Lisbon, Valley City, and Fargo, along with Northern States Power, Union Stockyards, American Crystal Sugar, Great Northern Railroad, Northern Pacific Railroad, and the Soo Line Railroad contributed a total of $276,200 toward the construction of Baldhill Dam.

The following is a list of the parties who cost shared the construction of Baldhill Dam and the volume of water that constituted their share based on the amount of cost share and populations:

Fargo	35,880 ac-ft
Grand Forks	20,023
Valley City	6,686
Southwest Fargo	959
Lisbon	1,780
American Crystal Sugar	2,732
Union Stock Yards	159
Great Northern RR Co.	235
Northern Pacific RR Co.	235
Soo Line RR Co.	76
Northern States Power Co.	235
Total	69,000

This plan was developed as a guide for dividing the water among the entities who shared in the construction costs. It did not constitute a right to the water; there were no agreements or contracts with either the State of North Dakota or the Corps of Engineers that represented a buying or selling of the stored water. The original contributors were still required to obtain a water use permit to use the water apportioned to them under this plan. The only way a right to the stored water could be obtained was through the process prescribed in Chapter 61-04 of the N.D. Century Code. Many of the municipalities did obtain water use permits for the use of their share of the water in the lake. The water permits issued for the use of water from Lake Ashtabula are listed below:

Permit No.	City	Acre-Feet
1091	Fargo	35,880
835A	Grand Forks	20,023
1096	Valley City	6,686
921	West Fargo	954
3588	Lisbon	373
	Total	**63,916**

The permits held by the cities of Fargo, Grand Forks, and Valley City were issued for the quantities listed in the Thompson-Acker plan. Water permit No. 921 held by the City of West Fargo is for 5 acre-feet less than the quantity listed in the Thompson-Acker plan, but this discrepancy appears to have resulted from a small error in the quantity requested in the conditional water permit application. The 373 acre-feet allocated to the City of Lisbon under permit No. 3588 represents their share based on their cash contribution. They have never filed a conditional water permit application for the remainder of their share, nor have they ever put to beneficial use the portion appropriated under permit No. 3588. The cities of Fargo and Valley City are the only permit holders who have actually put water from Lake Ashtabula to beneficial use.

In the early 1980's the State Engineer surveyed the other cash contributors as to their interest in their share of the water allocated to them by the Thompson-Acker plan of apportionment. As a result of this survey all claims to water from Lake Ashtabula were officially voided for five of the six industries that contributed money but never filed a water permit application. This included Northern States Power, Union Stock Yards, and all the various railroads.

American Crystal Sugar Company had filed a water permit application that was not acted on for several years, due in part to the fact that they had no identified means of diverting the water. This application was denied, and no new application has been filed.

Those entities that have failed to obtain a water use permit for their share of the stored water have abandoned all claims to this water. Therefore, a total of 63,916 acre-feet of water stored in Lake Ashtabula are presently appropriated. This leaves 5,184 acre-feet unappropriated. This unallocated water is the portion of the pool originally set aside for the other contributors, but for which all rights have since been abandoned. This unallocated portion of the pool is by state law, under the management of the State Engineer. It is this portion of unappropriated water that the State Engineer has requested be released to relieve the downstream drought conditions in past years.

Appendix B – Attachment 3

Surface Water Hydrology Model Configuration and Assumptions

Draft: 6/23/2004

DRAFT
Red River Valley Water Supply Project
Surface Water Hydrology Model Configuration and Assumptions
Comparison between Appraisal-Level and Feasibility-Level Modeling

Darrin Goetzfried, P.E.
Thomas R. Bellinger, P.H.

INTRODUCTION

Reclamation is using StateMod software for feasibility-level surface water modeling of the Red River Basin in North Dakota and Minnesota as part of the Red River Valley Water Supply Project. This document briefly outlines the primary configuration of the model and assumptions used in model development. Assumptions, methods, and model configuration will be documented in the Hydrology Appendix of the *Report on Red River Valley Water Supply Project Needs and Options* (Needs and Options Report).

The Red River Basin previously was modeled at an appraisal-level using the HYDROSS model (Reclamation 2000). Appraisal-level studies are preliminary investigations performed to determine if further detailed analyses are necessary. To expedite the process, appraisal-level studies use existing data while relying on general assumptions in lieu of collecting additional data. The primary configuration and assumptions of the previous appraisal-level study have been included in this document to compare with the current feasibility-level effort.

The current feasibility-level modeling study uses StateMod software. Like Hydross, StateMod is a water budgeting model. The current study is more detailed than the previous effort, includes all available recorded data, and uses more refined levels of analysis to fill data gaps or to improve upon the available datasets.

ASSUMPTIONS AND MODEL CONFIGURATION

1. Historic Flow Database – A historic flow database consists of the flows recorded at gaging stations.
Appraisal-level and Feasibility-Level Studies - Historic flow data are from the U.S. Geological Survey (USGS) stream gages and are assumed to be accurate. Historic data were used in the development of a naturalized flow dataset for both HYDROSS and StateMod Models. Reclamation has not altered these values.

2. Naturalized Flow Database - Naturalized flow is the flow within a channel without human influences. The naturalized flow database is used by surface flow models as a baseline to which demands, return flows, and other operational considerations are applied. The database represents the natural water supply.
Appraisal-Level Study - USGS developed a naturalized flow database for the years 1931 through 1984 for the appraisal-level study (Guenther 1990). The data set did not account

for return flows but represented a conservative level of natural flow and was deemed adequate for an appraisal-level study[1].

Feasibility-Level Study - USGS developed a naturalized flow database for a more extensive period of time, 1931 through 2001, at a greater level of detail than the previous effort (Emerson 2004). All assumptions and methods used by the USGS will be documented in a report to be completed this summer. Reclamation has reviewed USGS methods used for their calculations and assumes all draft output data to be at a feasibility level as follows:

- The Red River Basin was further divided into sub-basins, referred to as DEBs, allowing for additional streamflow data locations to be added into the model. DEBs are the name given to the sub-basins used by the USGS in the development of the naturalized flow database (DEB is an abbreviation for Doug Emerson Basin).
- Precipitation variations within each DEB and channel slope were examined and determined to be insignificant to the regression equations.
- Return flows were included in the natural flow development.
- Reservoir operations of Lakes Orwell, Mud, and Traverse were considered in the natural flow computations.

Comparison between Appraisal and Feasibility-Level Studies - The appraisal-level study did not consider these operations, and used the gaged flow at Fargo to represent natural conditions. Key flow points on the Sheyenne and Red rivers were compared to determine the net effect of the change between appraisal-level and feasibility-level modeling. That comparison showed little or no difference in the calculated natural flows; however, addition of multiple new flow locations refined the feasibility-level model's ability to perform more accurate simulations.

Although, multiple flow points were added to the feasibility-level model to account for tributary inflow, there were several instances where natural flows were not available at intermediate points or at the tributary headwaters. Thus, demands and return flows were located just downstream of each streamflow point (located at the tributary mouths). The StateMod model subtracted those demands from these points and return flows were placed just before the next streamflow point. This allowed for tracking shortages within the feasibility-level model.

3. Base Flow Database - The base flow database is the "natural flow" database created by StateMod.
Appraisal-Level - All baseline natural flow data were preprocessed and entered into HYDROSS, because this model cannot compute base flows.

Feasibility-Level - StateMod generates a database containing base flow values.

- A base flow database, was created by StateMod based on historic data.

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[1] In this document the term "conservative" means to make assumptions that guard against underestimating the available water supply.

- No assumptions were made and no variables were set that altered the equation used by the model to calculate base flow: base flow = historic gaged flow (-) imports (+) demands (-) return flows (+) change in storage (+) net evaporation.
- This action was performed within the model for calibration purposes. The results of this action are further defined in the calibration discussion below.

4. Calibration/Simulation -

Appraisal-Level - Some spot checks were performed in calibrating the model. Future demands were placed directly over flow data from 1931 to 1940. The model performed a balance for each node, however the calibration was weak. Weaknesses in the HYDROSS model included:

- Calibration:
    - Calibration checks were performed at a 1994 level of demand. No attempt was made to account for differences in demand between 1931 and 1988. Primary years used for checking were 1980-1988. No actual 1994 naturalized flow data had been developed by USGS at the time of model development.
- Simulation:
    - Demand distribution was based only on Fargo and Grand Forks distributions which were applied to nearby communities.
    - No lag times were incorporated due to the monthly time step of the model.

Feasibility-Level - The model was calibrated by comparing the model base flow (naturalized flow) values to those generated by the USGS. StateMod would only create base flow for periods where demand and return flow values are available (1979 through 2001). Reclamation in consultation with USGS and the Colorado's Decision Support Systems (StateMod software developer) determined that the model was calibrated when the net difference between the naturalized flow and the base flow equated to 0.5 percent for the years 1985 through 1994.

- Calibration:
    - The period 1985 through 1994 was used to create base flow within the model.
    - The net difference between the USGS natural and the base flow calculated by StateMod equated to 0.5 percent over the period of study. Reclamation assumed that the two datasets were similar enough to be interchangeable.
    - No delays or travel times were added into the system as these were assumed to be included in the monthly historic flow data.
- Simulation:
    - Based on the assumption that the two natural datasets were interchangeable, Reclamation will use natural flows generated by the USGS to perform model simulations.
    - The period 1985 through 1994 was chosen for future simulation. This time period aligned the worst demand year

(1988) with the worst flow year (1934) when the flow data from 1931 to 1940 (USGS) were imposed over the flow values for 1985 to 1994 (StateMod).
- The 2050 demands and return flows were then based on the trends of the 1985 to 1994 timeframe and were imposed again over the historic data.
- No delays or travel times were added into the system as these were assumed to be included in the monthly historic flow data.

Comparison between Appraisal and Feasibility-Level Studies - The feasibility-level model is more standardized and is more truly calibrated than the appraisal-level model. StateMod is considered to be more accurate because more detailed data were included in model development, and all data were developed to mesh with the StateMod program. StateMod also accounts for the peaks and valleys within the demand and return flow data as occurred historically.

5. Water Permits -
Appraisal-Level - Water rights were only considered on the mainstem Sheyenne and Red Rivers. Western Water Law applies to the North Dakota side of the Red River and Riparian Water Law to the Minnesota side. This was addressed as follows:
- Although administrative dates were not used in all cases, each mainstem North Dakota user was given a priority date based on permitted flow or on acreage.
- Minnesota water right dates were set to match the dates their counterparts held across the river. If no counterpart existed, the Minnesota user was assigned a senior tributary right to preserve Minnesota flow levels.
- Future use permits were given junior priority dates subordinate to existing uses.
- Illegal or unmeasured diversions were not considered in the appraisal-level study, but were assumed to be partially accounted for in the post-study discovery of an overestimation of losses on the Sheyenne River below Lake Ashtabula.
- Irrigation rights were based on full acreage and an east/west basin computation of crop mixes, crop water use, and on-site efficiency.

Feasibility-Level – All available demand and discharge permit data were entered into the model according to documented location, administration date, and decreed amount. Permit data were included for all mainstem and tributary locations in the basin.
- Administrative priority dates:
  - Administrative priority dates for North Dakota permits were set according to the permit issuance date.
  - Due to the difference in water law between North Dakota and Minnesota, the administrative priority on all demand permits located on tributaries in Minnesota were set to pre-date any existing permits from North Dakota. Administrative dates of the larger Minnesota municipal users on the Red River were set to match the most senior

water right of their counterpart municipality across the river. This was done to reflect the difference in Western Water Law versus Riparian Water Law allowing Minnesota users to withdraw water based on their riparian water rights versus permit dates.
    - Minnesota Q90 minimum instream flow administrative dates were set to predate other permits within that state; however, Reclamation assumed that municipalities located on the Minnesota tributaries would still be served even when flows drop below Q90. Thus, the municipal administrative priority dates were set to be one year more senior than the minimum instream flow administrative dates.
    - Future permits were considered to be junior and have an administrative date set to post-date existing permits.
- Decreed Diversion Amounts:
    - All decreed diversion amounts reflect permit data; however, some users withdraw more water than their decreed amount. A free water right was added into the model to account for this additional demand and to track overages.
    - Withdrawals exceeding 12.5 acre-feet per year for North Dakota and 1 million gallons per year for Minnesota require a permit. All withdrawals smaller than that amount were not accounted for individually and are considered to be included in gaging data.
    - Permits without decreed amounts were set to match their peak month of historic use.
    - New permits had the decreed amount set to account for their peak month.
    - Reclamation consulted with the North Dakota State Water Commission about estimating the amount of water used by illegal or unmeasured diversions and found that there was no available estimate. Reclamation assumes that historic illegal or unmeasured diversions are accounted for by gaged data.
- Location:
    - All permits were located in the model within the DEB at their intake or discharge point.

Comparison between Appraisal and Feasibility-Level Studies - The feasibility-level study more accurately depicts basin permits. A permit holder's ability to withdraw water is linked directly to their administrative permit date which reflects water laws and timing of withdrawals more closely than the previous study. This optimizes water usage, thus making the appraisal-level study the more conservative of the two.

6. Diversions/Demands -

Appraisal-Level - Diversion/demand data were compiled as part of hydrology modeling.

- Municipal, Rural, and Industrial (MR&I): Average monthly data were developed for key water users. Future population projections were then factored into demand data. Annual data were held constant for the period of record modeled and monthly distribution of demand was included in the dataset but repeated from year to year with no consideration for demand differences under wet, dry, or normal conditions.

  - When available, existing demand was based on input from the city of concern. Future demands were then extrapolated from Reclamation population projections. A separate set of simulations were performed using participant demand projections (higher estimates) that were not in agreement with Reclamation projections.

- Irrigation: Irrigation permits were compiled for the basin. No historic use data were gathered. The demand for irrigation was set to the full decreed amount of each permit and computed at the headgate based on an assumed crop mix, Blaney-Criddle crop consumptive requirements, and an assumed system efficiency based on sprinkler irrigation.
  - Irrigation water permits were only considered on the mainstem Sheyenne and Red Rivers. Depletions on the mainstem were based on the appraisal-level USGS naturalized flow database (Guenther 1990).
- Future demands added to the existing system were given a junior priority date.

Feasibility-Level - Diversion/demand data were compiled by Reclamation as part of the Needs and Options Report and by USGS during development of the naturalized flow database. These data were collected for the Sheyenne and Red Rivers including all major tributaries. These demand data are based directly on the historic record.

- MR&I: demand data for calibration came directly from the historic record. The demand data used for simulation came from needs assessment studies which used the historic record to calculate future values based on population projections and water conservation. This approach retains historic peaks and valleys within the data. These values were entered into the model.
  - Some municipal diversions were turned off for future simulations if it was assumed that they would be served by a bulk water user. These diversions will be discussed in the Needs and Options Report.
  - New demands were given a junior water right. Users requiring permits larger than their existing permit were given an additional junior water right.
- Irrigation: Similar to the diversion/demand, these diversions were collected for the entire basin and were based on the historic record compiled from the North Dakota State Water Commission and Minnesota Department of Natural Resources.
  - Irrigation demands were based upon recorded use rather than on decreed amount.
  - Future irrigation demand is junior in water right to this effort; thus, historic demands (1985 to 1994) were held constant in the future.
  - Demands for irrigation and golf courses were combined into one withdrawal point for each DEB. This minimized the number of individual river nodes in the model. Each permit retains its identity through priority date and allocation.

- Operational limitations – A surface water model accounts for use and storage of water within a system based on input data. Other than the average delays and losses included in the naturalized flow database for natural flows, most accounting models, including StateMod, do not recognize lag times between storage and delivery points or the inability of most systems to draw a surface water supply down to zero.
    - To simulate operational limitations and inefficiencies during the simulation of the No Action Alternative, the demand data for MR&I and Irrigation were set to "max month" for the period of record. Max month is defined as the maximum historically developed 2050 water demand for each month in the 10 year simulation period. Reclamation believes that this demand scenario will effectively model the comprehensive water needs of the Red River Valley.

Comparison between Appraisal and Feasibility-Level Studies - Shortages will change based on the outcome of the needs assessment studies and may occur at different locations based on StateMod's use of priority dates; however, shortages have been reduced because the model is no longer trying to serve the full decree of each irrigation permit.

7. Operational Rights -

Appraisal-Level -

- HYDROSS was not capable of modeling Fargo with intakes on both the Red and Sheyenne Rivers. To account for this, the model was run with multiple manual iterations in the following manner. After the shortage was computed for Fargo's Red River intake, this shortage was moved to the Sheyenne River intake as a demand, and then the model was re-run.
- Thomas-Acker Plan (Lake Ashtabula): Those entities who have Thomas-Acker storage allocation in Lake Ashtabula as specified in the Thomas-Acker Plan (Fargo, Valley City, Lisbon, Grand Forks, West Fargo) were given permit rights to receive water from an individual reservoir. Due to limitations of HYDROSS, each Thomas-Acker Plan participant was allocated storage in its own reservoir, which was in proportion to the full-sized Lake Ashtabula in terms of geometry, inflow, outflow, minimum release, minimum pool, dead pool, and evaporation. Again, this led to a manual iteration of data, as Fargo could not be modeled directly.

Feasibility-Level -

- All users with multiple water permits have operational rights that allow them to divert water from each permit based on water availability and administrative number. For instance, Fargo has an operational right that allows them to divert water from the Sheyenne when their supply on the Red River is exhausted. This operational right transports water from the intake on the Sheyenne to Fargo via a pipeline.
- Thomas-Acker Plan (Lake Ashtabula): Each city with a right to the storage in Ashtabula has an operational right that allows them to call for stored water

when their river supplies have been exhausted. Fargo diverts this water from storage through a Sheyenne River intake via a pipeline.

- The minimum instream Q90 flow point just below Lake Orwell has an operational right that allows that reservoir to release water from storage to meet the minimum instream flow when natural flows are inadequate.
- A minimum instream flow point was placed just below Lake Ashtabula to simulate the Corps of Engineers' (Corps) operational release requirement of 13 cubic feet per second (cfs). An operational right was placed on this point to release water from storage when the natural flow and/or operational release for Thomas-Acker falls below 13 cfs.

Comparison between Appraisal and Feasibility-Level Studies - The feasibility-level model performs as many as 20 iterations until it achieves results to the nearest acre foot. The appraisal-level model required manual iterations and generally did not achieve the same level of accuracy.

8. Return Flows -

Appraisal-Level - Return flows were assumed to be a percent of the water demand and varied based on the type of use and on-site and conveyance efficiency. As the demand changed, so did the corresponding return flow. Return flows values were usually released to the next downstream model node to account for a limitation in HYDROSS. If released into the same node under HYDROSS, users would have the water available for reuse – which was unrealistic. The downstream node transfer of water rights occasionally could bypass downstream users in the same node. This situation has been corrected in more recent versions of HYDROSS.

Feasibility-Level - Return flows within the model are based directly on historic record. The only modification to these numbers occurred during future simulation when their value was modified as a direct percentage of change between historic demand and future demand. These values were then combined for each DEB and returned to its terminus at the end of the month.

- StateMod requires that return flows be modeled as a percent of demand; however, this does not fit the historic trend within the valley where return flows sometimes exceed demands. The model will not allow for a negative percent to be entered into the system.
    - To mathematically account for this, return flow values were modeled as imports during calibration.
    - In order to mathematically account for this departure during the simulation of future scenarios, return flows were converted to wells that produced a volume equal to the return flows and returned that value to the system where designated. This allowed the model to track return flows mimicking the historic record including peaks and valleys within the data.
    - When water demands cannot be fully met during No Action Alternative simulations, return flows will be modified to account for consumptive use differences.

Comparison between Appraisal and Feasibility-Level Studies - Return flows are more accurately depicted based on historic events within the basin in the feasibility-level model. HYDROSS runs appear to be less accurate.

9. Minnesota Minimum Instream Flow Q90 – The Minnesota Department of Natural Resources established minimum instream flows (Q90) for all watersheds within the state using a hydrologic method (i.e., 90% exceedence flow) as a guideline. Using this method they set minimum instream flows at various points along the Red River and on its major tributaries. When flows fall below Q90, water users are prohibited from withdrawing water and irrigators are cut off before municipalities. There is no minimum instream flow requirement in North Dakota.

Appraisal-Level -

- No Q90 minimum instream flows were used in the model as the flow data and demands were not extended beyond the mouths of the Minnesota tributaries.
- The only minimum flow considered in the model was the 13 cfs minimum release from Lake Ashtabula.

Feasibility-Level -

- Q90 values were set in the model at points on tributaries above the Red River on the Minnesota side. Q90 flow limitations for Minnesota cities on the Red River were not incorporated into the model because these are not enforced due to the complexity of water laws dividing the river.
- Although not a true minimum instream flow, the operational release of 13 cfs by the Corps from Lake Ashtabula has been treated as one in the model. This allows the reservoir to release additional water when natural and project flows fall below 13 cfs.

Comparison between Appraisal and Feasibility-Level Studies - The Minnesota side of the basin is more refined under StateMod. Water availability to the Red River from that side of the basin will be more easily understood.

10. Reservoirs -

Appraisal-Level - This study only included Lake Ashtabula as a dynamic reservoir within the system. All other reservoirs were not included in the model because there was insufficient information available to include them. It was assumed that the existing gages within the model accounted for flows.

- Lake Ashtabula: The effect of Thomas-Acker could not be handled directly using HYDROSS. To simulate the effects of Thomas-Acker, Lake Ashtabula was sub-divided into five geometrically proportioned reservoirs based on storage allocations of the primary benefactors (Fargo 56.1%, Grand Forks 31.3%, Valley City 10.5%, West Fargo 1.5%, and Lisbon 0.6%).
    - The starting volume was assumed to be 28,000 acre-feet, which is the fish and wildlife conservation pool in the Corps operating plan.
    - Minimum pool allowed was at the 28,000 acre-feet fish and wildlife conservation level.

  - Sedimentation/dead pool is discussed in the sedimentation section of this document.
  - Filling/Net Evaporation: All reservoirs shared in reservoir filling while net evaporation was applied proportionally to each reservoir.
  - Target Volumes: drawdowns for flooding from spring runoff were set based on the Corps' operating plan.
- Lake Orwell, Lake Traverse, Mud Lake, and Red Lake were not included in direct operational computation in the model. The reaches of the basin concerning these water bodies were converted to unregulated reservoirs by assuming the same recorded outflow as past conditions. No attempt was made to consider pre-reservoir operations, which probably contributed to the conservative nature of the appraisal-level study. No other small impoundments were considered in this study.

Feasibility-Level -

- Lake Ashtabula: The effects of Thomas-Acker are being handled as separate accounts to the main reservoir. These accounts subdivide the reservoir into seven areas including dead pool (1240 acre-feet), fish and wildlife conservation (28,000 acre-feet), and the remaining storage based on Thomas-Acker (Fargo 56.1%, Grand Forks 31.3%, Valley City 10.5%, West Fargo 1.5%, and Lisbon 0.6%).
  - The starting volume was assumed to be 28,000 acre-feet, which is the fish and wildlife conservation pool in the Corps operating plan.
  - Minimum pool allowed was at the 28,000 acre-feet fish and wildlife conservation level.
  - Sedimentation/dead pool is discussed in the sedimentation section of this document.
  - Filling/Net Evaporation: All accounts in the reservoir share in filling and net evaporation.
  - Target Volumes: Drawdowns for flooding from spring runoff were set based on the new operational plan from the Corps that includes a 5-foot dam raise for flood protection.
  - Thomas-Acker allocation: When a city depletes their storage allocation, they are not allowed to use another city's allocation.
  - Winter drawdown targets will remain at elevation 1264.0 throughout model simulation[2].
- Lake Orwell: No set operational plan for this reservoir was found.
  - Starting volume was set to the lowest recorded volume in January from 1985 through 1994.
  - Reservoir is set as a spill-only reservoir with an operational right supplying the Q90 structure downstream with required flows.
- Red Lake Reservoir: There were no data available for inflows to Red Lake Reservoir. Reclamation turned this reservoir off in lieu of having 1930s flow data just below the outlet structure. This flow was entered into the model as

[2] The Corps' operational plan for Baldhill Dam maintains a drawdown of elevation 1264.0 when forecasted runoff is less than 25,000 acre-feet.

natural flow and all demands above this point were moved just downstream in order to properly account for them.

- Lake Traverse & Mud Lake: There are no operational plans available for either of these reservoirs. It appears that they operate primarily for flood purposes with releases being constrained by water quality issues. These reservoirs have no operational water rights associated with them and only supply water to the system when they spill over. However, during a 1930's drought, the net evaporation on both reservoirs is approximately equal to the inflow for both. Historic gage data below Mud Lake show outflow to be zero during much of the 1930s.
- Smaller reservoirs or impoundments were not included as part of this model. Where more information is needed, an individual reservoir and its storage potential may be analyzed outside of the model.

Comparison between Appraisal and Feasibility-Level Studies - There are more data and refinement in the feasibility-level study as compared to the appraisal-level study. Any inconsistencies have been eliminated that may have been introduced by dividing Lake Ashtabula into five reservoirs followed by performing iterations. The HYDROSS model is considered to be more conservative with respect to reservoir operations. StateMod can more directly handle these allocations than can HYDROSS.

11. Precipitation/Evaporation -

Appraisal-Level -

- Monthly precipitation and evaporation were computed for Lake Ashtabula to account for monthly net evaporation. These data were established as a time series to account for meteorological conditions occurring monthly from 1931 to 1988.
- Net effective precipitation data were used to compute Blaney-Criddle Crop Irrigation Requirements for the crop mix assumed in the river basin.

Feasibility-Level-

- Precipitation and evaporation data gathered by USGS for analyzed basin reservoirs will be used as a basis for computing monthly net evaporation.
- No attempt will be made to determine precipitation or evaporation outside of these reservoirs as this is assumed to be accounted for by gage data.

12. Sedimentation -

Appraisal-Level - Sedimentation for Lake Ashtabula at year 2050 was estimated to be 5000 acre-feet for the reservoir. This was based on an appraisal-level estimate of sedimentation performed by Larry Kaiser of the Reclamation Technical Service Center (Reclamation Supporting Materials – Phase II, circa 1992). Sediment was not distributed in Lake Ashtabula for future conditions, rather it was placed in the dead pool to account for some potential capacity loss.

Draft: 6/23/2004

Feasibility-Level -

- Lake Ashtabula: Future sedimentation values were calculated for Lake Ashtabula based on historic patterns. These values were calculated to be approximately 100 acre-feet per year (which equates to 5000 acre-feet over the period of study and matches previous results) and will be subtracted from the storage capacity for future scenarios. This sedimentation is assumed to be on the bottom or lake bed of the reservoir.
- Other reservoirs: Sedimentation rates for the remaining reservoirs within the basin were assumed to be negligible; no accounting for sedimentation is included in the model. Reclamation and the Corps predict sedimentation at less than 100 acre-feet for each reservoir.

Comparison between Appraisal and Feasibility-Level Studies - There is no appreciable difference.

13. River Gains and Losses – Due to the variance in technical opinions on the losses associated with the Sheyenne River during the early stages of the feasibility-level study, Reclamation contracted with the USGS to compile the report *River Gains and Loss Studies for the Red River of the North Basin, North Dakota and Minnesota*. This report was the compilation of all known studies and reports pertaining to gains and losses associated with the Sheyenne and Red Rivers. This report showed a large range of values associated with losses on the Sheyenne River.

Upon further development of the surface water model, Reclamation determined that the average gains and losses are tracked by the model based on their values represented within the gage data. Reclamation recognized that the model did not account for those losses associated with project flows (greater than natural flows that occur due to human influence). Since the losses in Williams-Sether (2004), *River Gains and Loss Studies for the Red River of the North Basin, North Dakota and Minnesota,* do not distinguish natural losses from project losses, Reclamation tasked the USGS with developing a value for the additional losses that would result from adding project water. The value only will be associated with feasibility-level future simulations.

Appraisal-Level - Project flow losses were factored into the model by entering in a 15% efficiency loss. These losses were tied to project releases from Lake Ashtabula. Since HYDROSS was limited in its handling of losses, it was assumed that losses represented in the model were a worst case scenario and were counterbalanced by illegal diversions of water. These estimated loss computations added to the conservative nature of the appraisal-level study.

Feasibility-Level – Based on the project flow loss analysis performed by the USGS, there was a 3.5 cfs loss for each additional 100 cfs of project flow added into the channel. This 3.5 cfs was comprised of the additional surface water width, loss to bank storage, and transpiration.

- Reclamation assumed the project water flows to be approximately 100 cfs based on appraisal-level results. This results in a project water loss of 3.5 cfs on the Sheyenne River and 3.5 cfs on the Red River from West Fargo to Grand Forks. Reclamation added into the model an additional 3 cfs loss to account for the distance between Grand Forks and the Canadian border. These losses will be modeled as a constant demand to the system that has 100% consumptive use.

i. These losses may be modified based on actual project flows that will be determined through modeling future alternatives.

Comparison between Appraisal and Feasibility-Level Studies - The efficiency loss used in the appraisal-level model was too conservative. The net result was a double accounting of losses which elevated shortages within the system. By modeling with a consumptive demand in the feasibility-level study, the gain and loss values are accounted for and are assumed to more accurately reflect actual events.

14. Devils Lake Outlet -

Appraisal-Level - There were no proposals for a Devils Lake outlet when this study was conducted so it was not considered.

Feasibility-Level -

- Reclamation has been tasked with performing modeling scenarios that account for a Devils Lake Outlet (either state or federal) releasing water to the Sheyenne River.
- Reclamation will analyze information in the Corps' Devils Lake Outlet environmental impact statement and water quality restrictions placed on the proposed outlet to determine how a federal outlet should be modeled. Reclamation will also consult with the North Dakota State Water Commission and North Dakota Department of Health on restrictions on the proposed state outlet to determine how it should be modeled.

Comparison between Appraisal and Feasibility-Level Studies – The appraisal-level study did not include a Devils Lake Outlet. During the feasibility-level study, if water quality permit restrictions would not permit releases during low flows on the Sheyenne River or if the lake level dropped sufficiently so that the outlet would not be operating during a dry scenario, then outflow from Devils Lake will not be modeled. If water would be predicted to be released from Devils Lake during the model's period of study, this outlet to the Sheyenne River would be modeled as an import.

15. Daily Modeling -

Appraisal-Level - No daily modeling was performed for this level of study. It was assumed that the effects of daily modeling would be offset by water conservation.

Feasibility-Level -

- Daily modeling will be performed for the worst month when 1931-1940 flow data are overlaid on 1985-1994 demand data which have been modified to account for 2050 demands.

- The demand data for daily computations will come from the needs assessment studies. The demand for the months leading up to and following will be interpolated linearly from their associative monthly demands. This will be performed for a full year as StateMod requires at least one full year of data to run.
- Daily flow data will be achieved through association within StateMod. There are existing flow points within the model that have daily information available for the 1930s. StateMod will use its associative subroutine and monthly flow values for those flow points that lack daily data. This results in flow points having the same trend as the existing daily gages, depending upon the associated gage.

Comparison between Appraisal and Feasibility-Level Studies - The appraisal-level study did not included daily step modeling. The feasibility-level study includes water conservation as a reduction of demand (Reclamation 2004). The daily modeling will show peak demands on a daily basis that are larger than monthly averages. This will assist Reclamation in determining the daily availability of water within the system and aid in the sizing of supply, distribution and/or storage structures.

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Appendix B – Attachment 4

Peer Review of Model

Memorandum
Draft

To: File
From: Ray R. Bennett
Subject: Peer Review of StateMod Application of the Red River Valley Water Supply Project No-Action Analysis
Date: June 11, 2004

Introduction

On June 4, 2004 Darrin M. Goetzfried, P.E. of the USBR in Bismarck North Dakota requested a peer review of the StateMod application to the Red River Valley Water Supply Project No-Action alternative. The peer review was asked to focused on the model operation and execution while all input data (flows, demands, returns, end-of-month contents, targets, net evaporation, etc..) were assumed to be correct. This memorandum summarizes that peer review.

Approach

The procedure used to provide peer review was to evaluate:

- Warnings provided by the model, StateMod and
- Model Setup for the Basic No Action Alternative.

For ease of review the questions provided by the USBR were copied. Comments and recommendations resulting from the peer review process immediately follow.

WARNINGS FROM LOG FILE:

1. Riginp; Warning the following reservoir has at least one right tied to an account with multiple accounts. When the one fill rule is implemented on the admin date, water is allocated from the reservoir to water rights by priority. This might cause this account to be unable to fill. To correct, allow all accounts to fill proportionally and use an operating rule to book water from other accounts into a senior account.

#	Res ID	Right ID	Account	Tot Acc
1	RNDEB23.R1	RNDEB23.R1	1	7
2	RNDEB39.R2	RNDEB39.R2	1	2
3	RNDEB10.RL	RNDEB10.RL	1	3
4	RNDEB37.R1	RNDEB37.R1	1	2
5	RNDEB39.R1	RNDEB39.R1	1	2
6	WFAquifer	WFAquifer	1	2

Reclamation: We do not know how this affects us or if it does?

Ray Bennett comment: Except aquifer ID WFAquifer none of the above reservoirs has the 1 fill rule implemented. Therefore the warning is potentially not valid for any reservoir except WFAquifer. Aquifer WfAquifer has two accounts; Recharge of 30,000 af and

LossTo Ground of 8,000 af. The warning is telling the user that account 2 may not fill with its storage right. However, the user starts this aquifer full and has 2 operating rights associated with this reservoir turned off.

Ray Bennett recommendation:. To avoid confusion, future versions of StateMod will be revised to check if the 1 fill rule is on before providing the above warning.

Ray Bennett recommendation: When/If the reservoir WfAquifer is operated the user should confirm that they want the reservoir water right to only fill account 1. If, as implied by the reservoirs name and the operating right file, the reservoir will be filled by another water right (DvDeb34.99V) then it might be prudent to turn off the reservoir water right and/or tell it to fill both accounts..

Ray Bennett recommendation: The reservoir right file has data located beneath the WfAquifer entry. Because the entry below WfAquifer has a blank ID StateMod thinks it is through reading data and ignores all data from that point forward. The user should confirm this is what is intended (e.g. reservoir rights for Maquifer, MissReservor and Mquifer are not intended to be operational.

Reclamation response: The blank ID below WFAquifer was fixed 6/11/04, Darrin Goetzfried, P.E.

2. Riginp; Warning. Structure with no water rights or free water rights only (admin # .gt. 99998.9) (may be OK if very junior or controlled by an opr right)

#	Structure ID	Name	Type	OUR EXPLAINATION
1	DM1091ND	FARGO, CITY OF	Div	OPERATIONAL RIGHT
2	DM1124ND	HUNTER, CITY OF	Div	PERMIT OFF
3	DM1244ND	DRAYTON, CITY OF	Div	OPERATIONAL RIGHT
4	DM1328ND	CRYSTAL, VILLAGE OF	Div	PERMIT OFF
5	DM1419ND	Hatton, City of	Div	PERMIT OFF
6	DM228ND	NECHE, CITY OF	Div	PERMIT OFF
7	DM258ND	CASSELTON, CITY OF	Div	PERMIT OFF
8	DM2671ND	MAYVILLE, CITY OF	Div	PERMIT OFF
9	DM3261ND	GRANDIN, CITY OF	Div	PERMIT OFF
10	DM4054ND	PEMBINA, CITY OF	Div	PERMIT OFF
11	DM4718ND	FARGO, CITY OF	Div	OPERATIONAL RIGHT
12	DM4832ND	LANGDON, CITY OF	Div	OPERATIONAL RIGHT
13	DM580001MN	OTTER TAIL POWER CO	Div	PERMIT OFF
14	DM630449MN	GRAND FORKS, CITY OF	Div	OPERATIONAL RIGHT
15	DM640504MN	DRAYTON, CITY OF	Div	OPERATIONAL RIGHT
16	DM670191MN	MOORHEAD PUBLIC SERV	Div	OPERATIONAL RIGHT
17	DM695ND	PORTLAND, CITY OF	Div	PERMIT OFF
18	DM696ND	CASSELTON, CITY OF	Div	PERMIT OFF
19	DM697ND	PARK RIVER, CITY OF	Div	PERMIT OFF
20	DM713ND	MAYVILLE, CITY OF	Div	PERMIT OFF
21	DM737ND	MINTO, CITY OF	Div	PERMIT OFF
22	DM758ND	PEMBINA, CITY OF	Div	PERMIT OFF
23	DM823ND	CAVALIER, CITY OF	Div	PERMIT OFF
24	DM835ND	GRAND FORKS, CITY OF	Div	OPERATIONAL RIGHT
25	DM874ND	NECHE, CITY OF	Div	PERMIT OFF
26	DM893ND	GRAFTON, CITY OF	Div	OPERATIONAL RIGHT
27	Rflow03.98	ReturnFLowSimAsImport	Div	USED ONLY IN CALIBRATION
28	Rflow04.50	ReturnFLowSimAsImport	Div	USED ONLY IN CALIBRATION
29	Rflow08.50	ReturnFLowSimAsImport	Div	USED ONLY IN CALIBRATION
30	Rflow08.99	ReturnFLowSimAsImport	Div	USED ONLY IN CALIBRATION
31	Rflow09.99	ReturnFLowSimAsImport	Div	USED ONLY IN CALIBRATION
32	Rflow10.50	ReturnFLowSimAsImport	Div	USED ONLY IN CALIBRATION

```
33 Rflow10.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
34 Rflow11.50   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
35 Rflow13.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
36 Rflow14.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
37 Rflow15.50   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
38 Rflow15.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
39 Rflow17.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
40 Rflow21.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
41 Rflow22.50   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
42 Rflow23.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
43 Rflow24.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
44 Rflow26.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
45 Rflow27.50   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
46 Rflow27.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
47 Rflow28.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
48 Rflow29.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
49 Rflow30.50   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
50 Rflow31.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
51 Rflow32.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
52 Rflow33.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
53 Rflow34.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
54 Rflow35.50   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
55 Rflow35.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
56 Rflow37.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
57 Rflow39.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
58 Rflow40.99   ReturnFLowSimAsImport    Div        USED ONLY IN CALIBRATION
59 IFDEB37.50   Q90DEB37.50              Isf        OPERATIONAL RIGHT
60 IFDEB39.75   Q90DEB39.75              Isf        TURNED OFF
61 RNDEB10.RL   REDLAKE                  Res        TURNED OFF
62 MAquifer     MAquifer                 Res        TURNED OFF
63 MissReservor MissReservor             Res        TURNED OFF
```

Ray Bennett comment. The column titled "Our Explanation" indicates the user has reviewed the above and the model is operating these structures as expected.

Ray Bennett recommendation. None.

3. Demcons; Warning the following demand is limited by water rights or capacity. May be OK if Controlled by an operating right. Note; only 1 value per year printed All units are af

```
Year   Mon    # ID          Name                        Demand    Rights Capacity Type
____ ____ _____ __________ __________________________ ________ ________ ________ ____
 1985  JUN      1 DM292ND    GRAFTON, CITY OF               70.      60. 5950441.  Div
      CONTROLLED BY OPERATIONAL RIGHT
 1985  JAN      4 DM4354ND   GRAND FORKS, CITY OF         1538.     280. 6148789.  Div
      CONTROLLED BY OPERATIONAL RIGHT
 1985  JUN     16 DM771852MN MOORHEAD PUBLIC SERV          639.     622. 5950441.  Div
      CONTROLLED BY OPERATIONAL RIGHT
 1985  JUL     19 DM921ND    WEST FARGO, CITY OF           419.     370. 6148789.  Div
      CONTROLLED BY OPERATIONAL RIGHT
 1985  FEB     21 PROJECTLOSS PROJECTLOSS                  300.     278. 5553745.  Div
      ERROR FOUND AND CORRECTED after this was created
 1985  JAN     22 IFDEB37.50 Q90DEB37.50                  2213.       0.      -1.  Isf
 1985  JAN     34 IFDEB39.75 Q90DEB39.75                    18.       0.      -1.  Isf
```

Reclamation: We checked the operational rights and it appeared that the first four were working properly. However, these should be checked to make certain the model is not missing something, 6/04/04, Darrin Goetzfried, P.E.

Ray Bennett comment: The above comment indicates the user has reviewed the first 4 above and the model is operating these structures as expected. The two are valid warnings and occur because the instream flow right file (.ifr) has these rights turned off.*

Ray Bennett recommendation: The user confirmed they want the instream flow rights turned off for the last two entries. The first is tied to an operating right. The last is not.

Basic No-Action Model configuration

<u>IDs:</u>

demands

DM___ND is for a permit in North Dakota

DM___MN is for a permit in Minnesota

River network

RN___ is a designation for a river node that a non-demand structure is associated with.

Instream flows

IFDEB__.__ designates min instream flow points.

Reservoirs

RNDEB__.R1 designates a reservoir and the __ is the basin it is located in.

Rflow

These IDs are remnants from calibration and are not used in simulation.

RFGage

These points were a failed attempt at modeling return flows – they now are used by the return flow wells as a return ID.

Ray Bennett comment. None.

<u>Diversions</u>: cities drawing on more than one permit had their demands combined into one primary demand and one demand ID. The cities then use operational rights to draw water from remaining permits at differing demand/river IDs.

Ray Bennett comment: Combining a structure (city) that has multiple supplies into one primary demand and one demand ID and tying them to a number of operational rights is an appropriate method to simulate the future use of multiple supplies.

Ray Bennett Recommendation: None.

Some permits were shut off. Their demands were left in the model. However, they are either moving to ground water and are no longer considered as part of the surface system or will be served by a larger hub city/water districts demand.

Ray Bennett comment: Turning a structure or water right (permit) off appears reasonable since, as described above, these demands are expected to change from surface water to ground water in the future and the current application does not include simulation of *ground water. Leaving demands in the model should cause no negative impact except that certain reports will identify these structures as being shorted which the knowledgeable user will need to recognize is expected.*

Ray Bennett Recommendation: If, as I suspect, time is an issue leave the model as is. On the other hand, if time allows I recommend you remove the demand or tie them to ground water in order to explicitly show what is occurring and simplify the interpretation and analysis of output.

Reclamation response: The permit demand data was left in the model until further confirmed by the Needs Assessment that these permits will truly be served by a bulk water supplier, 6/11/04, Darrin Goetzfried, P.E.

Free Water Permits: Free water permits were set up for those cities wither historically pulling more water than permitted or requiring larger permits in the future. Future water permits usually were named as NEW.

Ray Bennett comment: *Adding a free water right (permit), with a relatively junior administration date is a reasonable approach to replicate historic and future diversions by a structure that exceeds their permitted amount. When performing a future analysis the user needs to carefully evaluate the administration number assigned to these rights with respect to other future changes (e.g. if a future operation is senior to a free water right then the free right may divert less than it did historically).*

Ray Bennett Recommendation: None

Admin #s: We entered dates into the model in place of the admin #s. The value is year.mmdd0. Minnesota operates under riparian water law and all permits were set to predate the diversion dates for North Dakota that is under western water law. You may note that most of the MN dates are 1800.01010. This was done to make certain that MN permits are being served before the water enters into ND (the scope of our study). Those MN cities located on the Red River adjacent to ND cities had their admin date set to the same as the most senior date for the ND permits. This was done to more reasonably simulate the way water is withdrawn.

Ray Bennett comment: The use of dates as a surrogate for an administration numbers is reasonable. Assigning Minnesota a date that is earlier than any in North Dakota will achieve the modeler's "objective to make certain that MN permits are being served before the water enters into ND". *Assigning Minnesota rights for cities adjacent to North Dakota cities to the same date as the most senior North Dakota permit seems to conflict with the above objective since it could result in Minnesota and North Dakota rights competing for water during a shortage. Apparently this "*was done to more reasonably simulate the way water is withdrawn". *IF water is never short then both rights should receive their full amount. However if, as described, the exact same administration date is specified then the model will provide water in the order data is read by the model (e.g. if the Minnesota water right is provided first, it will be served first. Similarly if the North Dakota right is provided first, it will be served first). StateMod's water right report can* *be used to verify the results of the water right sort and verify which right is senior to whom.*

*Ray Bennett Recommendation: I suspect you do not need the adjacent city adjustment to "*more reasonably simulate the way water is withdrawn"*. Therefore without more information I recommend you remove this exception and make all Minnesota rights the same. This recommendation is more a documentation issue since it is not expected to create a problem with the model's operation of historic or future water supplies. The most critical issues is how the Minnesota water rights react with future alternatives.*

Reclamation response: All MN permit were set to date 1800 except cities that exist on tributaries with Q90. Those cities were set to 1749 to predate the 1750 date of Q90. Cities not located on the tributaries (Moorhead) were set to be senior to their counterpart across the river by one day, 6/11/04, Darrin Goetzfried, P.E.

Min Instream Flows: MN has requirement for minimum instream flows referred to as Q90. These were entered into the model and their admin date was set to 1750.01010 as water is shut off to users when a gage falls below the Q90 value. However, our assumption is that MN will continue to serve municipal beyond Q90, so we gave some cities the date of 1749.01010 to account for this. We are aware of that IFDEB39.75 is shut off. The others that are shut off were done so due to the tie to operation rights.

Ray Bennett comment: Providing some cities a water right that is senior to the minimum instream flow achieves the modeler's objective to provide water even when the Q90 value is exceeded.

*Ray Bennett Recommendation: Since the model is performing as the user intended I recommend you clearly point this out to reviewers so that it is clearly understood that it is an "*assumption" *that water is allowed to divert, even if Q90 value is exceeded. Clearly some might interpret this operation as overstating the available water supply; particularly for a future what if.*

Reclamation response: This will be done in documentation. However, it was Reclamations assumption that even with Q90, the cities along the tributaries were not going to be left high and dry. Thus, these cities would still be pulling water beyond Q90. This gives a conservative approach to their water needs, not allowing for this water to be used by other downstream users once it leaves the tributary and enters a mainstem, 6/14/04, Darrin Goetzfried, P.E..

Ray Bennett comment: An instream right should not be turned off by an operational rule unless the right is part of the operating rule (which is a very unusual use of an instream flow right). I suspect your description of why some instream flow rights are turned off is in error. A review of the water right report verifies that the only instream flow rights turned off have been done so in the instream flow file (.ifr).*

Ray Bennett recommendation: .Review the instream flow rights that are turned off to be sure they are operating as intended. At a minimum revise your discussion appropriately.

Reclamation response: The instream flows that are turned off are done on purpose to model more closely to historic. Both are located near reservoirs for which one is completely shut off from the system and the other is operating only to recover evaporative losses. Since, no project diversions are coming from them during modeling it is impossible for the model to accurately use these minimum instream flow points as they were intended, 6/14/04, Darrin Goetzfried, P.E.

ND has no real instream flow requirements. However, one is being used IFAshout to simulate the minimum COE release of 13 cfs from Lake Ashtabula (RNDEB23.R1). This instream requirement needs only to be met when project or natural flows from the reservoir fall below 13cfs.

Ray Bennett comment: Use of an instream right to implement an operating arrangement is reasonable. I have reviewed the instream right and associated operating right that ties it to reservoir RNDEB23.R1. Both appear to meet the modeler's objective to first benefit from water in the stream and second release reservoir water if short.

Ray Bennett Recommendation: None

Return Flows: The return flows were modeled by placing their historic values (indexed for future demands) as well withdrawals. These wells were then given a 0% efficiency and the water was returned to the end of each basin for the returns from that basin. Efficiencies are being modified manually by our shop to account for those demands that are not being 100% met during No-Action (we are aware of this and are working on it – you may already see this in the efficiencies for the well in DEB34).

Ray Bennett comment: The above approach to include return flows is an effective method to exactly matching historic return flow data. An alternative is to model return flows as a function of the amount diverted. The drawback associated with the users approach is that future return flows are not a function of the amount diverted and must be calculated after a model run then added in. The user recognizes this limitation and has determined the benefit of exactly matching return flows exceeds the benefit of using the model's efficiency capability and the limitations it may cause with respect to exactly matching historic return flows.

Ray Bennett Recommendation:. None

Reservoirs:
RNDEB10.R1 – Red Lake reservoir. This reservoir is turned off as there was no flow data above the reservoir. We are assuming a black box above the stream gage located just downstream.

Ray Bennett Comment: I am not sure I agree with calling the above approach a black box because that implies some type of magic occurs. If, as I suspect, you include some type of inflow below the reservoir then a more pleasing description (to me) is that you are operating the reservoir in the future the same as it did historically because you have no flow data. If, on-the-other hand you estimate inflow is zero then that appears to be a conservative estimate made because you have no flow data.

Ray Bennett Recommendation:. None

RNDEB23.R1 – Lake Ashtabula. This is the main storage reservoir for our model. It has a fish & wildlife conservation pool that we are trying to maintain above 28,000 af. The remainder of the storage above the 28,000 (spill is 70,700 af) is used to serve 5 cities that are part of Thomas Acker. Through Thomas Acker, five cities have a % right to the storage. Operational rights are being used to tie these cities in (Fargo, Grand Forks, Valley City, Lisbon, and West Fargo). All accounts are sharing in both the net evap and the refill. No one-fill applies.

Ray Bennett Comment: I have reviewed the reservoir and operational right files and it appears you have the reservoir and 5 operational rights set up and operating such that model to performs as the user intended. Also I have reviewed the operational right output and each of the above appears to operate as the user intended.

Ray Bennett Recommendation: None

RNDEB39.R1 and RNDEB39.R2 – Lake Traverse and Mud Lake. These reservoirs do not have operational rights associated with them. We have set targets to simulate actual occurrences. We also understand that there is no water draining out of Mud to be used by the system during the simulation period.

*Ray Bennett Comment: RNDEB39.R! (Mud Lake SD) does have an operational right to release to target (type 9). I am not sure what you mean by when you say "*We have set targets to simulate actual occurrences". *Based on a review of the reservoir output file (*.xre) targets are set to capacity and all this reservoir does is evaporate the water it started off with. It rarely diverts because it seems to be located on a tributary with no inflow? This is clearly different than the operation implied in the end-of-month file for this reservoir.*

Ray Bennett Recommendation: The user should confirm these reservoirs are operating as intended. Based on your discussion you may want the target file to equal the historic end of month file if you want them to divert and store as they did historically. At a minimum the description of how you intend them to operate should be revised.

Ray Bennett Comment: Similarly I have confirmed RNDEB39.R2 (Lake Traverse) has an operating right to release to target (type 9). Again it has targets set to capacity. It seems to divert whatever is available to it and evaporate as appropriate.

Ray Bennett Recommendation: Similar to Mud Lake comment (above).

Reclamation response: This will be further refined, however, Reclamation does not feel that there is any appreciable water available for supply based on inflow and evaporation data. Thus, the reservoirs will be balanced so evaporation will occur on both instead of only Traverse. However, the total net evaporation occurring on both will have the net effect of no water being released beyond Mud during the period of study, 6/14/04, Darrin Goetzfried, P.E.

RNDEB37.R1 – Lake Orwell. This reservoir is being used as the storage to serve a minimum instream Q90 flow just downstream. An operational right is used to make certain there is enough flow in at the Q90 location.

Ray Bennett comment: I have reviewed the input and output and confirm it serves water to IFDEB37.50.

Ray Bennett comment: Because the instream right this reservoir serves is turned off, it is only satisfied by reservoir releases. The user should confirm this instream flow right cannot benefit from other water that may pass through the reservoir.

Reclamation response: We do not know how this affects us or if it does? (This was done to make certain that Q90 was met. It was assumed to be a conservative approach that was used to make certain MN demands were met before water entered into the mainstem, 6/14/04, Darrin Goetzfried, P.E.)

Aquifer Recharge: This is set up in this model. However, it is not considered part of No-Action and is turned off.

Ray Bennett comment:. None
Ray Bennett recommendation:. None.

Replacement Reservoir: This is shut off for No-Action.

Ray Bennett comment:. None
Ray Bennett recommendation: None.

Losses: We believe there to be additional losses occurring on the Sheyenne when project water greater than the natural flow is being transported. To account for this we placed a demand at the end of DEB 33 that has a constant 100% consumptive use and an admin # of 1. The demand number was calculated and is being documented by the USGS.

Ray Bennett comment:. The above approach appears to operate as the user intended.

Ray Bennett recommendation:. None.

Other
Check Module output (*.xtb)

Stream flows

Ray Bennett comment: I have run the check module and notice the base flow estimates are very close to the historic flow estimates. In general the base flow should be significantly different than the historic to account for man's impact over time and to allow future scenarios to be compared to history. Recall the historic stream flow is used for two purposes; 1 calculated base flows and 2 compare model results to historic observations. The user may choose to not to use them to generate base flows.

Ray Bennett recommendation: Double check that the historic stream flows are really historic data so they can be user by the check and report module.

Reclamation response: These values have been compared and Reclamation is satisfied with the closeness in values between base flows and historic. This is reasonable as both of these values come from the 1930s. We believe that there was little influence by man during that period, leading to the similarity between the data sets. The confusion may have occurred during the peer review because the model uses the dates 1985 through 1994, the flows are actually from 1931 to 1940 to simulate a drought accurately during a time interval for which future flows were based. 6/14/04, Darrin Goetzfried, P.E.

Demands:

Ray Bennett comment: Why do so many diversions have no demand?

Water Budget
Ray Bennett comment: Following is the systems average water budget. As shown total inflow is about 634,800 af/yr consisting of 560,700 inflow and 73,100 returns (modeled as wells).

Total outflow is 634,800 of which only about 90,100 (15%) is diverted.

*Ray Bennett comment: The user should confirm the relationship, if any between diversions and return flows. It appears 90,100 is diverted and 73,100 returns. IF they are related then about 19% of the diversions (90100 – 73100)/ 90100 * 100) are consumed. My initial reaction is that 19% is reasonable for M&I users.*

Reclamation response: There are numerous diversions without demands during the period of study. This is caused by permits that no longer exist or are not being used during the period of study. These permits have remained in the model, although their demand may be zero, that we truly accounted for all permits located in the valley.

The relationship between use and return was not performed as the demands and the returns are based on historic recorded values. Unless those numbers were recorded improperly, the results should stand as is. 6/14/04, Darrin Goetzfried, P.E.

Water Budget

Year	Mo	Stream Inflow (+)	Return (+)	Total Inflow N/A	Divert (5) (-)	Reservoir Evaporation (-)	Stream Outflow (-)	Reservoir Change (-)	Total Outflow N/A	Delta N/A
Ave	JAN	5626	2626	8251	4530	-456	4284	-106	8252	0
Ave	FEB	5518	2508	8026	4082	-467	4789	-378	8026	0
Ave	MAR	39500	2830	42330	7799	-385	27733	7183	42330	0
Ave	APR	246262	6825	253087	13630	-72	228296	11233	253087	0
Ave	MAY	122812	9276	132088	11734	1323	115661	3370	132088	-1
Ave	JUN	52630	9303	61932	8856	1769	49959	1349	61932	0
Ave	JUL	29622	6349	35970	8385	4295	27083	-3793	35971	-1
Ave	AUG	19430	7432	26863	7621	3494	21108	-5361	26863	-1
Ave	SEP	11639	8576	20216	6607	3554	14738	-4683	20216	0
Ave	OCT	9634	6362	15996	6839	2050	10075	-2967	15997	-1
Ave	NOV	11130	7136	18265	5393	-831	13521	182	18265	0
Ave	DEC	7901	3868	11769	5290	-378	7722	-865	11770	0
Ave	**Tot**	**561704**	**73091**	**634794**	**90767**	**13896**	**524969**	**5166**	**634798**	**-4**

NoActOpt.xtb

Water Budget in acre-feet

Year	Mo	Stream Inflow (+)	Return (+)	Total Inflow N/A	Divert (-)	Reservoir Evaporation (-)	Stream Outflow (-)	Reservoir Change (-)	Total Outflow N/A	Delta N/A
Ave	JAN	5626	1778	7404	4446	-452	3551	-141	7405	0
Ave	FEB	5518	1746	7264	3846	-463	3509	371	7264	0
Ave	MAR	39500	1928	41428	7821	-385	26937	7055	41428	0
Ave	APR	246262	5400	251662	13610	-71	226864	11259	251662	0
Ave	MAY	122812	7384	130196	11753	1319	113621	3505	130197	-1
Ave	JUN	52630	7624	60254	8989	1758	48276	1231	60254	0
Ave	JUL	29622	5075	34697	8603	4254	25893	-4052	34698	-1
Ave	AUG	19430	5894	25324	7787	3479	19748	-5689	25325	-1
Ave	SEP	11639	6872	18512	6751	3513	13106	-4858	18512	0
Ave	OCT	9634	5112	14746	6901	2037	8962	-3153	14747	-1
Ave	NOV	11130	5838	16968	5320	-820	12268	199	16968	0
Ave	DEC	7901	2835	10737	4977	-374	6745	-611	10737	0
Ave	**Tot**	**561704**	**57488**	**619191**	**90805**	**13794**	**509480**	**5116**	**619195**	**-4**

Reclamation response: This output came after changes were made based on Ray Bennett's comments were received and return flows were adjusted to account for the effects of shortages on return flows as Reclamation has set up the model. The consumptive use is now (90805 – 57488)/90805 *100 = 36.7%. 6/14/04, Darrin Goetzfried, P.E.

Appendix B – Attachment 5

Appraisals of Major Aquifers in the Red River Valley (Lindvig)

North Dakota State Water Commission

900 EAST BOULEVARD - BISMARCK, ND 58505-0850 - 701-328-2750 - TDD 701-328-2750 - FAX 701-328-36%

WATER APPROPRIATION DIVISION
(701)328-2754

May 10, 1995

Mr. Roger Burnett
Bureau of Reclamation
P. O. Box 25007
Building 67, Denver Federal Center
Denver, CO 80225-0007

Dear Mr. Burnett:

In response to your letter of April 18, 1995, 1 am enclosing copies of the appraisals of the major aquifers occurring in the Red River Valley. They include the Sheyenne Delta, West Fargo, Wahpeton/Colfax, Galesburg/Page, Elk Valley, Inkster, Grand Forks, and Emerado.

If you have questions regarding this information, please feel free to call or write.

Sincerely yours,

Milton O. Lindvig, Director
Water Appropriation Division

MOL:mb/237 Encl.

Wahpeton Buried Valley Aquifer

The Wahpeton buried valley (WBV) aquifer is located in the northeast portion of Richland County in southeastern North Dakota. The ancest stream that eroded the Wahpeton buried valley entered North Dakota from the southeast about 2 mi north of the city of Wahpeton and exited north of the city of Abercrombie. The WBV aquifer underlies about 16 mi^2 between the cities of Wahpeton and Abercrombie and is comprised of fluvial deposits of sand and gravel between 140 to 300 ft below the ground surface. Water from the WBV aquifer is a calcium-magnesium bicarbonate type with an average total dissolved solids of about 650 mg/L.

The Wahpeton sand plain (WSP) aquifer overlies the WBV aquifer and consists of outwash deposits of silt, sand, and gravel between 80 to 140 ft below the ground surface. The areal extent of the WSP aquifer is wider than the WBV aquifer and in some locations there is direct hydraulic connection between the two aquifers.

The major water users from the WBV and WSP aquifers include the cities of Wahpeton and Breckenridge and the Minn-Dak Farmers Cooperative. Currently, 4 water permits allocate an annual withdrawal of 2480 acre-ft of ground water from the WBV and WSP aquifers for municipal and industrial use. This does not include an annual withdrawal of about 500 acre-ft of ground water for municipal use by the city of Breckenridge. There is potential for additional development within the WBV and WSP aquifers. However, future development is limited by the existing water rights and a pending water permit application for a significant volume of ground water for industrial use.

Colfax Aquifer

The Colfax aquifer is located in the northeast portion of Richland County and consists of buried outwash deposits of medium and coarse sand about 150 ft below the ground surface. Hydraulic properties of the Colfax aquifer are not known. However, many wells near the cities of Galchutt and Colfax have considerable head and many flow. Water from the Colfax aquifer is a sodium sulfate type with total dissolved solids of about 2400 mg/L. The chemical character of the water indicates hydraulic connection with the underlying Dakota Sandstone.

There are no major water users from the Colfax aquifer. However, future development is limited by the poor chemical quality of the ground water.

Emerado aquifer

The Emerado aquifer is a buried outwash aquifer which underlies about , square miles. It is composed of several feet of medium to coarse sand interspersed with the glacial till.

The Emerado aquifer is confined by glacial till to a depth of about 50 to 80 feet. The static piezometric surface is typically about 10 to 20 feet below land surface. The transmissivity is in the range of 1000 to 2000 ft2/day according to an aquifer test performed on a well completed in the aquifer. The storage coefficient is about 0. 000 1.

Water quality in the aquifer is generally poor. Leakage from the underlying Paleozoic formations have caused dissolved solids concentrations to typically be above 2000 mg/l. Water in this aquifer is not of suitable quality to serve as an alternative supply to existing water supplies in the Red River Valley.

Grand Forks aquifer

The Grand Forks aquifer is a small deeply buried sand and gravel deposit located in the vicinity of the City of Grand Forks. The aquifer is poorly defined. The depth of the aquifer is typically 200 feet and the thickness is probably less than 20 feet in most places. Glacial till and lake clays overlie the deposit. Water in the aquifer is highly mineralized with dissolved solids concentrations often exceeding 5000 mg/l. For this reason, the aquifer is not used as a water potable supply.

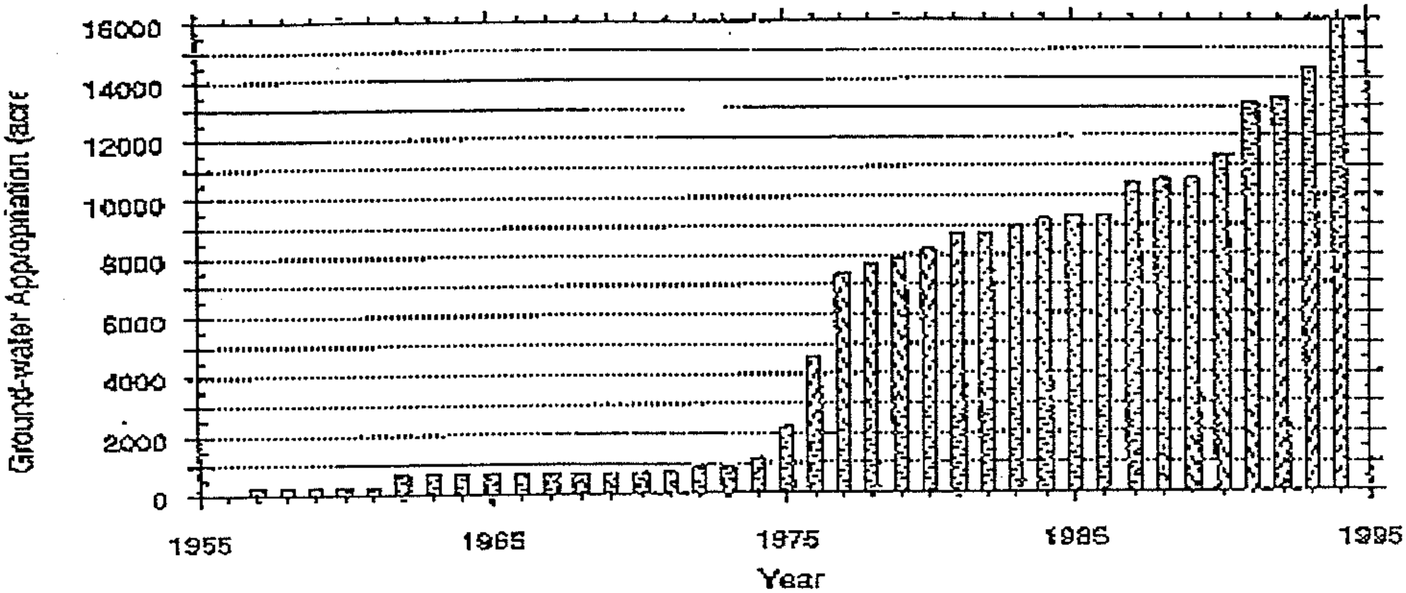
Sheyenne Delta Aquifer

The Sheyenne delta occupies about 750 mi^2 in Richland, Cass, Ranso- and Sargent Counties in southeastern North Dakota. The delta is compri: of sediments transported by the ancestral Sheyenne River and deposited in glacial Lake Agassiz during the Pleistocene Epoch. The delta is bordered on the north and east by lake sediments of glacial Lake Agassiz and on the south and west by till deposits. The Sheyenne River has eroded a valley about 100 ft deep through the delta deposits. The present river channel is sinuous and incised about 15 to 25 ft below the flood plain.

Sheyenne delta deposits can be divided into three units: 1) a lower unit of silt interbedded with clay and sand, 2) an upper unit of well sorted sand, and 3) a surficial layer of wind-blown sand. The lower silty unit is thickest near the northeastern margin of the delta and thins southwestward. The upper sand unit is thickest near the southwestern margin and thins northeastward. The Sheyenne delta aquifer is comprised of the upper unit of well-sorted deltaic sand and overlying wind-blown sand.

The Sheyenne delta aquifer is unconfined. An estimated 4 to 8 in of the annual 20 in of precipitation infiltrates as recharge to the aquifer. Ground-water discharge from the aquifer occurs primarily as groundwater inflow to the Sheyenne River and evapotranspiration. Depth to the water-table fluctuates between 2 to 10 ft below ground surface depending on precipitation and evapotranspiration. Hydraulic gradients range from as gentle as 5 ft per mile within the central portion of the aquifer to as steep as 100 ft per mile adjacent to the Sheyenne River valley.

Estimated transmissivity of the Sheyenne delta aquifer ranges between 288 and 1200 ft2 per day, based on an average saturated thickness of 40 ft and hydraulic conductivities of 7.2 and 30 ft per day for very fine to fin sand and fine to medium sand, respectively. Well yields range between : to 500 gpm in the southwestern portion of the aquifer and decrease to 50 250 gpm in the eastern and northern portions of the aquifer. Water from the Sheyenne delta aquifer is a calcium bicarbonate type with an average total dissolved solids of about 400 mg/L.



Currently, 61 water permits allocate an annual withdrawal of 15,900 acre-ft of ground water from the Sheyenne delta aquifer. Of the 61 permits, one is for a rural water supply and the rest are for irrigation. The greatest concentration of development is in the western portion of the aquifer. The potential for future development within the Sheyenne delta aquifer is dependent upon the following factors:

The effects on existing water rights.

The effect on the existing contribution of the aquifer to the baseflow of the Sheyenne River.

The well yield limitations in the eastern and northern portions of the aquifer.

The economic feasibility of constructing multiple well systems.

The accessibility and potential impacts on the National Grasslands.

There is potential for additional development within the Sheyenne delta aquifer. However, areas of future development are limited by the existing development in the western portion of the aquifer, the National Grasslands in the central portion of the aquifer, and decreasing well yield in the eastern and northern portions of the aquifer.

WEST FARGO AQUIFER SYSTEM

The West Fargo aquifer system is predominantly comprised of three separate, but .cerrelated aquifers. The West Fargo North (WFN) aquifer stretches north and south. and occurs from the bend in 1-94 (south of West Fargo) to several miles north-northeast of Harwood. The aquifer is generally 1 to 1 ½ miles wide, although the aquifer is 2 to 3 miles wide from Highway 10 to a couple of miles north of Highway 10. The West Fargo South (WFS) aquifer stretches north and south and occurs from just south of Highway 10 near 45th Street SW, south to the vicinity of St. Benedict (about 10 miles). The aquifer is about 1 to 1 1/4 miles wide the entire length. The Horace (HOR) aquifer is the westernmost aquifer of these three, and occurs from about 6 miles northwest of Horace to the Christine area trending south-southeast (a distance of about 20 to 25 miles). Another portion of the Horace aquifer occurs between the Christine area and two miles south of St. Benedict. The Horace aquifer is about three-fourths of a mile to a mile in width, except for the area near Christine where the two portions of the aquifer come together and the width is up to about 2 miles.

All three aquifers are buried channel aquifers consisting of glacial sand and gravel deposits. The WFS and HOR aquifers are generally found at depths of 80 to 370 feet, most commonly 150 to 300 feet in depth. The WFN aquifer occurs from 100 to 250 feet in depth, most commonly 100 to 200 feet in depth.

The WFN aquifer has been used significantly since the mid- 1930s. Water levels had declined from near land surface to near 120 feet below land surface by 1970. The HOR and the WFS aquifers slowly leaked into the WFN aquifer such that water levels of the HOR and WFS near the WFN aquifer were 40 to 50 feet below land surface in the mid 1960s, even though there was no significant use of the aquifers until the 1970s. Utilization of the 'S aquifer in the 1970s and 1980s have resulted in water levels declining to 60 to 115 ;t below land surface depending on the distance from areas of higher use.

For the most part, the water quality of the HOR, WFN, and WFS aquifers can be broadly characterized as poor, medium, and good, respectively. The HOR aquifer is known to have total dissolved solids (TDS) varying from 600 to 1900 milligrams per liter (mgl), with most analyses about 1100 to 1350 mgl. The WFN aquifer has TDS values ranging from 600 to 1500 mgl with most analyses about 800 to 1050 mgl. The WFS aquifer has TDS values ranging from 375 to 700 mgl with most analyses about 450 to 600 ppm.

The West Fargo aquifer system is presently being studied. While the study is presently in progress and more interpretive work needs to be done, a couple of important factors are becoming quite clear. All parts of the aquifer system are experiencing water level declines. The declines are slow and not alarming, but the declines are historically persistent. The second factor is that preliminary analysis of stable isotope data indicates that there is very little, if any, recharge to the West Fargo aquifer system. These two factors indicate that the development potential of the West Fargo aquifer system is not promising.

PAGE/GALESBURG AQUIFER

The Page/Galesburg aquifer covers about 400 square miles located in three countir In most recent reports and memos, this aquifer is generally referred to as the I aquifer. The Page aquifer occurs in northwestern Cass County, southeastern Steele Coun., and southwestern Traill County. The aquifer is predominantly unconfined in Steele and especially Traill. counties, and is predominantly leaky-confined to confined in Cass County. In Steele County the aquifer varies significantly between 80 to 200 feet in depth with water levels of 10 to 35 feet below land surface. In Traill County the aquifer is generally 40 to 100 feet in depth with water levels of about 5 to 25 feet. In Cass County the aquifer varies significantly between 100 to 250 feet in depth with water levels between 5 and 75 feet.

Over this large area a number of different depositional environments occur, but overall the sediment is predominantly fine to very fine sand grading into silt. In some areas, particularly in southeast Steele County, there are some coarser sands that are usually found toward the bottom of the aquifer section. In these areas wells yielding more than 500 gpm can be developed. In the topographically higher area of Cass County the saturated thickness of the aquifer is sometimes large enough (120+ feet) that 500-gpm wells can be developed even though the aquifer material is predominantly a very fine sand. In Traill County the shallow, unconfined, fine-grained nature of the aquifer generally means yields of a few hundred gpm at most.

The water quality of the Page aquifer is best in Cass County along a ridge of topographically high ground stretching generally north-south about 4 miles east of Page. The poorest water quality is in Steele County in an area between Colgate and Hope and stretching north. Even in the areas of poorest quality, the chloride levels do not exceed 50 mg/l, and generally they are below 10 mg/l in value. Virtually, all of the chemical analyses of water samples taken from observation wells located in Cass and Trai counties in the Page aquifer show chlorides less than 10 mg/l.

About 15,000 acre-feet/year are allocated from the Page aquifer. About 68% of this allocation lies in Cass County, 27% in Steele, and 5% in Traill County. About 92% of this total allocation is for irrigation. The remainder is either municipal or rural water use. There are areas in all three counties where there is a potential for some additional development of water supplies, however significant portions of the Page aquifer in Cass County have limited development potential. Because of the potentially lower yielding wells in Traill County, any development there of a significant water supply would likely require multiple wells.

Inkster Aquifer

The Inkster aquifer is a glacial outwash deposit which underlies a flat to gently lling plain. The aquifer has an overall areal extent of about 12 to 15 square miles. The lithology of the aquifer is generally a quartzose sand, detrital shale sand, and detrital bedrock and shield silicate gravels. The average saturated thickness is 20 to 50 feet. The Inkster aquifer is of similar geologic and hydrologic setting as the Elk Valley aquifer which lies directly to the west. The aquifers are separated by the long ridge-like Edinburg moraine. There does not appear to be any direct hydraulic connection between the two aquifers.

The aquifer is for the most part unconfined. There is typically no thick barrier of clay to impede the movement of water from the surface to the water table. The water table is generally 5 to 20 feet below land surface. The soils overlying the aquifers are generally sandy and highly transmissive. The soils readily absorb snowmelt and carry water to the aquifer as recharge. Also, summer and fall surplus rainfall, not taken by evapotranspiration, is recharged into the aquifer.

As a result of the highly permeable soils, there is little surface drainage over most of the aquifer as most of the surplus water is absorbed and moves downward rather than leaving as runoff.

Discharge from the aquifer occurs mainly by evaporation and plant transpiration during the growing season. Also, natural discharge occurs through springs and seeps where the North Branch of the Forest River transects the aquifer. A third means of discharge occurs from the pumping of high capacity wells for irrigation and rural water supply purposes.

Water samples obtained from the aquifers indicate a fairly good water quality. The .DS concentration is generally about 500 mg/I in this part of the aquifer. Sodium values are low, usually under 50 mg/l.

An aquifer test was performed on a well located at 154-055-23baa. The test was done on the "Groth" well in 1965. The aquifer parameters which were calculated from the 4500 minute test ranged from T=5500 to 9200 ft2/day and S = .13 to .22.

There are currently 12 active water permits which allow withdrawals from the Inkster aquifer for a total of 3586 acre-feet appropriated. Irrigation accounts for 83 percent.

Water level declines as a result of the water supply developments are very apparent. Because of the large existing appropriation from the aquifer in relation to its size, the Inkster aquifer should not be considered as a viable alternative source of supply for existing supplies.

Elk Valley Aquifer

The Elk Valley aquifer occupies about 200 square miles in the western portion of Grand Forks County. The aquifer was deposited during the Pleistocene epoch and is part the Elk Valley Delta (Kelly and Paulson, 1970). The delta formed as eastern flowi. drainage flowed into the western margin of the glacial Lake Agassiz basin. Lake Agassiz is dated in the latter part of the Pleistocene epoch about 10,000 to 15,000 years before present (Hansen and Kume, 1970). The aquifer is underlain by glacial drift deposits. The aquifer is bounded by the Pembina escarpment to the west, the Forest River on the north, and the Edinburg moraine in the northern portion of the east side. The aquifer pinches out in into the surrounding glacial drift deposits along the remaining perimeter on the south and east.

There is a general gradation from coarser materials in the north to finer materials in the south. The aquifer is generally unconfined with water table depths typically 5 to 15 feet below land surface. Soils on the point of diversion are generally sandy loams (Arvilla and Inkster series, Grand Forks County Soil Survey). These permeable soils along with the permeable aquifer deposits allow rainfall and snowmelt to be readily absorbed as recharge.

Ground water flow patterns are dominated by the discharge areas of the aquifer. The two predominant discharge mechanisms of the Elk Valley aquifer are springs and evapotranspiration. Springs and seeps occur where drainage depressions of rivers and ditches intersect with the water table of the aquifer. Evapotranspiration occurs where the water table is within a few feet of land surface such as around marshes and sloughs (Kelly and Paulson, 1970).

Four aquifer tests have been conducted on wells in the Elk Valley aquifer. The tests indicate that the transmissivity ranges from about 1,000 to 10,000 ft2/day. The specific yield ranges from about 0.12 to 0.20.

Water samples obtained from the aquifer indicate a fairly good water quality in most of the aquifer with Total Dissolved Solids (TDS) concentrations generally about less than about 500 mg/l. Higher TDS concentrations occur in the southern portion of the aquifer.

Presently, there are 63 permits which allocated 15,738 acre-feet of water from the Elk Valley aquifer. Irrigation water accounts for about 82 percent of the permitted appropriation. There are 37 permit applications totaling 14,152 acre-feet of water from the Elk Valley aquifer pending at the present time. Many of these applications have priority dates which date back to 1990 and 1991. Given the high level of existing development and the current number of pending water permit applications, the Elk Valley aquifer should not be considered as a possible alternative source for existing municipal water supplies in the Red River Valley.

Appendix B – Attachment 6

Appraisals of Selected Aquifers in the Red River Valley of North Dakota (Ripley)

North Dakota State Water Commission
900 EAST BOULEVARD AVENUE, DEPT 770 • BISMARCK, NORTH DAKOTA 58505-0850 • 701-328-2750
TDD 701-328-2750 • FAX 701-328-3696 • INTERNET: http://www.swc.state.nd.us/

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		Allen S.
CLASSIFICATION		
PROJECT		
CONTROL NO.		
FOLDER I.D.		

WATER APPROPRIATION DIVISION
(701)328-2754

January 27, 2005

Mr. Allen Schlag
U.S. Bureau of Reclamation
PO Box 1017
Bismarck, ND 58502

Dear Allen,

In response to your e-mail of December 17, 2004, I am enclosing copies of appraisals for each of the aquifers you requested. Included are the Wahpeton Buried Valley, Colfax, Emerado, Grand Forks, Sheyenne Delta, the West Fargo Aquifer System, Page/Galesburg, Inkster, Elk Valley, Fordville, Fairmount, Oakes, and Sonora aquifers.

If you have any questions, please feel free to call or write.

Sincerely,

Dave

Dave Ripley, Director
Water Appropriation Division

DR:mb
Encl.

Ground-Water Availability in the Wahpeton Buried Valley Aquifer (January, 2005)

The Wahpeton Buried Valley (WBV) aquifer is located in the northeast part of Richland County, North Dakota, and in a small portion of the west-central part of Wilkin County, Minnesota. The north limit of the aquifer is about two miles west-northwest of Abercrombie, North Dakota, and the southern terminus is about a mile northeast of Breckenridge, Minnesota.

The WBV aquifer is a sand and gravel aquifer that is located in a buried channel. The buried channel is about one-mile to one-and-a-half miles wide, is about 14 miles long, and is oriented SSE to NNW. The aquifer is composed of medium to coarse sand to gravel, which generally occurs from about 140 to 300 feet below land surface. Wells completed in this aquifer produce in excess of 1000 gpm. Overlying and directly connected to the WBV aquifer is the Wahpeton Sand Plain aquifer (WSP), which has sand and gravel deposits from about 80 to 140 feet below land surface. In some areas there are shallow sands overlying the WSP aquifer. These shallow sand and gravel lenses are irregularly placed and occur at different intervals anywhere from the surface to depths of about 80 feet below land surface.

The WBV aquifer is used as a water supply for many farmsteads in the area. The aquifer is also used by the cities of Wahpeton and Breckenridge and by the Minn-Dak and Cargill processing plants. However, the ground-water supply for the Cargill processing plant is only a back-up water supply for their surface-water supply that is derived from the Red River. Ground-water use for the past 15 years from the Wahpeton Buried Valley aquifer has averaged about 1800 acre-feet per year. Water use in recent years has ranged from 1400 to 2100 acre-feet.

Water rights currently in place total about 3250 acre-feet per year, while the water use in recent years has been below 2100 acre-feet per year. The 3250 acre-feet per year includes 578 acre-feet per year that is the maximum use by the city of Breckenridge. The city of Breckenridge does not have, and does not need, a water permit for their water right in the State of Minnesota. Additionally, the 3250 acre-feet per year includes 212 acre-feet per year, which is the anticipated average annual use for the 3000 acre-feet per year as back-up water supply for the Cargill corn processing plant. The Cargill plant has a surface water permit for their use from the Red River. The water permit that grants this right is conditioned to stop use from the Red River under certain low-flow conditions. Only under these low-flow conditions can the plant use ground water up to 3000 acre-feet per year. Based on flow records of the Red River since the 1940s, the average use over those 50 plus years would be 212 acre-feet per year.

The Cargill water permit request originally requested 12,000 acre-feet per year from ground water. Only 3,000 acre-feet per year have been approved, and the remaining 9,000 acre-feet per year are still held in abeyance pending additional data acquisition. Until Cargill decides that the plant size will not increase, the remaining volume of water of this pending application must be considered because current plans are to expand the size of the plant. Any new permit applications would be considered in this context, and would be junior to established water rights and these pending rights, if approved. Determination of what total volume can be approved from this aquifer system awaits additional study.

A report on a study to determine the extent and character of the Wahpeton Buried Valley aquifer system is currently being completed. This will be the foundation for future work to determine the amount of recharge to the WBV aquifer system. Until the additional work is completed, it will not be possible to act upon new ground-water permit applications. Given the pending water rights currently held in abeyance, the lack of understanding of how easily the aquifer is recharged, and the maximum level of sustainable development, any new water permit request will wait many years for approval or denial.

Colfax Aquifer:

The Colfax aquifer located within the northeast portion of Richland County consists of buried outwash deposits of medium and coarse sand. Hydrologic properties of the Colfax aquifer are unknown. However, many wells near the cities of Galchutt and Colfax have considerable head and flow at land surface. Water from the Colfax aquifer is a sodium-sulfate type with total dissolved solids of about 2,400 mg/L. The chemical character of the ground water indicates hydraulic connection to water-bearing beds within the Dakota Sandstone.

Additional water use from the Colfax aquifer is feasible. Maximum well yield up to 250 gallons per minute may be possible. Additional water use from the Colfax aquifer may be limited by water quality concerns.

Emerado aquifer

The Emerado aquifer is a buried outwash aquifer which underlies about 15 square miles. It is composed of several feet of medium to coarse sand interspersed with the glacial till.

The Emerado aquifer is confined by glacial till to a depth of about 50 to 80 feet. The static piezometric surface is typically about 10 to 20 feet below land surface. The transmissivity is in the range of 1000 to 2000 ft2/day according to an aquifer test performed on a well completed in the aquifer. The storage coefficient is about 0.0001.

Water quality in the aquifer is generally poor. Leakage from the underlying Paleozoic formations have caused dissolved solids concentrations to typically be above 2000 mg/l. Water in this aquifer is not of suitable quality to serve as an alternative supply to existing water supplies in the Red River Valley.

Grand Forks aquifer

The Grand Forks aquifer is a small deeply buried sand and gravel deposit located in the vicinity of the City of Grand Forks. The aquifer is poorly defined. The depth of the aquifer is typically 200 feet and the thickness is probably less than 20 feet in most places. Glacial till and lake clays overlie the deposit. Water in the aquifer is highly mineralized with dissolved solids concentrations often exceeding 5000 mg/l. For this reason, the aquifer is not used as a potable water supply.

Sheyenne Delta Aquifer:

The Sheyenne Delta aquifer underlies about 450 square miles in Richland, Cass, Ransom and Sargent counties of southeastern North Dakota. The aquifer is unconfined and comprised of very fine to medium sand transported by the ancestral Sheyenne River and deposited as deltaic sediments in glacial Lake Agassiz. Water from the Sheyenne Delta aquifer is a calcium-bicarbonate type with total dissolved solids of about 400 mg/L.

Additional water use from the Sheyenne Delta aquifer is feasible. Maximum well yield up to 250 gallons per minute may be possible. Additional water use from the Sheyenne Delta aquifer will be limited by 1) existing water development within the southwest portion of the aquifer, 2) impact upon the Sheyenne National Grasslands located in the central portion of the aquifer and 3) low well yield in the southeast portion of the aquifer.

Ground-Water Availability in the West Fargo Aquifer System (January, 2005)

The West Fargo aquifer System (WFAS) underlies the communities of West Fargo and Fargo, as well as areas as far north as Harwood, as far west as Horace, and as far south as Christine. The lower part of the geology of the Fargo/West Fargo area consists of Cretaceous shales and siltstones deposited on top of an irregular Precambrian igneous rock base. There are occasional sandstone layers interlayered in the cretaceous material. This bedrock surface was eroded, and the resulting surface consisted of some Cretaceous and some Precambrian material at land surface. Repeated glacial events subsequently deposited a complex sequence of tills, sands, gravels, and lake clays on top of the Cretaceous/Precambrian preglacial surface. Many sand and gravel bodies were deposited in the study area, and nine significant aquifers comprise the aquifer system known as the WFAS. These sand and gravel bodies are surrounded by aquitards comprised of Cretaceous and Precambrian sediments, as well as glacial tills and clays.

All of the nine aquifers comprising the WFAS have been utilized as a source of ground water to varying degrees. Each of the nine aquifers is surrounded by aquitards. Even though the aquifers are enclosed in aquitards, these nine aquifers are interconnected in ways that resulted in ground-water level declines even in aquifers from which not much ground water has been historically withdrawn. Water levels in the WFAS vary in depth below land surface from 40 to 150 feet.

The West Fargo North (WFN) aquifer has been the most heavily used aquifer in the WFAS. The WFN is the second-largest aquifer in the WFAS. The WFN averages about 79 in thickness over an area of about 27 square miles. The water levels have declined about 0.5 feet per year in the last 15 years. The water is a sodium/chloride type with total dissolved solids generally ranging between 800 to 1,100 mg/l. The water is suitable for most purposes.

The Fargo aquifer was the first of the nine discussed aquifers in the WFAS to be utilized as a source of ground water. The Fargo aquifer averages about 40 feet in thickness over an area of about 0.5 square miles. The water levels have decline about 0.7 feet per year during the last 15 years. The water is a sodium type with no dominant anion. Total dissolved solids generally range between 700 to 800 mg/l. The water is suitable for most purposes.

The Nodak aquifer averages about 68 feet in thickness over an area of about 2.6 square miles. The water levels have declined about 1.1 feet per year during the last 15 years. The water is a sodium type with no dominant anion. Total dissolved solids generally range between 500 to 900 mg/l. The water is suitable for most purposes.

The 94/10 aquifer averages about 48 feet in thickness over an area of about 3.2 square miles. The water levels have declined about 0.5 feet per year during the last 15 years. The water is a sodium-chloride type with total dissolved solids generally ranging between 1,050 to 1,200 mg/l. The water is suitable for some purposes and marginal for other purposes.

The Prosper aquifer averages about 75 feet in thickness over an area of about 14.6 square miles. The water levels have declined about 0.4 feet per year during the last 15 years. The water is a sodium-chloride type with total dissolved solids generally ranges between 1,000 to 3,000 mg/l. The water is marginal for most purposes.

The West Pleasant aquifer averages about 57 feet in thickness over an area of about 3.2 square miles. The water levels have declined about 0.9 feet per year during the last 15 years. The water is a calcium type with no dominant anion. Total dissolved solids generally range between 1,000 to 3,000 mg/l . The water is marginal for most purposes.

The Horace aquifer is the largest aquifer in the WFAS. The Horace averages about 103 feet in thickness over an area of about 26.8 square miles. The water levels have declined about 1.3 feet per year during the last 15 years. The water in the eastern part of the aquifer is a sulfate type with no dominant cation. The water in the western part of the aquifer is a calcium type with no dominant action. Total dissolved solids generally range between 500 to 2000 mg/l. The water is suitable for most purposes.

The Ponderosa aquifer averages about 100 feet in thickness over an area of about 3.2 square miles. The water levels have declined about 1.0 feet per year during the last six years. The water is a sodium type with no dominant anion. Total dissolved solids generally range between 800 to 1,300 mg/l. The Water is suitable for most purposes.

The West Fargo South aquifer averages about 90 feet in thickness over an area of about 13.8 square miles. The water levels have declined about 2.3 feet year during the last 15 years. The water is a sodium-bicarbonate type with total dissolved solids generally ranging between 400 to 600 mg/l. The water is suitable for most purposes. The WFS aquifer has the best water quality of any of the aquifers in the WFAS.

The ground-water flow pattern for the West-Fargo Aquifer System has varied through time. The general historical pattern has been for the aquifer from which the most water is being withdrawn to have the water levels of that aquifer drawn down to the lowest levels. This generally causes water from nearby aquifers that are slightly hydraulically connected, to move into the aquifer from which the most water is being withdrawn. The resultant ground-water flow patterns through time have been variable and quite complex, because the history of water use is different for each aquifer, because of the different spatial relationships between aquifers, and because the degree of connection between aquifers varies greatly.

Inadequate data currently exists to depict the ground-water flow interaction between the WFAS and the surrounding aquitards. Limited data does indicate that the surrounding aquitards are being dewatered. This suggests that there is significant movement of water from the aquitards into the aquifers of the WFAS. It is probable that this is a one-time occurrence. As more water is drawn out of the surrounding aquitards, less water will move from the aquitards into the aquifers, because the aquitards are probably being drained at a significantly greater rate than the rate at which they are being recharged. Additionally, inadequate data exists to characterize both the variable water chemistry and the reasons for that variability. Continued use of ground water could lead to changes in the water chemistry in any of the aquifers comprising the WFAS.

Stable isotope data (deuterium and oxygen-18) shows that almost all samples are in a "snowfall" range. This range of isotope values is strikingly cold in its signature. This range does not suggest modern-day recharge, unless there is a mechanism whereby only snowmelt recharges the aquifer. This is most unlikely. It is just as unlikely, that the aquifer is receiving any significant amount of meteoric water as recharge. Currently, the isotopic values of water samples collected from WFAS wells indicate that the ground water was emplaced under colder than present climatic conditions. Analysis of the available isotope data leads to a conclusion that modern-day recharge is insignificant in the WFAS. The strong interference is that the ground water in the WFAS is predominantly trapped Pleistocene water.

Water budget analyses resulted in an estimate of about 433 billion gallons of water being contained in the nine aquifers comprising the WFAS in 1870. An estimate of water contained in the same aquifers in 1995 is about 415 billion gallons. An estimate of the total water use from these aquifers over that same time period is about 33 billion gallons. It appears that water is being derived from sources additional to the aquifers that comprise the WFAS. The major source for this additional water is likely the aquitards that surround the WFAS.

Ground-water withdrawals exceed the leakage replenishment capacity of the aquitards, resulting in a steady water-level decline (of different rates) in all the aquifers in the WFAS. Leakage from the surrounding aquitards is merely reducing the rate of water-level decline in the WFAS. The overall decline indicates that under the present rate of use, the sustained yield of the aquifer is being exceeded.

There are several management actions that could mitigate these water-level declines to varying degrees. Some possibilities are the purchase of existing water rights, appropriating unappropriated ground water rights, the reuse of wastewater, aquifer storage and recovery procedures, water conservation measures, and developing unused surface water allocations. Depending on the development costs, and the proportion of the available resources that could be developed, these possibilities could be significant options for additional water, rather than continuing the depletion of the WFAS. The feasibility of approving any new large withdrawals from the WFAS is highly unlikely. The potential for the utilization of currently-held, perfected and conditional surface-water allocations appears to be of sufficient volume and feasibility, such that this is the most promising available alternative to augment or replace water supplies currently obtained from the WFAS.

Ground-Water Availability in the Page/Galesburg Aquifer(s)
(January, 2005)

The Page/Galesburg aquifer(s) covers about 400 square miles located in three counties. In most recent reports and memos, this aquifer is generally referred to as the Page aquifer. This discussion will refer to the Page/Galesburg aquifers as the Page aquifer; however, a current study is evaluating whether the Page/Galesburg aquifer system is one aquifer system or two aquifers. The Page aquifer occurs in northwestern Cass County, southeastern Steele County, and southwestern Traill County. The aquifer is predominantly unconfined in Steele and especially Traill counties, and is predominantly leaky-confined to confined in Cass County. In Steele County the aquifer varies significantly between 80 to 200 feet in depth with water levels of 10 to 35 feet below land surface. In Traill County the aquifer is generally 40 to 100 feet in depth with water levels of about 5 to 25 feet. In Cass County the aquifer varies significantly between 100 to 250 feet in depth with water levels between 5 and 75 feet.

Over this large area, a number of different depositional environments occur, but overall the sediment is predominantly fine to very fine sand grading into silt. In some areas, particularly in southeast Steele County, there are some coarser sands that are usually found toward the bottom of the aquifer section. In these areas wells yielding more than 500 gpm can be developed. In the topographically higher area of Cass County the saturated thickness of the aquifer is sometimes large enough (120 plus feet) that 500-gpm wells can be developed even though the aquifer material is predominantly very fine sand. In Traill County the shallow, unconfined, fine-grained nature of the aquifer generally means yields of a few hundred gpm at most.

The water quality of the Page aquifer is best in Cass County along a ridge of topographically high ground stretching generally north-south about four miles east of Page. The poorest water quality is in Steele County in an area between Colgate and Hope, and stretching north.

About 15,000 acre-feet per year are allocated from the Page aquifer. About 68% of this allocation lies in Cass County, 27% in Steele, and 5% in Traill County. About 92% of this total allocation is for irrigation. The remainder is either municipal or rural water use. There are areas in all three counties where there is a potential for some additional development of water supplies; however, significant portions of the Page aquifer in Cass County have limited development potential. Because of the potentially lower yielding wells in Traill County, any development there of a significant water supply would likely require multiple wells.

Assessing the magnitude of any additional available water has been made difficult by the fact that since 1993 less than 24% of allocated water has been put to beneficial use. An unusual, long, wet climatic cycle has severely limited water use from the Page aquifer, and thus an assessment of the aquifer's response to the additional allocations made in the 1990s. Currently, there are 18 water permit applications requesting over 6500 acre-feet per year of water from the Page aquifer. These permit applications will need to be evaluated before additional available water could be considered.

Inkster Aquifer

The Inkster aquifer is a glacial outwash deposit which underlies a flat to gently rolling plain. The aquifer has an overall areal extent of about 12 to 15 square miles. The lithology of the aquifer is generally a quartzose sand, detrital shale sand, and detrital bedrock and shield silicate gravels. The average saturated thickness is 20 to 50 feet. The Inkster aquifer is of similar geologic and hydrologic setting as the Elk Valley aquifer which lies directly to the west. The aquifers are separated by the long ridge-like Edinburg moraine. There does not appear to be any direct hydraulic connection between the two aquifers.

The aquifer is for the most part unconfined. There is typically no thick barrier of clay to impede the movement of water from the surface to the water table. The water table is generally 5 to 20 feet below land surface. The soils overlying the aquifers are generally sandy and highly transmissive. The soils readily absorb snowmelt and carry water to the aquifer as recharge. Also, summer and fall surplus rainfall, not taken by evapotranspiration, is recharged into the aquifer.

As a result of the highly permeable soils, there is little surface drainage over most of the aquifer as most of the surplus water is absorbed and moves downward rather than leaving as runoff.

Discharge from the aquifer occurs mainly by evaporation and plant transpiration during the growing season. Also, natural discharge occurs through springs and seeps where the North Branch of the Forest River transects the aquifer. A third means of discharge occurs from the pumping of high-capacity wells for irrigation and rural water supply purposes.

Water samples obtained from the aquifers indicate a fairly good water quality. The TDS concentration is generally about 500 mg/l in this part of the aquifer. Sodium values arc low, usually under 50 mg/l.

The aquifer parameters determined from an aquifer test ranged from T=5500 to 9200 ft^2/day and S = .13 to .22.

There are currently 13 active water permits which allow annual withdrawals from the Inkster aquifer up to a total of 3586 acre-feet. Irrigation accounts for 83 percent.

Water-level declines as a result of the water supply developments are very apparent. Because of the large existing appropriation from the aquifer in relation to its size, the Inkster aquifer should not be considered as a viable alternative to serve as an alternative to existing water supplies in the Red River Valley.

Elk Valley Aquifer

The Elk Valley aquifer occupies about 200 square miles in the western portion of Grand Forks County. The aquifer was deposited during the Pleistocene epoch and is part of the Elk Valley Delta (Kelly and Paulson, 1970). The delta formed as eastern flowing drainage flowed into the western margin of the glacial Lake Agassiz basin. Lake Agassiz is dated in the latter part of the Pleistocene epoch about 10,000 to 15,000 years before present (Hansen and Kume, 1970). The aquifer is underlain by glacial drift deposits. The aquifer is bounded by the Pembina escarpment to the west, the Forest River on the north, and the Edinburg moraine in the northern portion of the east side. The aquifer pinches out in into the surrounding glacial drift deposits along the remaining perimeter on the south and east.

There is a general gradation from coarser materials in the north to finer materials in the south. The aquifer is generally unconfined with water-table depths typically 5 to 15 feet below land surface. Soils overlying the aquifer are generally sandy loams (Arvilla and Inkster series, Grand Forks County Soil Survey). These permeable soils, along with the permeable aquifer deposits, allow rainfall and snowmelt to be readily absorbed as recharge.

Ground-water flow patterns are dominated by the discharge areas of the aquifer. The two predominant discharge mechanisms of the Elk Valley aquifer are springs and evapotranspiration. Springs and seeps occur where drainage depressions of rivers and ditches intersect with the water table of the aquifer. Evapotranspiration occurs where the water table is within a few feet of land surface such as around marshes and sloughs (Kelly and Paulson, 1970).

Water samples obtained from the aquifer indicate a fairly good water quality in most of the aquifer with Total Dissolved Solids (TDS) concentrations generally less than about 500 mg/l. Higher TDS concentrations occur in the southern portion of the aquifer.

Presently, there are 80 permits which allocate 19,535 acre-feet of water from the Elk Valley aquifer. Irrigation water accounts for about 85 percent of the permitted appropriation. There are an additional 46 permit applications requesting 17,171 acre-feet of water from the Elk Valley aquifer pending at the present time. The earliest of these applications have priority dates which date back to 1991. Given the high level of existing development and the current number of pending water permit applications, the Elk Valley aquifer should not be considered as a possible alternative source for existing water supplies in the Red River Valley.

Fordville aquifer

The Fordville aquifer is located on the western margin of the Red River Valley in Walsh County. The aquifer trends north-south and may have an overall area of approximately 33 square miles. The aquifer was described by Joe Downey in the Nelson and Walsh County Ground Water Study (1973). The Fordville aquifer consists of delta deposits that accumulated along the west edge of glacial Lake Agassiz. The lithology of the aquifer is generally a quartzose sand, detrital shale sand, and Canadian shield silicate sands and gravels. The average saturated thickness is about 10 to 30 feet.

The Fordville aquifer is for the most part unconfined although it is buried in part by the Edinburg moraine. The soils overlying the unconfined portion of the aquifer are generally sandy and highly transmissive. The soils readily absorb snow-melt and carry water to the aquifer as recharge. Also, summer and fall rainfall, not used by evapotranspiration or soil storage, is recharged into the aquifer.

A major portion of the natural discharge from the aquifer occurs through springs and seeps along the North Branch of the Forest River as it transects the aquifer, to the Middle Branch of the Forest River along the southern boundary of the aquifer, and on the eastern side of the Edinburg moraine where the aquifer outcrops. In addition, pumping for rural-water/municipal, irrigation, and industrial uses, as well as evaporation and plant transpiration, remove water from the aquifer system.

An aquifer test was conducted on the Fordville aquifer in 1968 by Roger Schmid, State Water Commission. The test was done on a well located at 156-56-26BCC. The tests indicate that the transmissivity is in the range of about 5800 to 8900 ft^2/day and the storage coefficient is about 0.18 to 0.20.

Water samples obtained from the aquifers indicate a fairly good water quality. The total dissolved solids (TDS) concentration is generally less than 500 mg/l and sodium values are under 50 mg/l.

There are 10 water permits which allocate 2068 acre-feet of water from the Fordville aquifer. Municipal/rural-water use accounts for 75 percent of the allocation. There are no pending applications from the aquifer at the present time, however, major future appropriations in the future are unlikely due to indications that the aquifer is near it's sustained yield capability given its current level of appropriation.

Fairmount Aquifer:

The Fairmount aquifer consists of buried, thin, discontinuous deposits of sand and gravel. The areal extent of the Fairmount aquifer appears to be much smaller than the original delineation. The Fairmount aquifer should not be considered as a possible Red River Valley water supply.

Ground-Water Availability in the Oakes Aquifer

The Oakes aquifer occupies an area of about 90 square miles in southeastern Dickey and southwestern Sargent counties. To date, the State Engineer has allocated 21,088.7 acre-feet of ground water annually from the Oakes aquifer to irrigate 14,299.7 acres of land. In addition, the State Engineer has allocated 800.0 acre-feet annually for municipal use (city of Oakes). The State Engineer has deferred action on 6,732.5 acre-feet of ground water annually from the Oakes aquifer to irrigate 4,458.7 acres of land pending the acquisition of additional hydrologic data and finalization by the Federal government on the status of Oakes Irrigation Test Area.

The southeast part of the Oakes aquifer in Sections 12, 13, 24, and 25, Township 129 North, Range 59 West and Sections 7, 18, 19, and 30, Township 129 North, Range 58 West has the potential for additional ground-water appropriation. This area is underlain by sand and gravel channel-fill deposits that occupy a north-south channel located along the eastern margin of the Oakes aquifer. The buried channel is about two miles in width and is comprised of sand and gravel, which varies in thickness from a few feet on the flanks to up to about 200 feet. Maximum individual well yields of about 2,000 gallons per minute are possible from properly constructed wells in this part of the Oakes aquifer. Chemically, the ground water associated with the buried channel is calcium-magnesium-bicarbonate type characterized by high iron and manganese concentrations and in some places, high arsenic concentrations.

A comprehensive ground-water modeling study will be required to evaluate the potential for additional ground-water appropriations in this part of the Oakes aquifer. A study of this type could take up to a year to complete.

Sonora Aquifer:

The Sonora aquifer consists of a buried, narrow deposit of sand and gravel. Previous attempts to utilize the Sonora aquifer for large-capacity water use have not been successful. The Sonora aquifer should not be considered as a possible Red River Valley water supply.

Appendix C – Engineering

Introduction

This appendix contains supplemental information and analysis used in the development of the features and options (alternatives) presented in chapter four of the Needs and Options Report. This includes documentation on the designs and cost estimates not included in the report text. A description of the supporting engineering reports used in the design and cost estimating of project features is included on the enclosed data CD (compact disc).

Two major topics are discussed: 1) how the water supply features and options were developed based on the results of surface water hydrologic modeling and 2) the development of cost estimates and the identification of resources in support of that effort. The alternative cost estimate spreadsheets are the primary study products documented in this appendix. The cost estimate includes the seven alternatives described in chapter four plus a peak day variation of the Lake of the Woods alternative that was investigated but has been eliminated from further consideration.

Engineering Reports Included on the Data CD

Prior to release of the Needs and Options Report, a number of technical reports were published in support of the engineering analysis conducted. These were produced by Reclamation and other entities. A list of the reports and their respective authors is included in table C.1. Each report is provided in PDF format on the enclosed CD.

Table C.1 – Tabulation of Needs and Options Supporting Reports.

Report Title	Source of Report
Design Criteria Red River Valley Water Supply Project Needs and Options Report, March 2005	Houston Engineering
Update of Garrison Diversion Unit Principal Supply Works Costs, Final Report, 2005	Bureau of Reclamation, Dakotas Area Office, Bismarck, North Dakota
Water Treatment Plant For Biota Removal and Inactivation, Preliminary Design & Cost Estimates, Red River Valley Water Supply Project, North Dakota, Great Plains Region, 2005	Bureau of Reclamation, Denver Technical Service Center, Denver, Colorado

C.1 - Hydrologic Modeling Results and Sizing of Features

As described in chapter three, each of the six supplemental alternatives was modeled using two water demands scenarios. The seventh alternative, GDU Water Supply Replacement Pipeline, was not sized based on hydrologic modeling but by the Red River Valley service area peak day demand. Table C.2 shows the capacity required to meet water demands of each option and both demand scenarios. For options that include an import, each model run was configured with a hypothetical reservoir and through an optimization process, the rate of water required to meet the water demands was determined. The North Dakota In-Basin Alternative was modeled exactly as it functions, by withdrawing water from the Red River north of Grand Forks and transferring it back to Lake Ashtabula.

North Dakota In-Basin, Red River Basin, Lake of the Woods, and the Missouri River to Red River Valley Import alternatives have generally similar capacity requirements. The Lake of the Woods Alternative is larger because the pipeline is designed to serve the water demand in the southeastern North Dakota while the other three alternatives propose to use groundwater sources from the surrounding area. The GDU Import to Sheyenne River Alternative is larger than the four alternatives mentioned above because it was designed to provide peak day water demands in the Sheyenne and Red Rivers. The previous four alternatives used a combination of groundwater and storage to meet peaking demands. The GDU Import Pipeline option capacity of 160 cfs (Scenario One) or 202 cfs (Scenario Two) is a combination of modeling results of 73 cfs or 100 cfs plus additional flow to meet peak day water demands of 79 cfs or 92 cfs respectively.

Columns four and five of table C.2 show the conveyance capacity requirements of each proposed option with an additional five percent included for pipeline losses. The American Water Works Association recommends limiting water losses to 10% or less, a loss estimate of five percent was assumed.

Table C.2 – Option Capacity Results from StateMod Modeling.

Option and Feature	Scenario One Sizing (cfs)	Scenario Two Sizing (cfs)	Scenario One Sizing (w/ 5% losses) (cfs)	Scenario Two Sizing (w/ 5% losses) (cfs)
North Dakota In-Basin - Grand Forks to Lake Ashtabula Pipeline	50	67	53	71
Red River Basin - Minnesota Groundwater and Pipeline	42	68	45	72
Lake of the Woods - Lake of the Woods Pipeline	66	93	70	96
GDU Import to Sheyenne River - McClusky Canal to Lake Ashtabula Pipeline	59	92	62	97
GDU Import Pipeline - McClusky Canal to Fargo and Grand Forks Pipeline	152	192	160	202
Missouri River to Red River Valley Import - Bismarck to Fargo Pipeline	42	60	44	63
GDU Water Supply Replacement Pipeline - Replacement Pipeline	324	391	341	411

Alternative capacity design notes developed for each alternative and are shown in Attachment 1 of this appendix. These design notes document how the capacity of all major conveyance features were estimated including the Lake of the Woods peak day in the pipeline. Schematic drawings showing the location of conveyance pipeline sizing requirements are shown in Attachment 2.

Tables C.3 and C.4 show the average and maximum annual water delivered by each of the alternatives under water demand Scenarios One and Two. The average annual water production values in table C.3 are the rounded values from table C.5 (table B.3.16 of Hydrology Appendix B). The average annual water delivery values are used in estimating annual operation, maintenance and replacement (OM&R) costs. The values are based on the 71-year flow database model runs which are summarized in table C.5.

The water production amounts in table C.3 represent the annual average results from hydrologic modeling. The values presented are for major conveyance features such as an import from the Missouri River, Lake of the Woods, Minnesota groundwater or from the lower Red River. Some of these alternatives also include other sources of groundwater from southeastern North Dakota or the Elk Valley Aquifer. Table C.3 also shows the average annual water production with an assumed 5% conveyance loss included. These volumes of water are also shown in table C.6.

Table C.3 – Average Annual Water Production for each Alternative Based on StateMod Results.

Option and Feature	Scenario One Average Annual Water Supplied (ac-ft)	Scenario One Average Annual Water Supplied with Losses (ac-ft)	Scenario Two Average Annual Water Supplied (ac-ft)	Scenario Two Average Annual Water Supplied with Losses (ac-ft)
North Dakota In-Basin – Grand Forks to Lake Ashtabula Pipeline	7,300	7,600	9,000	9,400
Red River Basin – Minnesota Groundwater and Pipeline	2,600	2,800	4,600	4,800
Lake of the Woods – Lake of the Woods Pipeline	17,800	18,700	20,200	21,200
GDU Import to Sheyenne River – McClusky Canal to Lake Ashtabula Pipeline	10,300	10,800	20,100	21,100
GDU Import Pipeline – McClusky Canal to Fargo and Grand Forks Pipeline	20,300	21,300	22,800	24,000
Missouri River Import to Red River Valley – Bismarck to Fargo Pipeline	19,700	20,600	22,800	23,900
GDU Water Supply Replacement Pipeline – Replacement Pipeline	86,300	90,600	110,900	116,400

The water production values in table C.3 were increased for OM&R cost estimating process because some of these alternatives do not convey flows during normal or wet climatic periods. To assure reliable operation of the treatment or conveyance features, these facilities were assumed to operate at least one month per year whether the supplemental water was needed or not. This operational assumption increased the values presented in table C.3. Section 4.2 in chapter four describes how each feature's OM&R water production values were modified to assure reliable operation.

The maximum annual water production values presented in table C.4 document the maximum water that would be treated or conveyed by each alternative, based on hydrologic modeling results. These values are only for the major treatment or conveyances feature for each alternative. The values in table C.4 also represent the maximum estimated depletion from various imported sources of water such as the Missouri River, Lake of the Woods or Minnesota groundwater. The table C.4 values do not include any conveyance losses which as assumed to be approximately 5%.

Table C.4 –Maximum Annual Water Volume Required per Option.

Option	Scenario One Maximum Annual Amount of Water Provided to Meet Shortages (ac-ft)	Scenario Two Maximum Annual Amount of Water Provided to Meet Shortages (ac-ft)
North Dakota In-Basin	29,566	42,669
Red River Basin	23,277	38,128
Lake of the Woods	41,421	57,658
GDU Import to Sheyenne River	41,525	65,752
GDU Import Pipeline	45,337	61,580
Missouri River to Red River Valley Import	30,410	43,435
GDU Water Supply Replacement Pipeline	113,702	142,380

Table C.5 summarizes the results from the StateMod surface water modeling. This same table is presented in Appendix B as table B.3.16. The table shows the average and maximum annual water capacity requirements of each alternative under Scenario One or Two water demands. The table also provides the average and maximum annual water volumes during different timeframes

Table C.5 - Depletion from Water Source Table.
(Additional volume of water required from project features to supply demand)

OPTION		North Dakot In-Basin Scenario One	North Dakot In-Basin Scenario Two	Red River Basin Scenario One	Red River Basin Scenario Two	Lake of the Woods Scenario One	Lake of the Woods Scenario Two	GDU Import to Sheyenne River Scenario One (*Peak Day in River*)	GDU Import to Sheyenne River Scenario Two (*Peak Day in River*)	GDU Import to Red River Valley Scenario One (*Peak Day in Pipe*)	GDU Import to Red River Valley Scenario Two (*Peak Day in Pipe*)	Missouri River to Red River Valley Import Scenario One	Missouri River to Red River Valley Import Scenario Two
	Filename	*Loop171*	*Loop271*	*BF1NGF71*	*BF2NGF71*	*BF1W71*	*BF2W71*	*I1NAWPOP*	*I2NAWPOP*	*BF1NAW71*	*BF2NAW71*	*I1D71*	*I2D71*
		ac-ft	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*	*ac-ft*
1931 to 1940	Min Year	11,606	12,986	10,594	18,745	28,135	38,958	29,163	49,700	30,817	41,724	27,748	39,325
	Max Year	29,566	42,669	23,277	38,128	41,421	57,658	41,525	65,752	45,337	61,580	30,410	43,435
	Avg. Year	20,385	27,487	17,487	29,363	35,640	49,511	36,042	58,445	39,076	52,943	29,612	42,245
	Total	203,850	274,866	174,867	293,625	356,395	495,109	360,419	584,453	390,755	529,434	296,124	422,445
1941 to 2001	Min Year	12	12	0	0	14,481	14,481	6	2	16,841	16,942	14,488	14,488
	Max Year	15,554	19,000	6,013	10,732	22,723	28,716	22,108	39,403	25,377	31,420	27,069	33,488
	Avg. Year	5,127	5,964	211	502	14,811	15,366	6,091	13,836	17,257	17,913	18,020	19,610
	Total	312,765	363,801	12,864	30,630	903,454	937,352	371,560	843,969	1,052,700	1,092,707	1,099,216	1,196,218
1931 to 2001	Average	7,276	8,995	2,644	4,567	17,744	20,176	10,310	20,119	20,330	22,847	19,653	22,798

plus overall averages. The average and maximum values during the period from 1931 to 1940 were much higher than the period from 1941 to 2001 because of the 1930s drought.

Table C.6 shows the annual average water production that would be delivered from each of the features under Scenario One or Two water demands. Some of these values have been adjusted to account for a minimum (one month) level of operation during all in-basin water supply conditions. Refer to section 4.2 in the Needs and Options Report for a discussion on how the average annual water delivery was estimated for each feature.

Table C.6 – Average Annual Water Production for Estimating OM&R Costs.

Features	Scenario One Average Annual OM&R Water Production (ac-ft)	Scenario Two Average Annual OM&R Water Production (ac-ft)
Biota Treatment Plant		
GDU Import to Sheyenne River	14,500	26,900
GDU Import Pipeline	21,300	24,000
Missouri River to Red River Valley Import	20,600	23,900
GDU Water Supply Replacement Pipeline	90,600	116,400
Bismarck to Fargo Pipeline	20,600	23,900
CRWUD Interconnection with Fargo	340	780
GFTWD Interconnection with Grand Forks	230	560
GDU – Assigned Costs Related to Principal Supply Works	na	na
Grand Forks to Lake Ashtabula Pipeline	14,500	26,900
Lake of the Woods Pipeline	18,700	21,200
McClusky Canal to Fargo and Grand Forks Pipeline	21,300	24,000
McClusky Canal to Lake Ashtabula Pipeline	16,600	24,700
Minnesota Groundwater and Pipeline	5,500	9,100
Moorhead ASR	120	130
Moorhead Peak Day - Expanded use of Buffalo Aquifer	74	178
New Groundwater to Serve Industries	1,300	2,130
Peak Day Water Demand using Storage	na	na
Pipeline to serve Southeast North Dakota Industries	1,300	2,130
Purchase Elk Valley Aquifer Water Rights	780	820
Replacement Pipeline	90,600	116,400
Relocation of Grafton River Intake	9,30	1,070
Water Conservation	na	na
West Fargo North ASR	620	920
West Fargo South ASR	510	610

C.2 - Project Features

Table C.7 lists the 20 features that make up the seven alternatives considered in the Needs and Options Report. All but two of the features involve providing water supply to the Red River Valley. Fargo Moorhead Metro Area Water System Improvements (feature 3) and Grand Forks Metro Area Water System Improvements (feature 4) are "related" or "infrastructure" features. These two features include the cost of upgrading water treatment, storage and distribution costs in the Fargo and Grand Forks metro areas so they can take advantage of the new sources of water supply proposed in each alternative. The costs associated with these "related" features are presented separately in the cost estimates shown in subsection C3 of this appendix.

Table C.7 (Table 4.2.1, Chapter 4) – Options and Features Matrix.

		Options						
Features	**Feature Number**	**North Dakota In-Basin**	**Red River Basin**	**Lake of the Woods**	**GDU Import to Sheyenne River**	**GDU Import Pipeline**	**Missouri River to Red River Valley Import**	**GDU Water Supply Replacement Pipeline**
Biota WTP	1				x	x	x	x
Bismarck to Fargo Pipeline	2						x	
CRWUD Interconnection with Fargo	3	x	x	x	x	x	x	
GFTWD Interconnection with Grand Forks	4				x	x		
Grand Forks to Lake Ashtabula Pipeline	5	x						
Lake of the Woods Pipeline	6			x				
McClusky Canal to Fargo and Grand Forks Pipeline	7					x		
McClusky Canal to Lake Ashtabula Pipeline	8				x			
Minnesota Groundwater and Pipeline	9		x					
Moorhead ASR	10	x	x	x			x	
Moorhead Peak Day - Expanded use of Buffalo Aquifer	11	x	x	x			x	
New Groundwater to Serve Industries	12	x	x				x	
Peak Day Water Demand using Storage	13	x	x	x			x	
Pipeline to serve Southeast North Dakota Industries	14			x	x	x		
Purchase Elk Valley Aquifer Water Rights	15	x	x	x			x	
Replacement Pipeline	16							x
GDU – Assigned Costs Related to Principal Supply Works	17				x	x		x
Relocation of Grafton River Intake	18	x	x	x	x	x	x	
Water Conservation	19	x	x	x	x	x	x	x
West Fargo North ASR	20	x	x	x			x	
West Fargo South ASR	21	x	x	x			x	

"SCPP" is Snake Creek Pumping Plant.

C.3 - Feature and Option Cost Estimates

The costs associated with various features were developed from a number of sources and combined into an overall Excel spreadsheet which is shown in Attachment 3 of this appendix. Table C.8 shows the types of costs estimated and the source of the data. These sources are also provided in the appendix or referenced and included on the enclosed CD.

Table C.8 –Cost Estimate Sources.

Type of Cost Estimate	Source of Information
Overall Option Cost Estimates including Conveyance Features including Pipelines, Pumping Stations and Operational Storage – **Attachment 3 and 4**	Developed by Houston Engineering, Inc. and documented in the master cost estimate Excel spreadsheet.
Groundwater Features – **Attachment 5**	• *Central Minnesota Wellfield Cost Opinion*, Montgomery Watson Harza Technical Memorandum, May 6, 2005 • *Southeast North Dakota Wellfield*, Montgomery Watson Harza Technical Memorandum, May 6, 2005 • *Elk Valley Aquifer Wellfield Discussion and Cost Opinion*, Montgomery Watson Harza Technical Memorandum, May 6, 2005 • *WFS ASR Cost Opinion*, Montgomery Watson Harza Technical Memorandum, May 6, 2005 • *WFN ASR Cost Opinion*, Montgomery Watson Harza Technical Memorandum, May 6, 2005 • *Moorhead ASR Cost Opinion,* Montgomery Watson Harza Technical Memorandum, May 13, 2005 • *Moorhead Expansion to Buffalo Aquifer Cost Opinion*, Montgomery Watson Harza Technical Memorandum, May 13, 2005
Rights-of-Way – **Attachment 6**	*Report on Red River Valley Water Supply Project Needs and Options – Estimated Right-of-Way Cost*, Bureau of Reclamation, 2005
Cass Rural Water Users District Interconnection to the city of Fargo – **Attachment 7**	May 13, 2005 e-mail between Advanced Engineering, Inc. and Houston Engineering, Inc. Used the finished water transmission and storage costs from the 52nd Avenue alternative in the F-M Metro Water System Concept Plan.
Supervisory Control and Data Acquisition (SCADA) – **Attachment 7**	*SCADA Cost RRV Project Alternatives,* Montgomery Watson Harza Technical Memorandum, May 11, 2005
GDU – Assigned Costs Related to Principal Supply Works – **Attachment 7**	*Report on Red River Valley Needs and Options Computation of Assigned GDU Supply Works Costs*, May 2005, Bureau of Reclamation, Dakotas Area Office, Bismarck, North Dakota. The costs to bring the existing GDU Principal Supply Works up to full working order were documented in *Update of Garrison Diversion Unit Principal Supply Works Costs, Draft Report*, 2005, Bureau of Reclamation, Dakotas Area Office, Bismarck, North Dakota. Cost estimates were modified from original version when used as input into the master cost estimate Excel spreadsheet as documented in Attachment 7.
Biota Water Treatment Plants – **Attachment 7**	Original cost estimates taken from *Water Treatment Plant For Biota Removal and Inactivation , Preliminary Design & Cost Estimates, Red River Valley Water Supply Project*, North Dakota, Great Plains Region, 2005, Bureau of Reclamation, Denver Technical Service Center, Denver, Colorado. Cost estimates were modified from original version when used as input into the master cost estimate Excel spreadsheet as documented in Attachment 7.
Pumping Plant, PRV and Reservoir Estimating Documentation – **Attachment 7**	March 25, 2005, memo from Houston Engineering, Inc. documenting the methods used to estimate pumping plants, PRVs and reservoirs.
Documentation on Contractor OH&P, Contractor Costs and Non-Contract Costs – **Attachment 7**	February 4, 2005, memo from Montgomery Watson Harza, Inc.

The option cost estimates shown in Attachment 3 are a combination of calculated and lump sum cost estimates from other sources compiled using Microsoft Excel. The first sheet shows the summary costs of each alternative for Scenarios One and Two water demands. A peak day capacity version of the Lake of the Woods option is also included. This option was not included in chapter four of the Needs and Options Report because it is not being considered for further evaluation.
The subsequent cost estimate spreadsheets show the lookup tables used to estimates pipeline costs and a summary table including the cost of all lump sum items obtained from other reports as previously identified.

OPINION OF PROBABLE COST

10/30/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"

Summaries for Design Alternatives

Alternative Number (Click Below for Details)	Alternative Name	Scenario 1	Scenario 2	Feature Maps (Click Below for Details)
		Peak Flow		
		Annual Cost		
		Construction Cost		
1	"North Dakota In-Basin"	53 cfs	71 cfs	1
		$6,685,749	$7,514,748	
		$ 557,859,000	$ 637,891,000	
2	"Red River Basin"	45 cfs	72 cfs	2
		$7,481,024	$8,868,765	
		$ 549,166,000	$ 750,150,000	
3	"Lake of the Woods"	70 cfs	96 cfs	3
		$7,773,848	$8,764,899	
		$ 937,228,000	$ 1,112,579,000	
4	"GDU Import to Sheyenne Import"	78 cfs	120 cfs	4
		$3,819,050	$4,978,178	
		$ 434,052,000	$ 585,002,000	
5	"GDU Import Pipeline"	160 cfs	202 cfs	5
		$5,329,890	$6,309,599	
		$ 1,202,248,000	$ 1,407,721,000	
6	"Missouri River Import to Red River Valley"	44 cfs	63 cfs	6
		$9,897,122	$10,990,870	
		$ 875,378,000	$ 1,013,951,000	
7	"GDU Water Supply Replacement Pipeline"	341 cfs	411 cfs	7
		$25,434,896	$31,674,350	
		$ 2,226,667,000	$ 2,518,023,000	

The cost estimate then sequentially shows the detailed costs for each option, including an estimate for each feature. Features with cost estimates are listed on the left side of the summary sheet. Attachment 4 shows option drawings with the referenced location of all features using the feature number listed on the summary sheet.

Markup costs to account for contractor costs (30%) and profit (15%), unlisted items (5%), contingencies (25%) and non-contract costs (25%) are added on to the unburdened field costs to account for total alternative costs. Documentation describing these markup costs are provided in Attachment 7. The estimated do not include interest during construction.

Each option has right-of-way costs estimated separately on the bottom of the summary spreadsheet. Right-of-way costs were not considered a feature; but were estimated using different methods as described in Attachment 6. Total construction costs plus right-of-way costs represent the total cost required to construction an option.

Attachment 7 provides documentation of information used to estimate costs in the cost estimating spreadsheet (Attachment 3). This includes the methods used to estimate pumping plants, pressure reducing valves, storage reservoirs, biota water treatment plants, the share of costs associated with the repayment of the Garrison Diversion Unit, Principal Supply Works, and the "related" or infrastructure work required for the Fargo/Moorhead and Grand Forks metro areas.

OPINION OF PROBABLE COST

Draft: 5/12/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 1
"North Dakota In-Basin"

"SUPPLY FEATURES"

Feature No.	Feature Name	Scenario 1	Scenario 2
1.1	Intake and Pump Station on Red River at Grand Forks	$ 7,146,000	$ 10,359,000
1.2	Pipeline - Grand Forks to Pump Station NE of Hillsboro	$ 36,925,652	$ 38,935,601
1.3	Pump Station NE of Hillsboro	$ 4,216,680	$ 5,922,639
1.4	Pipeline - Hillsboro Pump Station to Pump Station NE of Hope	$ 22,657,230	$ 23,890,516
1.5	Pump Station NE of Hope	$ 6,452,798	$ 8,901,076
1.6	Pipeline - Pump Station NE of Hope to Lake Ashtabula	$ 26,195,782	$ 28,175,090
1.7	Discharge Structure Lake Ashtabula	$ 155,000	$ 210,000
1.8	Improvement of Red River Intake for Grafton	$ 1,550,572	$ 1,550,572
1.9	Improvements to the Moorhead and Buffalo Aquifers for Moorhead	$ 1,708,392	$ 1,708,392
1.10	ASR Moorhead	$ 688,970	$ 688,970
1.11	ASR West Fargo North Aquifer	$ 22,124,478	$ 22,124,478
1.12	ASR West Fargo South Aquifer	$ 20,166,538	$ 22,022,618
1.13	SE Aquifer Well System and Conveyance Pipeline for SE Industrial Needs	$ 23,303,006	$ 38,665,281
1.14	Elk Valley Aquifer Well System and Conveyance Pipeline	$ 31,870,476	$ 31,870,476
1.15	Storage Reservoirs in Northern Red River Valley	$ 12,000,000	$ 15,200,000
1.16	Electrical Infrastructure	$ 1,833,938	$ 1,833,938
1.17	CRWUD Interconnection with Fargo	$ 2,705,865	$ 2,705,865
1.18	SCADA control of main delivery pipeline system	$ 3,226,000	$ 3,226,000
	SUBTOTAL (Direct Costs)	$ 224,927,000	$ 267,991,000
	Contractor O H&P (30%)	$ 67,478,000	$ 77,397,000
	Contractor Costs (15%)	$ 33,739,000	$ 38,699,000
	SUBTOTAL (Burdened Costs Including mobilization)	$ 326,144,000	$ 374,087,000
	Unlisted Items (5% of Sub-total)	$ 16,307,000	$ 18,704,000
	CONTRACT COST	$ 342,451,000	$ 392,791,000
	Contingency (25% of Contract Cost)	$ 85,613,000	$ 98,198,000
	FIELD COST	$ 428,064,000	$ 490,989,000
	Non-Contract Costs (25% of Field Cost)	$ 107,016,000	$ 122,747,000
	Right of Way Acquisition Cost (click here)	$ 23,923,166	$ 23,964,509
	CONSTRUCTION COST (w/ROW)	$ 559,003,000	$ 637,701,000

C.4 - Summary of MR&I System Analysis

Attachment 8 provides a table that summarizes the results of the Needs and Options Report for each MR&I system in the Red River Valley service area and the present and future industrial water demands. The table identifies the current and future water source(s) available to each MR&I system and provides comments summarizing the analysis conducted on selected systems. Reclamation assumed that most small towns would be served by rural water systems in the future while larger cities would continue to treat their own water sources.

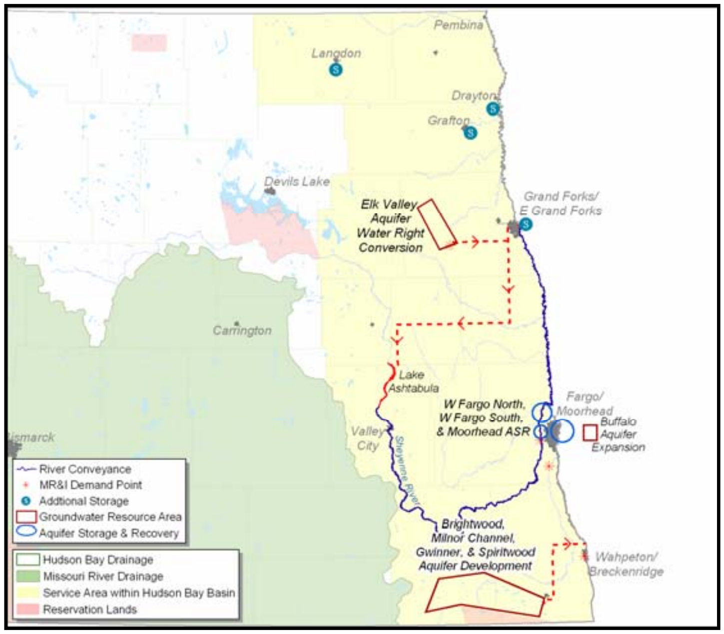
C.5 – Additional Alternative Analysis

Reviewers of the Draft Needs and Options Report suggested some additional technical analyses of the proposed options. Attachment 9 evaluates implementing drought contingency water demand reduction measures by quantifying potential cost savings of various levels of drought contingency and estimating the economic costs of imposing such measures. Attachment 10 evaluates the aquatic needs recommended by the North Dakota Game and Fish Department. Attachment 11 evaluates each of the alternatives financially showing per household and per unit costs of water service.

Appendix C – Attachment 1

Option Capacity Notes

North Dakota In-Basin Alternative



Peak Day Demand Method:
Use groundwater where available plus storage reservoirs.

Pipeline Capacity Notes:
Pipeline from Grand Forks to Lake Ashtabula - Modeling results indicate a recirculation pipeline requires a capacity of 50 cfs under Scenario One or 67 cfs under Scenario Two. Assuming 5% pipeline losses, the pipelines will be designed to carry 53 cfs or 71 cfs, respectively.

Pipeline Serving the SE Industries from ND groundwater - Capacity requirement is 511.6 ac-ft for Scenario One or 744.5 ac-ft for Scenario Two. This is equivalent to 8.32 cfs or 12.1 cfs, respectively. Assuming 5% pipeline losses, the pipelines will be designed to carry 9 cfs or 13 cfs, respectively.

Cass Rural Water Users – Capacity requirement is 2.1 cfs under Scenario One or 3.2 cfs under Scenario Two, including 5% losses.

Capacity Notes:
Fargo WTP Supply Sources

- Existing Fargo WTP will be expanded to a capacity of 45 mgd or 69.6 cfs.
- The existing Red River intake structure will be modified to a capacity of 45 mgd or 69.6 cfs.

Moorhead WTP Supply Sources

- The Moorhead WTP will be expanded to a capacity of 14.5 mgd (22.5 cfs) under Scenario One or 18.6 mgd (28.9 cfs) under Scenario Two.
- The Moorhead WTP will need to withdraw water from the Sheyenne River in a drought so a 22.5 cfs (Scenario One) or a 28.9 cfs (Scenario Two) interconnection with the Fargo WTP will be required.
- The Moorhead WTP Red River intake will be modified to increase the capacity to 14.5 mgd or 22.5 cfs under Scenario One or 18.6 mgd or 28.9 cfs under Scenario Two.
- Moorhead will continue to use 1.0 cfs of groundwater from the Moorhead Aquifer.
- Moorhead will continue to use 1.9 cfs of groundwater from the Buffalo Aquifer.
- To meet peak day water needs additional capacity in the Buffalo Aquifer will be developed. An addional 1.0 cfs of well capacity under Scenario One or 2.3 cfs under Scenario Two will be added to the existing 6.0 cfs capacity for a total of 7.0 cfs under Scenario One or 8.3 cfs under Scenario Two.

Regional WTP Supply Sources

- The capacity of the Regional WTP is equal to the peak day water demand for Fargo (123.42 cfs Scenario One or 147.35 cfs Scenario Two) minus the capacity of the existing expanded Fargo WTP (69.6 cfs) plus the peak day water demands for West Fargo (14.5 cfs for Scenario One or 14.8 cfs for Scenario Two) which equals 68.3 cfs (44.1 mgd) for Scenario One or 92.5 cfs (59.8 mgd) for Scenario Two.
- The Regional WTP would require redundant intakes in both the Sheyenne and Red Rivers. The Red River intake structure would have a capacity equal to the plant capacity which is 68.3 cfs for Scenario One and 92.5 cfs for Scenario Two.

Sheyenne River Intake Structure – To reduce the number of Sheyenne River intake structures, all of the F-M Metro Area will be served by one intake structure. Fargo's existing intake structure in the Sheyenne River will be modified to a capacity of 162.4 cfs under Scenario One or 194.2 cfs under Scenario Two. This capacity is based on the combined capacity of the F-M Metro Area WTPs which includes the existing Fargo WTP (Q = 69.6 cfs for both scenarios), Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), Regional WTP (68.3 cfs for Scenario One or 92.5 cfs for Scenario Two), and CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two).

Sheyenne River Intake Pipeline – The intake pipeline will have a capacity equal to the intake structure up to the Regional WTP. The intake pipeline from the Regional WTP to the existing Fargo WTP will have a capacity equal to the Fargo WTP (69.6 cfs for both scenarios), plus the Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), plus the CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two) for a total of 94.2 cfs under Scenario One or 101.7 cfs under Scenario Two.

Fargo Peak Day Water Supply – Fargo's peak day water demand will be met by developing groundwater capacity in the West Fargo South Aquifer. Under Scenario One the groundwater capacity is 39.3 cfs or under Scenario Two the capacity is 46.7 cfs. The water will be treated by the Regional WTP.

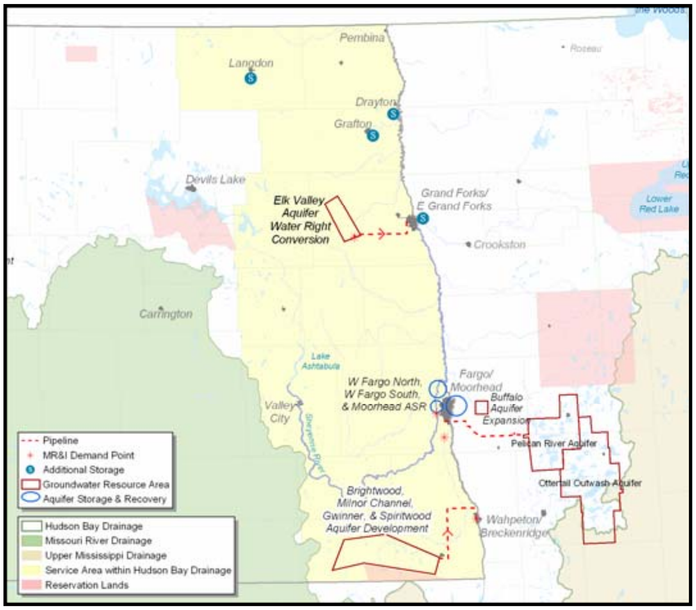
West Fargo Water Supply – Under drought conditions West Fargo's total water needs (normal and peak day) would be met from the aquifer storage and recovery (ASR) project. The ASR will have a capacity of 14.5 cfs under Scenario One or 14.8 cfs under Scenario Two. The water will be treated by the Regional WTP. Recharge water for the ASR project will be treated at the Regional WTP by reverse flow of the same pipeline.

Grand Forks Peak Day Water Supply – The city of Grand Forks will meet its peak day water needs by purchasing groundwater capacity from existing water permit holders in the Elk Valley Aquifer. The capacity of the pipeline is 27.1 cfs under Scenario One or 28.7 cfs under Scenario Two.

Grand Forks Traill Water District – Maximum month shortages of 2.6 cfs under Scenario One or 3.8 cfs under Scenario Two are met by additional well capacity in the Elk Valley Aquifer. This will also address peak day water demand shortages.

Red River Basin Alternative

Peak Day Demand Method:
Use groundwater where available plus storage reservoirs.



Pipeline Capacity Notes:
Pipeline from Minnesota Groundwater to Fargo Area - Modeling results indicate the pipeline conveying Minnesota groundwater to the F-M Metro Area requires a capacity of 42 cfs under Scenario One or 68 cfs under Scenario Two. Assuming 5% pipeline losses, the pipelines will be designed to carry 45 cfs or 72 cfs, respectively.

Pipeline Serving the SE Industries from the ND Groundwater - Capacity requirement is 511.6 ac-ft for Scenario One or 744.5 ac-ft for Scenario Two in the maximum month. This is equivalent to 8.32 cfs or 12.1 cfs, respectively. Assuming 5% pipeline losses, the pipelines will be designed to carry 9 cfs or 13 cfs, respectively.

Cass Rural Water Users – Capacity requirement is 2.1 cfs under Scenario One or 3.2 cfs under Scenario Two, including 5% losses.

Fargo-Moorhead Metro Area Capacity Notes:
Fargo WTP Supply Sources

- Existing Fargo WTP will be expanded to a capacity of 45 mgd or 69.6 cfs.
- The existing Red River intake structure modified to a capacity of 45 mgd or 69.6 cfs.

Moorhead WTP Supply Sources

- The Moorhead WTP will be expanded to a capacity of 14.5 mgd (22.5 cfs) under Scenario One or 18.6 mgd (28.9 cfs) under Scenario Two.
- The Moorhead WTP will need to withdraw water from the Sheyenne River in a drought so a 22.5 cfs (Scenario One) or a 28.9 cfs (Scenario Two) interconnection with the Fargo WTP will be required.
- The Moorhead WTP Red River intake will be modified to increase the capacity to 14.5 mgd (22.5 cfs) under Scenario One or 18.6 mgd (28.9 cfs) under Scenario Two.
- Moorhead will continue to use 1.0 cfs of groundwater from the Moorhead Aquifer.
- Moorhead will continue to use 1.9 cfs of groundwater from the Buffalo Aquifer.
- To meet peak day water needs additional capacity in the Buffalo Aquifer will be developed. An addional 1.0 cfs of well capacity under Scenario One or 2.3 cfs under Scenario Two will be added to the existing 6.0 cfs capacity for a total of 7.0 cfs under Scenario One or 8.3 cfs under Scenario Two.

Regional WTP Supply Sources

- The capacity of the Regional WTP is equal to the peak day water demand for Fargo (123.42 cfs Scenario One or 147.35 cfs Scenario Two) minus the capacity of the existing expanded Fargo WTP (69.6 cfs) plus the peak day water demands for West Fargo (14.5 cfs for Scenario One and 14.8 cfs for Scenario Two) which equals 68.3 cfs (44.1 mgd) for Scenario One or 92.5 cfs (59.8 mgd) for Scenario Two.
- The Regional WTP will require redundant intakes in both the Sheyenne and Red Rivers. The Red River intake structure will have a capacity equal to the plant capacity which is 68.3 cfs for Scenario One or 92.5 cfs for Scenario Two.

Sheyenne River Intake Structure – To reduce the number of Sheyenne River intake structures, all of the F-M Metro Area will be served by one intake structure. Fargo's existing intake structure in the Sheyenne River will be modified to a capacity of 162.4 cfs under Scenario One or 194.2 cfs under Scenario Two. The capacity is based on the combined capacity of the F-M Metro Area WTPs which includes the existing Fargo WTP (Q = 69.6 cfs for both scenarios), Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), Regional WTP (68.3 cfs for Scenario One or 92.5 cfs for Scenario Two), and CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two).

Sheyenne River Intake Pipeline – The intake pipeline will have a capacity equal to the intake structure up to the Regional WTP. The intake pipeline from the Regional WTP to the existing Fargo WTP will have a capacity equal to the Fargo WTP (69.6 cfs for both scenarios), plus the Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), plus the CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two) for a total of 94.2 cfs under Scenario One and 101.7 cfs under Scenario Two.

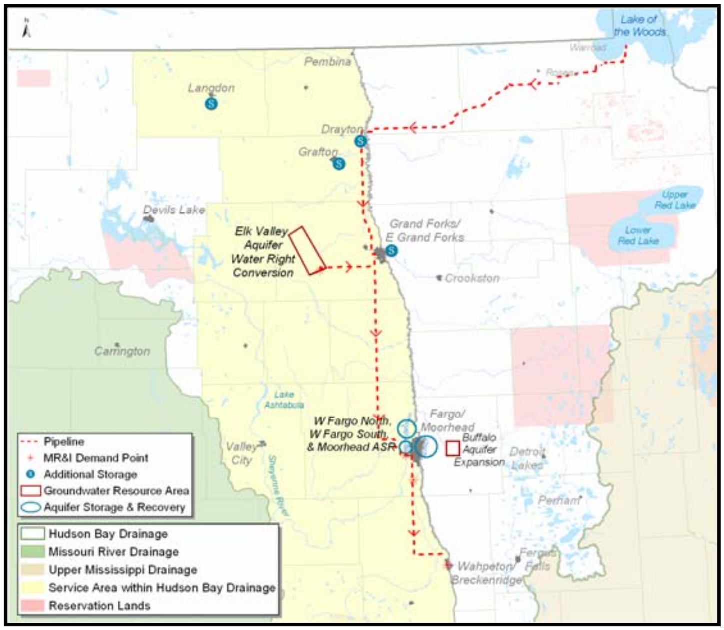
Fargo Peak Day Water Supply – Fargo's peak day water demand will be met by developing groundwater capacity in the West Fargo South Aquifer. Under Scenario One the groundwater capacity is 39.3 cfs or under Scenario Two the capacity is 46.7 cfs. The water will be treated by the Regional WTP.

West Fargo Water Supply – Under drought conditions West Fargo's total water needs (normal and peak day) will be met from the aquifer storage and recovery (ASR) project. The ASR will have a capacity of 14.5 cfs under Scenario One and 14.8 cfs under Scenario Two. The water will be treated by the Regional WTP. Recharge water for the ASR project will be treated at the Regional WTP by reverse flow of the same pipeline.

Grand Forks Peak Day Water Supply – The city of Grand Forks will meet its peak day water needs by purchasing groundwater capacity from existing water permit holders in the Elk Valley Aquifer. The capacity of the pipeline is 27.1 cfs under Scenario One or 28.7 cfs under Scenario Two.

Grand Forks Traill Water District – Maximum month shortages of 2.6 cfs under Scenario One or 3.8 cfs under Scenario Two are met by additional well capacity in the Elk Valley Aquifer. This will also address peak day water demand shortages.

Lake of the Woods Alternative



Peak Day Demand Method:

Use groundwater where available plus storage reservoirs.

Pipeline Capacity Notes:

Pipeline from Lake of the Woods to Grand Forks - Modeling results indicate the pipeline from Lake of the Woods to Grand Forks requires a capacity of 66 cfs under Scenario One or 91 cfs under Scenario Two. Assuming 5% pipeline losses, the pipelines will be designed to carry 70 cfs or 96 cfs, respectively.

Pipeline from Grand Forks to Fargo – Capacity is less 21 cfs (with 5% losses) required for Grand Forks or 49 cfs for Scenario One or 75 cfs for Scenario Two.

Pipeline Serving the SE Industries from the Fargo Area - Capacity requirement is 511.6 ac-ft for Scenario One one 744.5 ac-ft for Scenario Two in the maximum month. This is equivalent to 8.32 cfs or 12.1 cfs, respectively. Assuming 5% pipeline losses, the pipelines will be designed to carry 9 cfs or 13 cfs, respectively.

Cass Rural Water Users – Capacity requirement is 2.1 cfs under Scenario One or 3.2 cfs under Scenario Two, including 5% losses.

Fargo-Moorhead Metro Area Capacity Notes:

Fargo WTP Supply Sources –

- Existing Fargo WTP will be expanded to a capacity of 45 mgd or 69.6 cfs.
- The existing Red River Intake structure will also be modified to a capacity of 45 mgd or 69.6 cfs.

Moorhead WTP Supply Sources –

- The Moorhead WTP will be expanded to a capacity of 14.5 mgd (22.5 cfs) under Scenario One and 18.6 mgd (28.9 cfs) under Scenario Two.
- The Moorhead WTP will need to withdraw water from the Sheyenne River in a drought so a 22.5 cfs (Scenario One) or a 28.9 cfs (Scenario Two) interconnection with the Fargo WTP will be required.
- The Moorhead WTP Red River intake will be modified to increase the capacity to 14.5 mgd (22.5 cfs) under Scenario One and 18.6 mgd (28.9 cfs) under Scenario Two.
- Moorhead will continue to use 1.0 cfs of groundwater from the Moorhead Aquifer.
- Moorhead will continue to use 1.9 cfs of groundwater from the Buffalo Aquifer.
- To meet peak day water needs additional capacity in the Buffalo Aquifer will be developed. An addional 1.0 cfs of well capacity under Scenario One or 2.3 cfs under

Scenario Two will be added to the existing 6.0 cfs capacity for a total of 7.0 cfs under Scenario One or 8.3 cfs under Scenario Two.

Regional WTP Supply Sources –

- The capacity of the Regional WTP is equal to the peak day water demand for Fargo (123.42 cfs Scenario One or 147.35 cfs Scenario Two) minus the capacity of the existing expand Fargo WTP (69.6 cfs) plus the peak day water demands for West Fargo (14.5 cfs for Scenario One and 14.8 cfs for Scenario Two) which equals 68.3 cfs (44.1 mgd) for Scenario One or 92.5 cfs (59.8 mgd) for Scenario Two.
- The Regional WTP would require redundant intakes in both the Sheyenne and Red Rivers. The Red River intake structure would have a capacity equal to the plant capacity which is 68.3 cfs for Scenario One or 92.5 cfs for Scenario Two.

Sheyenne River Intake Structure – To reduce the number of Sheyenne River intake structures, all of the F-M Metro Area will be served by one intake structure. Fargo's existing intake structure in the Sheyenne River will be modified to a capacity of 162.4 cfs under Scenario One and 194.2 cfs under Scenario Two. The capacity is based on the combined capacity of the F-M Metro Area WTPs which includes the existing Fargo WTP (Q = 69.6 cfs for both scenarios), Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), Regional WTP (68.3 cfs for Scenario One or 92.5 cfs for Scenario Two), and CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two).

Sheyenne River Intake Pipeline – The intake pipeline will have a capacity equal to the intake structure up to the Regional WTP. The intake pipeline from the Regional WTP to the existing Fargo WTP will have a capacity equal to the Fargo WTP (69.6 cfs for both scenarios), plus the Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), plus the CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two) for a total of 94.2 cfs under Scenario One or 101.7 cfs under Scenario Two.

Fargo Peak Day Water Supply – Fargo's peak day water demand will be met by developing groundwater capacity in the West Fargo South Aquifer. Under Scenario One the groundwater capacity is 39.3 cfs or under Scenario Two the capacity is 46.7 cfs. The water will be treated by the Regional WTP.

West Fargo Water Supply – Under drought conditions, West Fargo's total water needs (normal and peak day) will be met from the aquifer storage and recovery (ASR) project. The ASR will have a capacity of 14.5 cfs under Scenario One or 14.8 cfs under Scenario Two. The water will be treated by the Regional WTP. Recharge water for the ASR project will be treated at the Regional WTP by reverse flow of the same pipeline.

Grand Forks Peak Day Water Supply – The city of Grand Forks will meet its peak day water needs by purchasing groundwater capacity from existing water permit holders in the Elk Valley Aquifer. The capacity of the pipeline is 27.1 cfs under Scenario One or 28.7 cfs under Scenario Two.

Grand Forks Traill Water District – Maximum month shortages of 2.6 cfs under Scenario One or 3.8 cfs under Scenario Two are met by additional well capacity in the Elk Valley Aquifer. This will also address peak day water demand shortages.

GDU to Sheyenne Import Alternative

Peak Day Demand Method:

Peak day demands will be supplied in the pipeline and in the river.

Pipeline Capacity Notes:

Pipeline from McClusky Canal to Lake Ashtabula - Modeling results indicate that a pipeline from the McClusky Canal to Lake Ashtabula requires a capacity of 59 cfs under Scenario One or 92 cfs under Scenario Two. Assuming 5% pipeline losses, the pipelines will be designed to carry 62 cfs or 97 cfs, respectively.

Pipeline Serving the SE Industries from the Fargo Area - Capacity requirement is 511.6 ac-ft for Scenario One or 744.5 ac-ft for Scenario Two in the maximum month. This is equivalent to 8.32 cfs or 12.1 cfs, respectively. Assuming 5% pipeline losses, the pipelines will be designed to carry 9 cfs or 13 cfs, respectively.

Cass Rural Water Users – Capacity requirement is 2.1 cfs under Scenario One or 3.2 cfs under Scenario Two, including 5% losses.

Fargo-Moorhead Metro Area Capacity Notes:

Fargo WTP Supply Sources –

- Existing Fargo WTP will be expanded to a capacity of 45 mgd or 69.6 cfs.
- The existing Red River Intake structure will be modified to a capacity of 45 mgd or 69.6 cfs.

Moorhead WTP Supply Sources –

- The Moorhead WTP will be expanded to a capacity of 14.5 mgd (22.5 cfs) under Scenario One or 18.6 mgd (28.9 cfs) under Scenario Two.
- The Moorhead WTP will need to withdraw water from the Sheyenne River in a drought so a 22.5 cfs (Scenario One) or a 28.9 cfs (Scenario Two) interconnection with the Fargo WTP will be required.
- The Moorhead WTP Red River intake will be modified to increase the capacity to 14.5 mgd (22.5 cfs) under Scenario One or 18.6 mgd (28.9 cfs) under Scenario Two.
- Moorhead will continue to use 1.0 cfs of groundwater from the Moorhead Aquifer.
- Moorhead will continue to use 1.9 cfs of groundwater from the Buffalo Aquifer.

Regional WTP Supply Sources

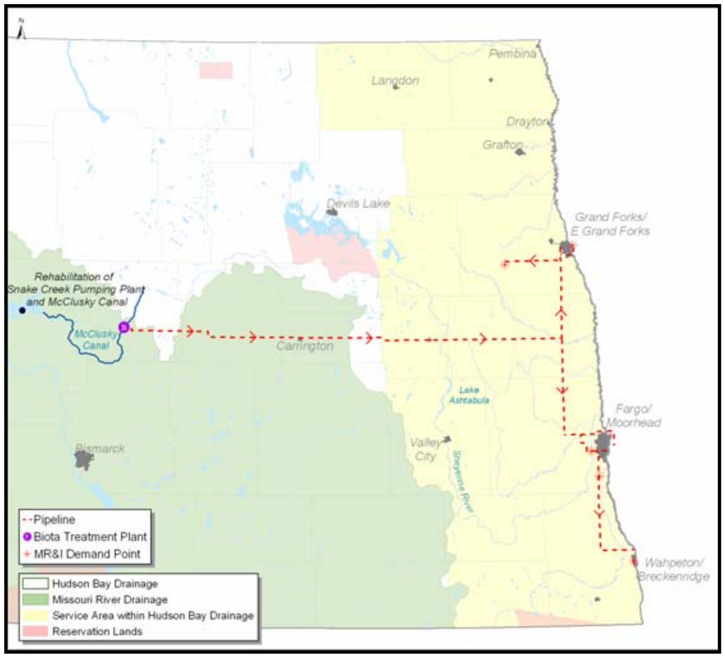
- The capacity of the Regional WTP is equal to the peak day water demand for Fargo (123.42 cfs Scenario One or 147.35 cfs Scenario Two) minus the capacity of the existing expand Fargo WTP (69.6 cfs) plus the peak day water demands for West Fargo (14.5 cfs for Scenario One or 14.8 cfs for Scenario Two) which equals 68.3 cfs (44.1 mgd) for Scenario One or 92.5 cfs (59.8 mgd) for Scenario Two.
- The Regional WTP will require redundant intakes in both the Sheyenne and Red Rivers. The Red River intake structure will have a capacity equal to the plant capacity which is 68.3 cfs for Scenario One or 92.5 cfs for Scenario Two.

Sheyenne River Intake Structure – To reduce the number of Sheyenne River intake structures, all of the F-M Metro Area will be served by one intake structure. Fargo's existing intake structure in the Sheyenne River will be modified to a capacity of 171.5 cfs under Scenario One or 207.2 cfs under Scenario Two. The capacity is based on the combined capacity of the F-M Metro Area WTPs which includes the existing Fargo WTP (Q = 69.6 cfs for both scenarios), Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), Regional WTP (68.3 cfs for Scenario One or 92.5 cfs for Scenario Two), and CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two). The industrial water demand would also be served from the intake structure so an additional 9.0 cfs under Scenario One or 13.0 cfs under Scenario Two is added to the above total.

Sheyenne River Intake Pipeline – The intake pipeline will have a capacity equal to the intake structure up to the Regional WTP. The intake pipeline from the Regional WTP to the existing Fargo WTP will have a capacity equal to the Fargo WTP (69.6 cfs for both scenarios), plus the Moorhead WTP (22.5 cfs under scenario 1 and 28.9 cfs under scenario 2), plus the CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two) for a total of 94.2 cfs under Scenario One or 101.7 cfs under Scenario Two.

Grand Forks Traill Water District – Maximum month shortages of 2.6 cfs under Scenario One or 3.8 cfs under Scenario Two (2.8 cfs or 4.0 cfs with pipelien losses) are met by purchasing water from Grand Forks. This will also address peak day water demand shortages.

GDU Import Alternative



Peak Day Demand Method:

Peak day demands will be supplied in the pipeline capacity.

Pipeline Capacity Notes:

Pipeline from the McClusky Canal to RRV - Modeling results indicate the pipeline from the McClusky Canal to the Red River Valley requires a capacity of 73 cfs under Scenario One or 100 cfs under Scenario Two. This alternative also uses increased pipeline capacity to meet peak day which is an additional 79.3 cfs for Scenario One or 91.6 cfs for Scenario Two. This results in a total capacity requirement of 153 cfs or 192 cfs, respectively. Assuming 5% pipeline losses, the pipelines will be designed to carry 160 cfs or 202 cfs, respectively.

Pipeline to Grand Forks and Pipeline to Fargo Area - The pipeline going north to Grand Forks will have a capacity of 56 cfs under Scenario One (includes 21 cfs mixing flow and 35 daily peaking flow) or 61 cfs under Scenario Two (includes 21 cfs mixing flow and 40 daily peaking flow). The pipeline going south to the Fargo area will have a capacity of 104 cfs under Scenario One or 141 cfs under Scenario Two.

Pipeline Serving the SE Industries from the Fargo area - Capacity requirement is 511.6 ac-ft for Scenario One or 744.5 ac-ft for Scenario Two in the maximum month. This is equivalent to 8.32 cfs or 12.1 cfs, respectively. Assuming 5% pipeline losses, the pipelines will be designed to carry 9 cfs or 13 cfs, respectively.

Cass Rural Water Users – Capacity requirement is 2.1 cfs under Scenario One or 3.2 cfs under Scenario Two, including 5% losses.

Fargo-Moorhead Metro Area Capacity Notes:

Fargo WTP Supply Sources

- Existing Fargo WTP will be expanded to a capacity of 45 mgd or 69.6 cfs.
- The existing Red River intake structure will be modified to a capacity of 45 mgd or 69.6 cfs.

Moorhead WTP Supply Sources

- The Moorhead WTP will be expanded to a capacity of 14.5 mgd (22.5 cfs) under Scenario One or 18.6 mgd (28.9 cfs) under Scenario Two.
- The Moorhead WTP will need to withdraw water from the Sheyenne River in a drought so a 22.5 cfs (Scenario One) or a 28.9 cfs (Scenario Two) interconnection with the Fargo WTP will be required.

- The Moorhead WTP Red River intake will be modified to increase the capacity to 14.5 mgd (22.5 cfs) under Scenario One or 18.6 mgd (28.9 cfs) under Scenario Two.
- Moorhead will continue to use 1.0 cfs of groundwater from the Moorhead Aquifer.
- Moorhead will continue to use 1.9 cfs of groundwater from the Buffalo Aquifer.

Regional WTP Supply Sources

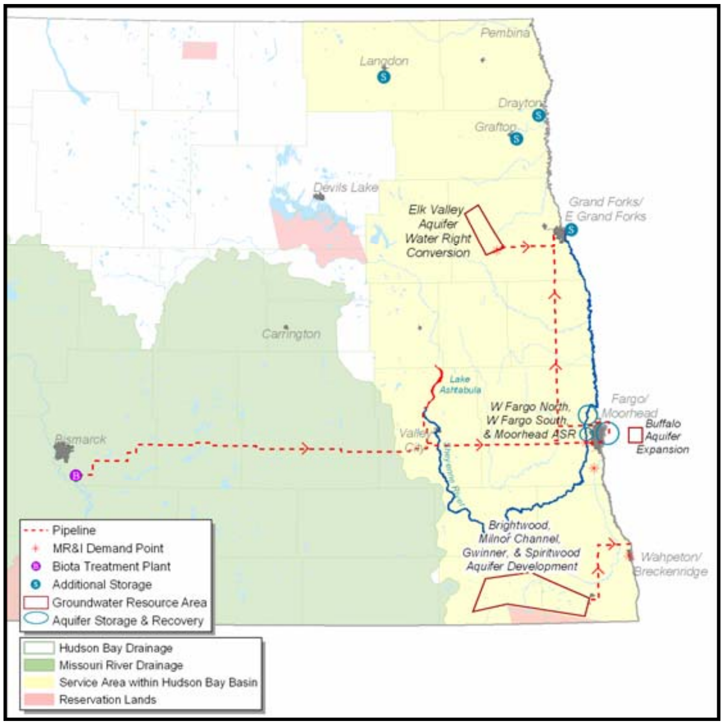
- The capacity of the Regional WTP is equal to the peak day water demand for Fargo (123.42 cfs Scenario One or 147.35 cfs Scenario Two) minus the capacity of the existing expand Fargo WTP (69.6 cfs) plus the peak day water demands for West Fargo (14.5 cfs for Scenario One or 14.8 cfs for Scenario Two) which equals 68.3 cfs (44.1 mgd) for Scenario One or 92.5 cfs (59.8 mgd) for Scenario Two.
- The Regional WTP will require redundant intakes in both the Sheyenne and Red Rivers. The Red River intake structure will have a capacity equal to the plant capacity which is 68.3 cfs for Scenario One or 92.5 cfs for Scenario Two.

Sheyenne River Intake Structure – To reduce the number of Sheyenne River intake structures, all of the F-M Metro Area will be served by one intake structure. Fargo's existing intake structure in the Sheyenne River will be modified to a capacity of 162.4 cfs under Scenario One or 194.2 cfs under Scenario Two. This capacity is based on the combined capacity of the F-M Metro Area WTPs which includes the existing Fargo WTP (Q = 69.6 cfs for both scenarios), Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), Regional WTP (68.3 cfs for Scenario One or 92.5 cfs for Scenario Two), and CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two).

Sheyenne River Intake Pipeline – The intake pipeline will have a capacity equal to the intake structure up to the Regional WTP. The intake pipeline from the Regional WTP to the existing Fargo WTP will have a capacity equal to the Fargo WTP (69.6 cfs for both scenarios), plus the Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), plus the CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two) for a total of 94.2 cfs under Scenario One or 101.7 cfs under Scenario Two.

Grand Forks Traill Water District – Maximum month shortages of 2.6 cfs under Scenario One or 3.8 cfs under Scenario Two (2.8 cfs or 4.0 cfs with pipeline losses) are met by purchasing water from Grand Forks. This will also address peak day water demand shortages.

Missouri River to Red River Valley Import Alternative



Peak Day Demand Method:

Use groundwater where available plus storage reservoirs**.**

Pipeline Capacity Notes:

Pipeline from Bismarck to Fargo- This alternative uses Lake Ashtabula as a re-regulation reservoir which reduces the capacity requirement in the Bismarck to Valley City portion of the pipeline. Modeling results indicate the Bismarck to Valley City pipeline capacity will be 42 cfs under Scenario One or 60 cfs under Scenario Two. Assuming 5% pipeline losses, the pipeline capacity is 44 cfs or 63 cfs, respectively. The pipeline spur from Valley City to Casselton will be the same 44 cfs or 63 cfs, respectively. The pipeline from Casselton to Fargo will not include the 21 cfs going to Grand Forks so the capacity will be 23 cfs for Scenario One or 42 cfs for Scenario Two.

Pipeline from Casselton to Grand Forks – The pipeline from Casselton to Grand Forks will have a capacity of 21 cfs, including 5% losses.

Pipeline from Valley City to Lake Ashtabula – The pipeline spur to Lake Ashtabula will have a capacity of 23 cfs or 42 cfs, respectively. This is 20 cfs less (21 cfs with losses) than the main pipeline from Bismarck to Valley City.

Pipeline Serving the SE Industries from ND Groundwater - Capacity requirement is 511.6 ac-ft under Scenario One or 744.5 ac-ft under Scenario Two in the maximum month. This is equivalent to 8.32 cfs or 12.1 cfs, respectively. Assuming 5% pipeline losses, the pipelines will be designed to carry 9 cfs or 13 cfs, respectively.

Cass Rural Water Users – Capacity requirement is 2.1 cfs under Scenario One or 3.2 cfs under Scenario Two, including 5% losses.

Fargo-Moorhead Metro Area Capacity Notes:

Fargo WTP Supply Sources

- Existing Fargo WTP will be expanded to a capacity of 45 mgd or 69.6 cfs.
- The existing Red River intake structure modified to a capacity of 45 mgd or 69.6 cfs.

Moorhead WTP Supply Sources

- The Moorhead WTP will be expanded to a capacity of 14.5 mgd (22.5 cfs) under Scenario One or 18.6 mgd (28.9 cfs) under Scenario Two.
- The Moorhead WTP will need to withdraw water from the Sheyenne River in a drought so a 22.5 cfs (Scenario One) or a 28.9 cfs (Scenario Two) interconnection with the Fargo WTP will be required.
- The Moorhead WTP Red River intake will be modified to increase the capacity to 14.5 mgd (22.5 cfs) under Scenario One or 18.6 mgd (28.9 cfs) under Scenario Two.
- Moorhead will continue to use 1.0 cfs of groundwater from the Moorhead Aquifer.
- Moorhead will continue to use 1.9 cfs of groundwater from the Buffalo Aquifer.
- To meet peak day water needs additional capacity in the Buffalo Aquifer will be developed. An addional 1.0 cfs of well capacity under Scenario One or 2.3 cfs under Scenario Two will be added to the existing 6.0 cfs capacity for a total of 7.0 cfs under Scenario One or 8.3 cfs under Scenario Two.

Regional WTP Supply Sources

- The capacity of the Regional WTP is equal to the peak day water demand for Fargo (123.42 cfs Scenario One or 147.35 cfs Scenario Two) minus the capacity of the existing expand Fargo WTP (69.6 cfs for both scenarios) plus the peak day water demands for West Fargo (14.5 cfs for Scenario One or 14.8 cfs for Scenario Two) which equals 68.3 cfs (44.1 mgd) for Scenario One or 92.5 cfs (59.8 mgd) for Scenario Two.
- The Regional WTP will require redundant intakes in both the Sheyenne and Red Rivers. The Red River intake structure will have a capacity equal to the plant capacity which is 68.3 cfs for Scenario One or 92.5 cfs for Scenario Two.

Sheyenne River Intake Structure – To reduce the number of Sheyenne River intake structures, all of the F-M Metro Area will be served by one intake structure. Fargo's existing intake structure in the Sheyenne River will be modified to a capacity of 162.4 cfs under Scenario One or 194.2 cfs under Scenario Two. The capacity is based on the combined capacity of the F-M Metro Area WTPs which includes the existing Fargo WTP (Q = 69.6 cfs for both scenarios), Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), Regional WTP (68.3 cfs for Scenario One or 92.5 cfs for Scenario Two), and CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two).

Sheyenne River Intake Pipeline – The intake pipeline will have a capacity equal to the intake structure up to the Regional WTP. The intake pipeline from the Regional WTP to the existing Fargo WTP will have a capacity equal to the Fargo WTP (69.6 cfs for both scenarios), plus the Moorhead WTP (22.5 cfs under Scenario One or 28.9 cfs under Scenario Two), plus the CRWU (2.1 cfs under Scenario One or 3.2 cfs under Scenario Two) for a total of 94.2 cfs under Scenario One and 101.7 cfs under Scenario Two.

Fargo Peak Day Water Supply – Fargo's peak day water demand will be met by developing groundwater capacity in the West Fargo South Aquifer. Under Scenario One the groundwater capacity is 39.3 cfs and under Scenario Two the capacity is 46.7 cfs. The water will be treated by the Regional WTP.

West Fargo Water Supply – Under drought conditions, West Fargo's total water needs (normal and peak day) will be met from the aquifer storage and recovery (ASR) project. The ASR will have a capacity of 14.5 cfs under Scenario One or 14.8 cfs under Scenario Two. The water will be treated by the Regional WTP. Recharge water for the ASR project will be treated at the Regional WTP by reverse flow of the same pipeline.

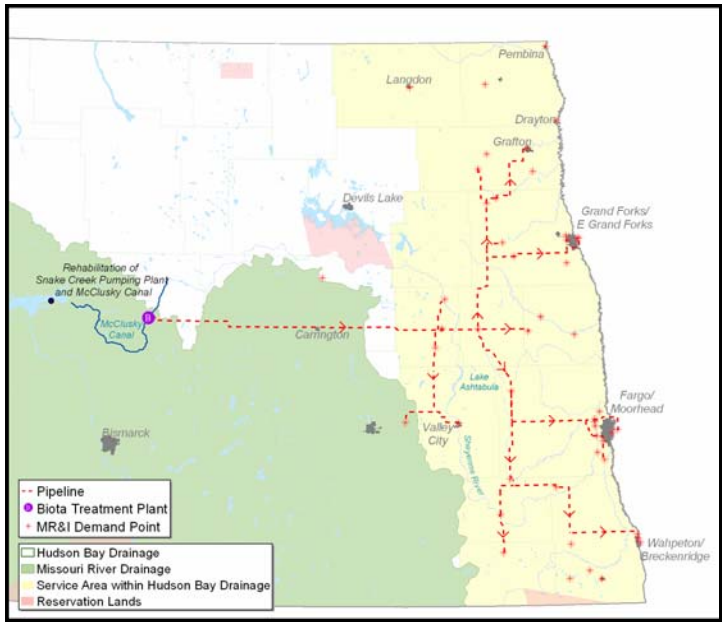
Grand Forks Peak Day Water Supply – The city of Grand Forks will meet its peak day water needs by purchasing groundwater capacity from existing water permit holders in the Elk Valley Aquifer. The capacity of the pipeline is 27.1 cfs under Scenario One or 28.7 cfs under Scenario Two.

Grand Forks Traill Water District – Maximum month shortages of 2.6 cfs under Scenario One or 3.8 cfs under Scenario Two are met by additional well capacity in the Elk Valley Aquifer. This will also address peak day water demand shortages.

GDU Water Supply Replacement Pipeline Alternative

Peak Day Demand Method:
The pipeline capacity is sized to meet peak day demands.

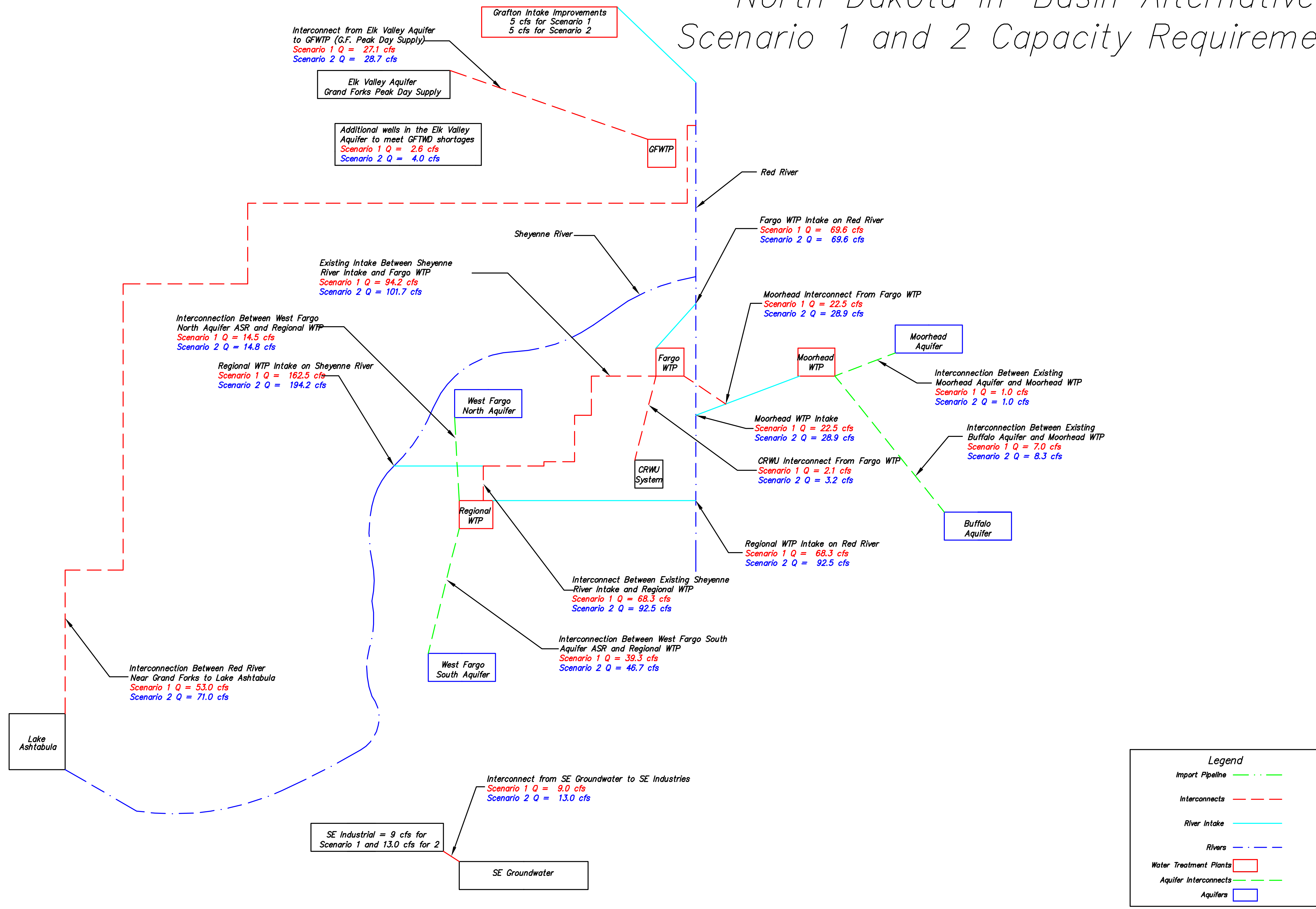
Pipeline Capacity Notes:
Replacement Alternative - Modeling results indicate the main conveyance pipeline from the McClusky Canal into the Red River Valley requires a capacity of 324 cfs under Scenario One or 391 cfs under Scenario Two. Assuming 5% pipeline losses, the pipelines will be designed to carry 341 cfs or 411 cfs, respectively. Other distribution pipelines have smaller capacity requirements and are not shown here.



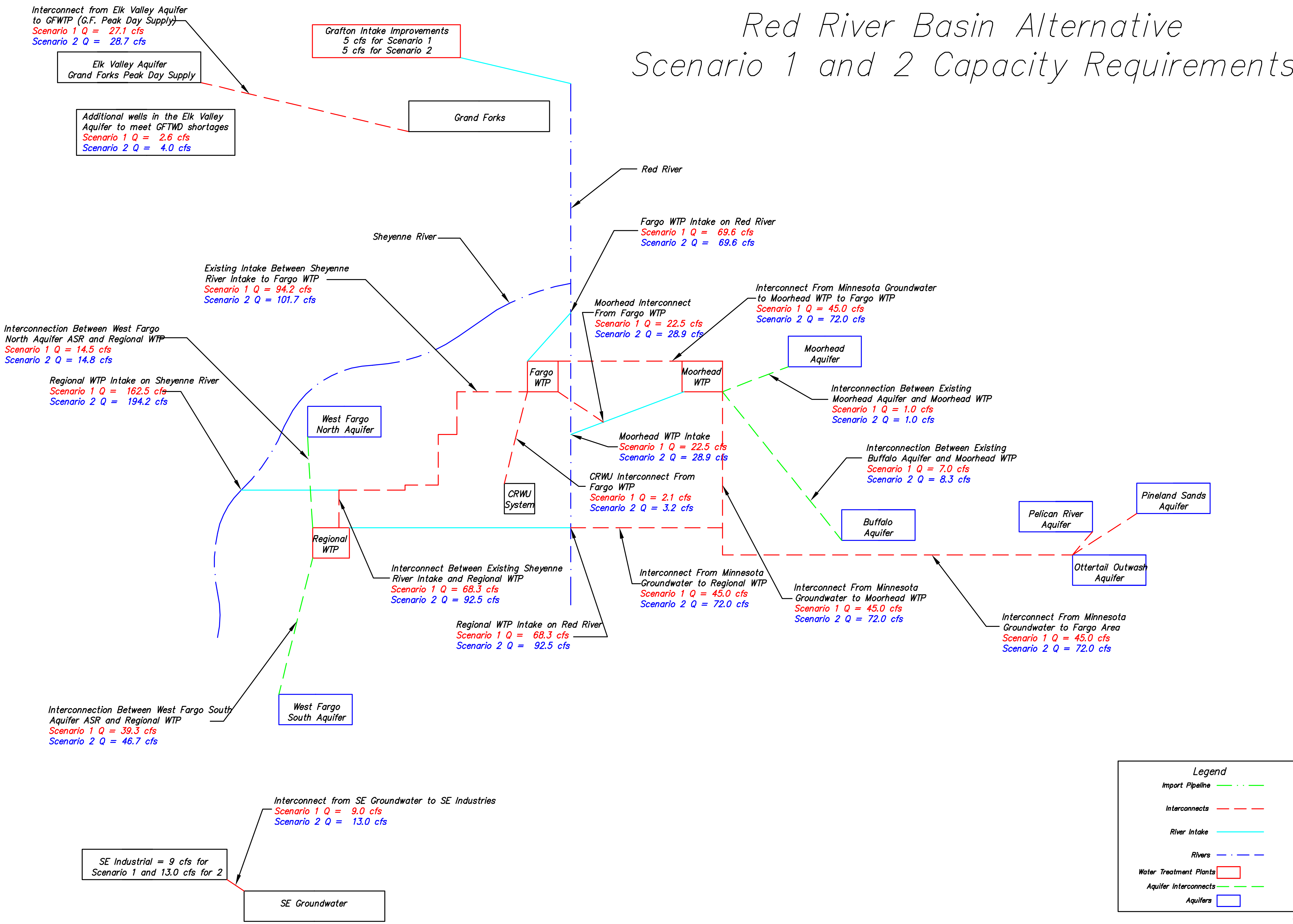
Appendix C – Attachment 2

Option Capacity Schematic Drawings

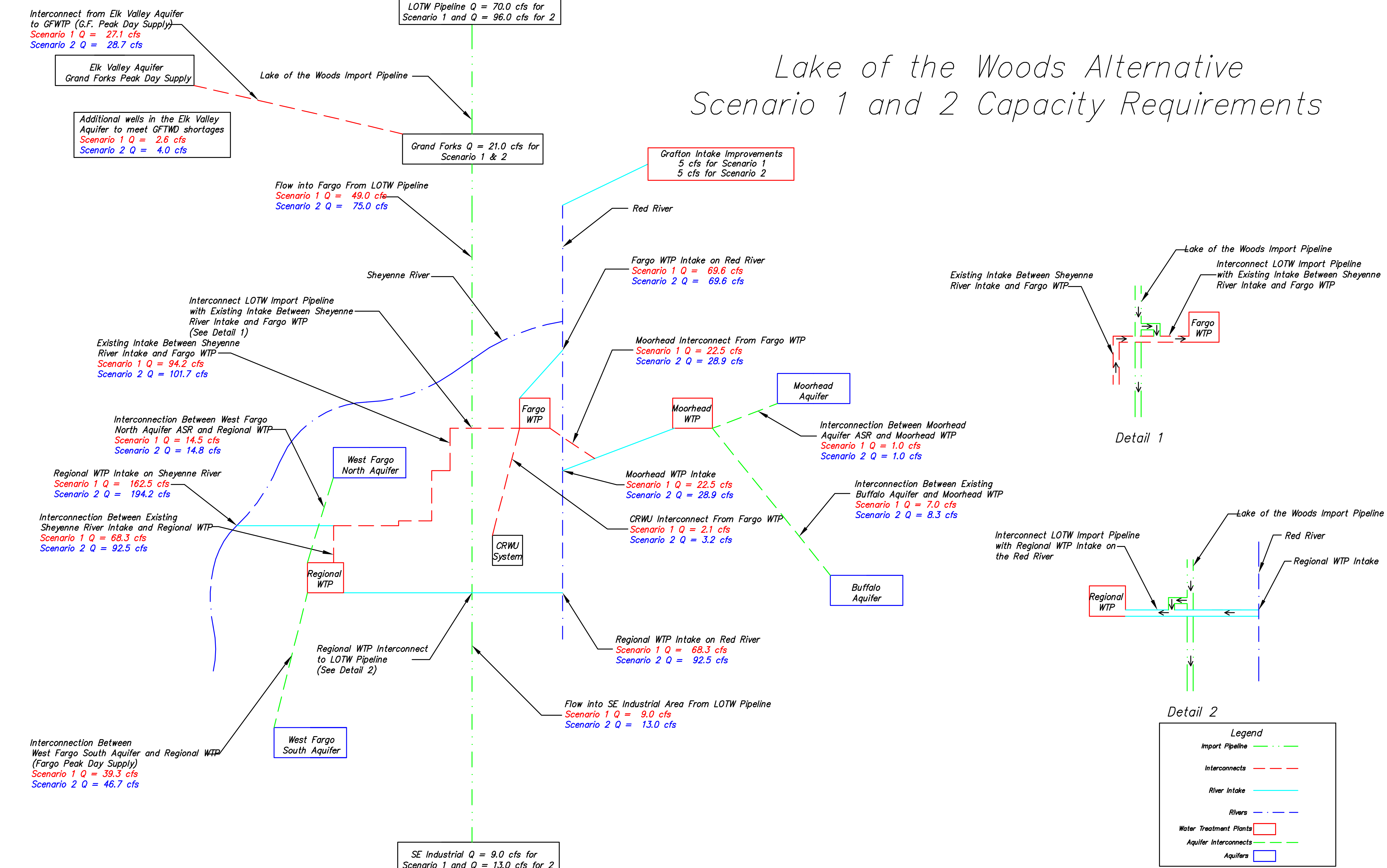
North Dakota In-Basin Alternative Scenario 1 and 2 Capacity Requirements



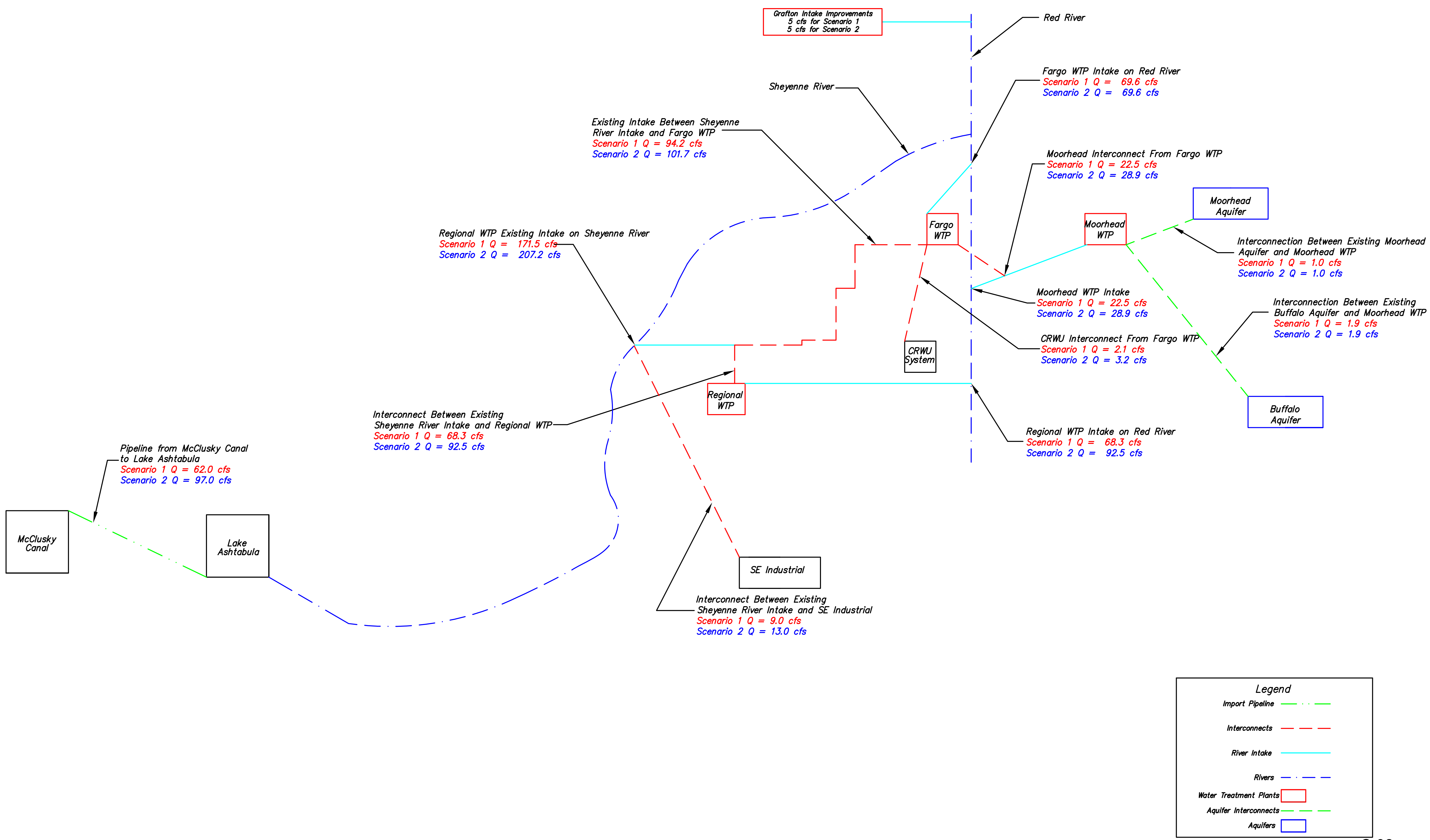
Red River Basin Alternative
Scenario 1 and 2 Capacity Requirements



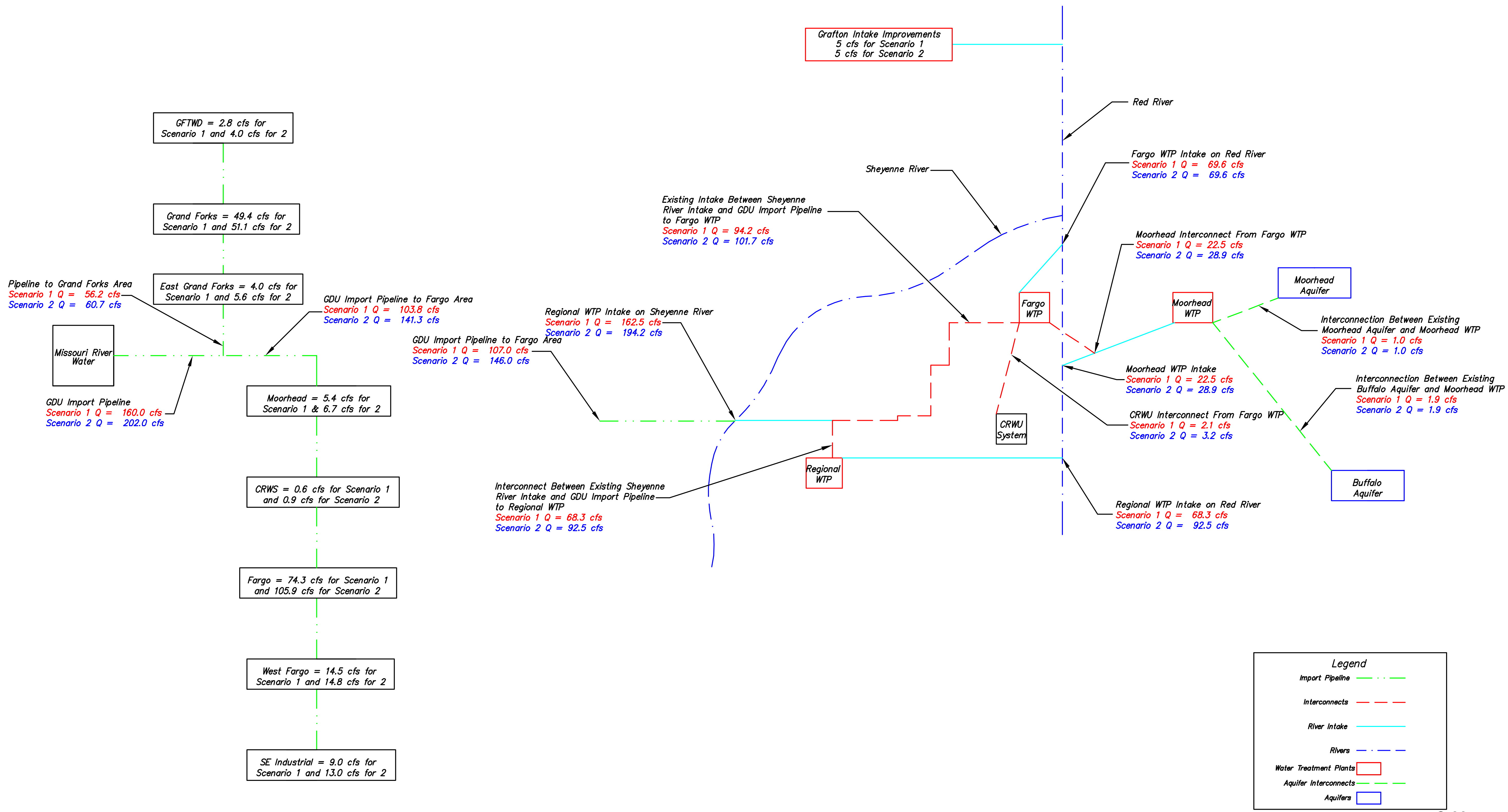
Lake of the Woods Alternative Scenario 1 and 2 Capacity Requirements



GDU to Sheyenne Import Alternative
Scenario 1 and 2 Capacity Requirements



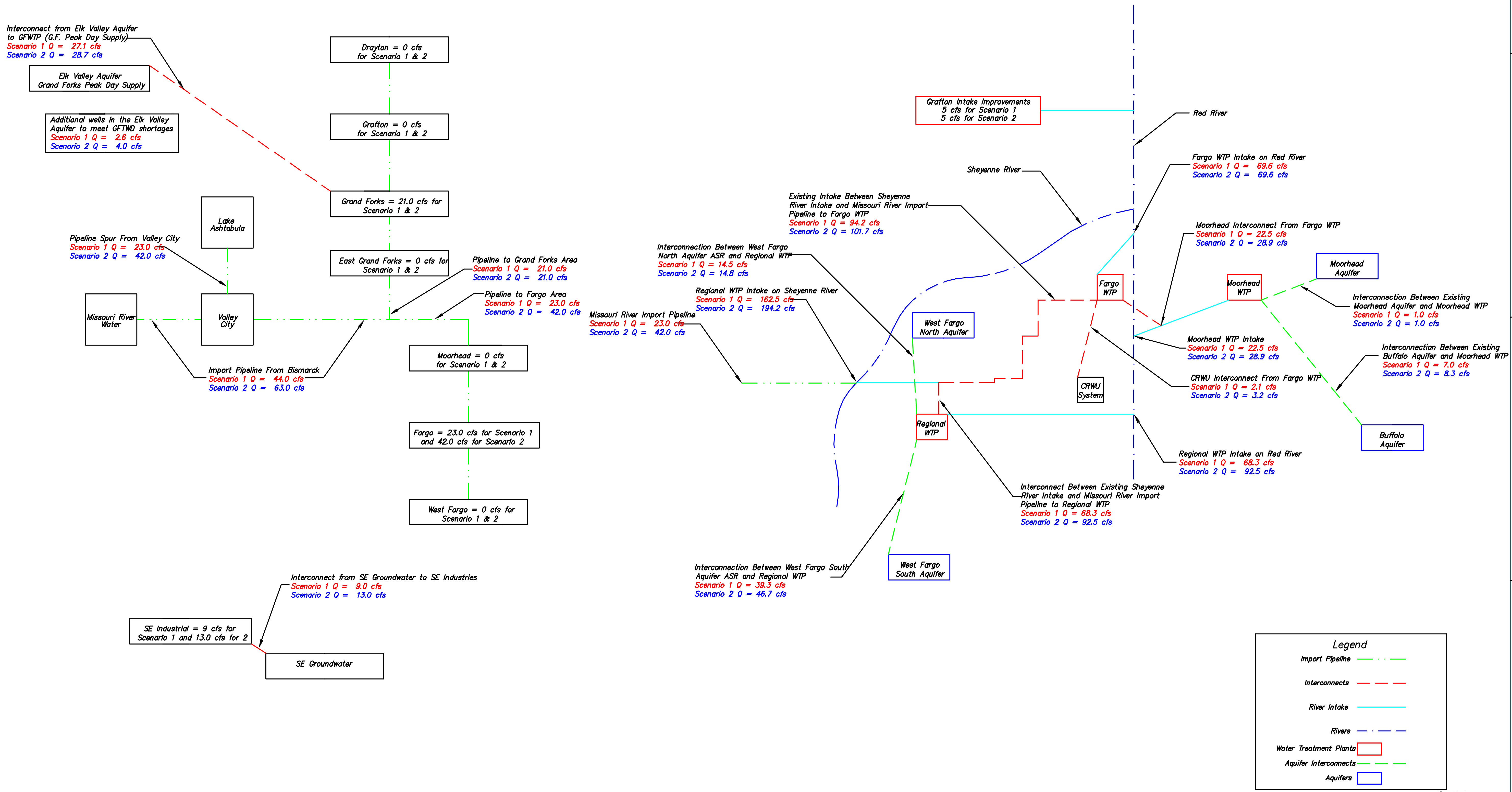
GDU Import Alternative
Scenario 1 and 2 Capacity Requirements



Draft: May 19, 2005

(22X34)

Missouri to Red River Valley Import Alternative
Scenario 1 and 2 Capacity Requirements



Appendix C – Attachment 3

Option Cost Estimates

OPINION OF PROBABLE COST

10/30/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"

Summaries for Design Alternatives

Alternative Number (Click Below for Details)	Alternative Name	Scenario 1	Scenario 2	Feature Maps (Click Below for Details)
		Peak Flow		
		Annual Cost		
		Construction Cost		
1	*"North Dakota In-Basin"*	*53 cfs*	*71 cfs*	1
		$6,685,749	*$7,514,748*	
		$ 557,859,000	$ 637,891,000	
2	*"Red River Basin"*	*45 cfs*	*72 cfs*	2
		$7,481,024	*$8,868,765*	
		$ 549,166,000	$ 750,150,000	
3	*"Lake of the Woods"*	*70 cfs*	*96 cfs*	3
		$7,773,848	*$8,764,899*	
		$ 937,228,000	$ 1,112,579,000	
4	*"GDU Import to Sheyenne Import"*	*62 cfs*	*97 cfs*	4
		$3,819,050	*$4,978,178*	
		$ 434,052,000	$ 585,002,000	
5	*"GDU Import Pipeline"*	*160 cfs*	*202 cfs*	5
		$5,329,890	*$6,309,599*	
		$ 1,202,248,000	$ 1,407,721,000	
6	*"Missouri River Import to Red River Valley"*	*44 cfs*	*63 cfs*	6
		$9,897,122	*$10,990,870*	
		$ 875,378,000	$ 1,013,951,000	
7	*"GDU Water Supply Replacement Pipeline"*	*341 cfs*	*411 cfs*	7
		$25,434,896	*$31,674,350*	
		$ 2,226,667,000	$ 2,518,023,000	

OPINION OF PROBABLE COST

Draft: 10/30/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 1
"North Dakota In-Basin"

"SUPPLY FEATURES"

Feature No.	Feature Name	Scenario 1	Scenario 2
1.1	Intake and Pump Station on Red River at Grand Forks	$ 7,146,000	$ 10,359,000
1.2	Pipeline - Grand Forks to Pump Station NE of Hillsboro	$ 36,925,652	$ 38,935,601
1.3	Pump Station NE of Hillsboro	$ 4,216,680	$ 5,922,639
1.4	Pipeline - Hillsboro Pump Station to Pump Station NE of Hope	$ 22,657,230	$ 23,890,516
1.5	Pump Station NE of Hope	$ 6,452,798	$ 8,901,076
1.6	Pipeline - Pump Station NE of Hope to Lake Ashtabula	$ 26,195,782	$ 28,175,090
1.7	Discharge Structure Lake Ashtabula	$ 155,000	$ 210,000
1.8	Improvement of Red River Intake for Grafton	$ 1,550,572	$ 1,550,572
1.9	Improvements to the Moorhead and Buffalo Aquifers for Moorhead	$ 1,146,392	$ 1,708,392
1.10	ASR Moorhead	$ 688,970	$ 688,970
1.11	ASR West Fargo North Aquifer	$ 22,124,478	$ 22,124,478
1.12	ASR West Fargo South Aquifer	$ 20,166,538	$ 22,022,618
1.13	SE Aquifer Well System and Conveyance Pipeline for SE Industrial Needs	$ 23,303,006	$ 38,665,281
1.14	Elk Valley Aquifer Well System and Conveyance Pipeline	$ 31,870,476	$ 31,870,476
1.15	Storage Reservoirs in Northern Red River Valley	$ 12,000,000	$ 15,200,000
1.16	Electrical Infrastucture	$ 1,914,594	$ 1,914,594
1.17	CRWUD Interconnection with Fargo	$ 2,705,865	$ 2,705,865
1.18	SCADA control of main delivery pipeline system	$ 3,226,000	$ 3,226,000
	SUBTOTAL (Direct Costs)	**$ 224,446,000**	**$ 258,071,000**
	Contractor OH,&P (30%)	$ 67,334,000	$ 77,421,000
	Contractor Costs (15%)	$ 33,667,000	$ 38,711,000
	SUBTOTAL (Burdened Costs including mobilization)	**$ 325,447,000**	**$ 374,203,000**
	Unlisted Items (5% of Sub-total)	$ 16,272,000	$ 18,710,000
	CONTRACT COST	**$ 341,719,000**	**$ 392,913,000**
	Contingency (25% of Contract Cost)	$ 85,430,000	$ 98,228,000
	FIELD COST	**$ 427,149,000**	**$ 491,141,000**
	Non-Contract Costs (25% of Field Cost)	$ 106,787,000	$ 122,785,000
	Right of Way Acquisition Cost (click here)	$ 23,923,166	$ 23,964,509
	CONSTRUCTION COST (w/ROW)	**$ 557,859,000**	**$ 637,891,000**
	ANNUAL COSTS (click here)	**$ 6,685,749**	**$ 7,514,748**

OPINION OF PROBABLE COST
"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 1 "North Dakota In-Basin"

SCENARIO 1:	**Field Cost**				**Annual Facility Cost**						**Annual Equipment & Labor**	**Annual Power**	**Annual Water Treatment**	**Total Annual OM&R**
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$169,660	$170,432
Grand Forks to Lake Ashtabula Pipeline	$163,236,799		$33,902,855		$24,486	$0	$169,514	$0	$8,845		$739,102	$671,357		$1,613,303
Moorhead ASR										$12,175	$54,827	$6,528	$54,000	$127,529
Moorhead Peak Day - Expanded Use of Buffalo Aquifer										$5,594	$54,827	$4,600		$65,021
New Groundwater to Serve Industries	$19,678,322		$2,397,780		$2,952		$11,989		$304,390	$84,047	$400,414	$52,521		$856,312
Peak Day Water Demand using Storage		$22,836,000				$3,425					$54,827			$58,252
Purchase Elk Valley Aquifer Water Rights	$23,697,554		$5,994,450		$3,555		$29,972		$2,362	$153,379	$649,074	$36,448		$874,789
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$22,362		$29,793
Water Conservation														$780,000
West Fargo North ASR	$6,096,802				$915				$525	$221,164	$530,594	$38,786	$309,380	$1,101,363
West Fargo South ASR	$290,324				$44				$25	$173,588	$530,594	$50,213	$254,490	$1,008,954
TOTALS					$32,748	$3,626	$218,679	$0	$316,147	$649,947	$3,014,256	$882,815	$787,530	***$6,685,749***

SCENARIO 2:	**Field Cost**				**Annual Facility Cost**						**Annual Equipment & Labor**	**Annual Power**	**Annual Water Treatment**	**Total Annual OM&R**
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$389,220	$389,992
Grand Forks to Lake Ashtabula Pipeline	$173,175,294		$47,922,708		$25,976	$0	$239,614	$0	$8,845		$739,102	$844,678		$1,858,215
Moorhead ASR										$12,175	$54,827	$6,947	$58,500	$132,448
Moorhead Peak Day - Expanded Use of Buffalo Aquifer										$16,288	$54,827	$9,420		$80,535
New Groundwater to Serve Industries	$19,678,322		$3,596,670		$2,952		$17,983		$304,390	$128,478	$400,414	$88,119		$942,336
Peak Day Water Demand using Storage		$28,925,600				$4,339					$54,827			$59,166
Purchase Elk Valley Aquifer Water Rights	$23,697,554		$5,994,450		$3,555		$29,972		$2,362	$153,379	$649,074	$39,252		$877,593
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$30,504		$37,935
Water Conservation														$780,000
West Fargo North ASR	$6,096,802				$915				$525	$221,164	$530,594	$48,525	$459,080	$1,260,802
West Fargo South ASR	$290,324				$44				$25	$199,809	$530,594	$60,866	$304,390	$1,095,727
TOTALS					$34,239	$4,540	$294,773	$0	$316,147	$731,293	$3,014,256	$1,128,311	$1,211,190	***$7,514,748***

OPINION OF PROBABLE COST

Draft: 10/30/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 2
"Red River Basin"

"SUPPLY FEATURES"

Feature No.	Feature Name	Scenario 1		Scenario 2	
2.1	Improvement of Red River Intake for Grafton	$	1,550,572	$	1,550,572
2.2	Improvements to the Moorhead and Buffalo Aquifers for Moorhead	$	1,146,392	$	1,708,392
2.3	ASR Moorhead	$	688,970	$	688,970
2.4	ASR West Fargo North Aquifer	$	22,124,478	$	22,124,478
2.5	ASR West Fargo South Aquifer	$	20,166,538	$	22,022,618
2.6	MN Aqifer Well System and Conveyance Pipeline	$	104,479,067	$	167,501,536
2.7	SE Aquifer Well System and Conveyance Pipeline for SE Industrial Needs	$	23,303,006	$	38,665,281
2.8	Elk Valley Aquifer Well System and Conveyance Pipeline	$	31,870,476	$	31,870,476
2.9	Storage Reservoirs in Northern Red River Valley	$	12,000,000	$	15,200,000
2.10	Electrical Infrastucture	$	97,328	$	97,328
2.11	CRWUD Interconnection with Fargo	$	2,705,865	$	2,705,865
2.12	SCADA control of main delivery pipeline system	Covered in individual features			
	SUBTOTAL (Direct Costs)	**$**	**220,133,000**	**$**	**304,136,000**
	Contractor OH,&P (30%)	$	66,040,000	$	91,241,000
	Contractor Costs (15%)	$	33,020,000	$	45,620,000
	SUBTOTAL (Burdened Costs including mobilization)	**$**	**319,193,000**	**$**	**440,997,000**
	Unlisted Items (5% of Sub-total)	$	15,960,000	$	22,050,000
	CONTRACT COST	**$**	**335,153,000**	**$**	**463,047,000**
	Contingency (25% of Contract Cost)	$	83,788,000	$	115,762,000
	FIELD COST	**$**	**418,941,000**	**$**	**578,809,000**
	Non-Contract Costs (25% of Field Cost)	$	104,735,000	$	144,702,000
	Right of Way Acquisition Cost (click here)	$	25,489,536	$	26,639,416
	CONSTRUCTION COST (w/ROW)	**$**	**549,166,000**	**$**	**750,150,000**
	ANNUAL COSTS (click here)	**$**	**7,481,024**	**$**	**8,868,765**

OPINION OF PROBABLE COST
"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 2 "Red River Basin"

SCENARIO 1:

	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$169,660	$170,432
Minnesota Groundwater and Pipeline	$43,719,481		$9,591,120		$6,558	$0	$47,956	$0	$3,677	$307,586	$1,655,555	$387,247		$2,408,579
Moorhead ASR										$12,175	$54,827	$6,528	$54,000	$127,529
Moorhead Peak Day - Expanded Use of Buffalo Aquifer										$5,594	$54,827	$4,600		$65,021
New Groundwater to Serve Industries	$19,678,322		$2,397,780		$2,952		$11,989		$304,390	$84,047	$400,414	$52,521		$856,312
Peak Day Water Demand using Storage		$22,836,000				$3,425					$54,827			$58,252
Purchase Elk Valley Aquifer Water Rights	$23,697,554		$5,994,450		$3,555		$29,972		$2,362	$153,379	$649,074	$36,448		$874,789
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$22,362		$29,793
Water Conservation														$780,000
West Fargo North ASR	$6,096,802				$915				$525	$221,164	$530,594	$38,786	$309,380	$1,101,363
West Fargo South ASR	$290,324				$44				$25	$173,588	$530,594	$50,213	$254,490	$1,008,954
TOTALS					$14,820	$3,626	$97,121	$0	$310,979	$957,533	$3,930,709	$598,705	$787,530	***$7,481,024***

SCENARIO 2:

	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$389,220	$389,992
Minnesota Groundwater and Pipeline	$60,051,600		$15,585,570		$9,008	$0	$77,928	$0	$3,677	$489,853	$2,022,695	$609,072		$3,212,232
Moorhead ASR										$12,175	$54,827	$6,947	$58,500	$132,448
Moorhead Peak Day - Expanded Use of Buffalo Aquifer										$16,288	$54,827	$9,420		$80,535
New Groundwater to Serve Industries	$19,678,322		$3,596,670		$2,952		$17,983		$304,390	$128,478	$400,414	$88,119		$942,336
Peak Day Water Demand using Storage		$28,925,600				$4,339					$54,827			$59,166
Purchase Elk Valley Aquifer Water Rights	$23,697,554		$5,994,450		$3,555		$29,972		$2,362	$153,379	$649,074	$39,252		$877,593
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$30,504		$37,935
Water Conservation														$780,000
West Fargo North ASR	$6,096,802				$915				$525	$221,164	$530,594	$48,525	$459,080	$1,260,802
West Fargo South ASR	$290,324				$44				$25	$199,809	$530,594	$60,866	$304,390	$1,095,727
TOTALS					$17,270	$4,540	$133,087	$0	$310,979	$1,221,146	$4,297,849	$892,704	$1,211,190	***$8,868,765***

OPINION OF PROBABLE COST

Draft: 10/30/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 3
"Lake of the Woods"

"SUPPLY FEATURES"

Feature No.	Feature Name	Scenario 1	Scenario 2
3.1	LOW Intake and Raw Water Pump Station near Rocky Point	$ 6,869,000	$ 7,799,000
3.2	Pipeline - Rocky Point Pump Station to Warroad	$ 15,793,023	$ 19,722,782
3.3	Warroad Pump Station	$ 5,332,931	$ 8,008,076
3.4	Pipeline - Warroad to Grafton	$ 104,843,920	$ 133,857,474
3.5	Grafton Booster Pump	$ 4,759,135	$ 6,758,260
3.6	Pipeline - Grafton to G.F.	$ 36,304,008	$ 46,350,449
3.7	Pump Station - G.F. to Hillsboro	$ 3,662,171	$ 6,274,391
3.8	Pipeline - G.F. to Hillsboro	$ 36,548,354	$ 39,615,959
3.9	Hillsboro Booster Pump	$ 3,225,073	$ 4,990,582
3.10	Pipeline - Hillsboro to Fargo	$ 42,431,960	$ 50,454,772
3.11	Pump Station - Fargo to Wahpeton	$ 672,644	$ 1,065,622
3.12	Pipeline - Fargo to Wahpeton	$ 16,805,184	$ 20,222,777
3.13	Improvement of Red River Intake for Grafton	$ 1,550,572	$ 1,550,572
3.14	Improvements to the Moorhead and Buffalo Aquifers for Moorhead	$ 1,146,392	$ 1,708,392
3.15	ASR Moorhead	$ 688,970	$ 688,970
3.16	ASR West Fargo North Aquifer	$ 22,124,478	$ 22,124,478
3.17	ASR West Fargo South Aquifer	$ 20,166,538	$ 22,022,618
3.18	Elk Valley Aquifer Well System and Conveyance Pipeline	$ 31,870,476	$ 31,870,476
3.19	Storage Reservoirs in Northern Red River Valley	$ 12,000,000	$ 15,200,000
3.20	Electrical Infrastucture	$ 3,144,272	$ 3,144,272
3.21	CRWUD Interconnection with Fargo	$ 2,705,865	$ 2,705,865
3.22	SCADA control of main delivery pipeline system	$ 9,837,000	$ 9,837,000
	SUBTOTAL (Direct Costs)	**$ 382,482,000**	**$ 455,973,000**
	Contractor OH,&P (30%)	$ 114,745,000	$ 136,792,000
	Contractor Costs (15%)	$ 57,372,000	$ 68,396,000
	SUBTOTAL (Burdened Costs including mobilization)	**$ 554,599,000**	**$ 661,161,000**
	Unlisted Items (5% of Sub-total)	$ 27,730,000	$ 33,058,000
	CONTRACT COST	**$ 582,329,000**	**$ 694,219,000**
	Contingency (25% of Contract Cost)	$ 145,582,000	$ 173,555,000
	FIELD COST	**$ 727,911,000**	**$ 867,774,000**
	Non-Contract Costs (25% of Field Cost)	$ 181,978,000	$ 216,944,000
	Right of Way Acquisition Cost (click here)	$ 27,338,945	$ 27,861,361
	CONSTRUCTION COST (w/ROW)	**$ 937,228,000**	**$ 1,112,579,000**
	ANNUAL COSTS (click here)	**$ 7,773,848**	**$ 8,764,899**

OPINION OF PROBABLE COST
"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 3 "Lake of the Woods"

SCENARIO 1:

	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$169,660	$170,432
Lake of the Woods Pipeline	$448,958,165		$45,383,333		$67,344	$0	$226,917	$0	$25,289		$942,337	$2,189,757	$59,400	$3,511,043
Moorhead ASR										$12,175	$54,827	$6,528	$54,000	$127,529
Moorhead Peak Day - Expanded Use of Buffalo Aquifer										$5,594	$54,827	$4,600		$65,021
Pipeline to Serve Industries in SE North Dakota	$31,980,266		$1,280,041		$4,797		$6,400		$4,558			$30,918		$46,673
Peak Day Water Demand using Storage		$22,836,000				$3,425					$54,827			$58,252
Purchase Elk Valley Aquifer Water Rights	$23,697,554		$5,994,450		$3,555		$29,972		$2,362	$153,379	$649,074	$36,448		$874,789
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$22,362		$29,793
Water Conservation														$780,000
West Fargo North ASR	$6,096,802				$915				$525	$221,164	$530,594	$38,786	$309,380	$1,101,363
West Fargo South ASR	$290,324				$44				$25	$173,588	$530,594	$50,213	$254,490	$1,008,954
TOTALS					$77,452	$3,626	$270,493	$0	$32,758	$565,900	$2,817,078	$2,379,612	$846,930	***$7,773,848***

SCENARIO 2:

	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$389,220	$389,992
Lake of the Woods Pipeline	$551,872,733		$64,379,078		$82,781	$0	$321,895	$0	$25,289		$942,337	$2,541,056	$66,300	$3,979,658
Moorhead ASR										$12,175	$54,827	$6,947	$58,500	$132,448
Moorhead Peak Day - Expanded Use of Buffalo Aquifer										$16,288	$54,827	$9,420		$80,535
Pipeline to Serve Industries in SE North Dakota	$38,483,945		$2,027,878		$5,773		$10,139		$4,558			$50,574		$71,044
Peak Day Water Demand using Storage		$28,925,600				$4,339					$54,827			$59,166
Purchase Elk Valley Aquifer Water Rights	$23,697,554		$5,994,450		$3,555		$29,972		$2,362	$153,379	$649,074	$39,252		$877,593
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$30,504		$37,935
Water Conservation														$780,000
West Fargo North ASR	$6,096,802				$915				$525	$221,164	$530,594	$48,525	$459,080	$1,260,802
West Fargo South ASR	$290,324				$44				$25	$199,809	$530,594	$60,866	$304,390	$1,095,727
TOTALS					$93,864	$4,540	$369,211	$0	$32,758	$602,815	$2,817,078	$2,787,144	$1,277,490	***$8,764,899***

OPINION OF PROBABLE COST

Draft: 10/30/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 4
"GDU Import to Sheyenne River"

"SUPPLY FEATURES"

Feature No.	Feature Name	Scenario 1	Scenario 2
4.1	GDU - Assigned Costs Related to Principal Supply Works	$ 2,374,597	$ 3,715,096
4.2	McClusky Canal Intake, Screens and Pump Station	$ 4,169,626	$ 4,909,426
4.3	Biota Treatment Plant for Sheyenne River Discharge	$ 9,907,657	$ 15,397,800
4.4	BiotaTreated Water Primary Pump Station Near Hoffer Lake	Included in 4.3 costs above	
4.5	Pipeline - Hoffer Lake Pump Station to Goodrich Resevoir	$ 10,119,049	$ 12,032,306
4.6	Goodrich Resevoir	$ 1,335,629	$ 2,089,613
4.7	Pipeline - Goodrich Resevoir to PRV Station E. of Bowden	$ 31,120,916	$ 44,814,175
4.8	PRV Station E. of Bowden	$ 620,000	$ 970,000
4.9	Pipeline - PRV Station E. of Bowden to Lake Ashtabula	$ 89,016,239	$ 123,459,327
4.10	Discharge Structure Lake Ashtabula	$ 242,378	$ 374,456
4.11	Pump Station - Fargo to Wahpeton	$ 601,040	$ 1,065,622
4.12	Pipeline - Fargo to Wahpeton	$ 16,803,571	$ 20,220,836
4.13	Pump Station - G.F. to G.F. Trail Booster	$ 185,640	$ 265,200
4.14	Pipeline - G.F. to G.F. Trail Booster	$ 1,663,787	$ 1,960,601
4.15	G.F. Trail Booster	$ 185,640	$ 265,200
4.16	Pipeline - G.F. Trail Booster to G.F. Trail Rural Water Users	$ 1,106,758	$ 1,304,200
4.17	Improvement of Red River Intake for Grafton	$ 1,550,572	$ 1,550,572
4.18	Electrical Infrastucture	$ 295,984	$ 295,984
4.19	CRWUD Interconnection with Fargo	$ 2,705,865	$ 2,705,865
4.20	SCADA control of main delivery pipeline system	$ 6,698,000	$ 6,698,000
	SUBTOTAL (Direct Costs)	**$ 180,703,000**	**$ 244,094,000**
	Contractor OH,&P (30%)	$ 54,211,000	$ 73,228,000
	Contractor Costs (15%)	$ 27,105,000	$ 36,614,000
	SUBTOTAL (Burdened Costs including mobilization)	**$ 262,019,000**	**$ 353,936,000**
	Unlisted Items (5% of Sub-total)	$ 13,101,000	$ 17,697,000
	CONTRACT COST	**$ 275,120,000**	**$ 371,633,000**
	Contingency (25% of Contract Cost)	$ 68,780,000	$ 92,908,000
	FIELD COST	**$ 343,900,000**	**$ 464,541,000**
	Non-Contract Costs (25% of Field Cost)	$ 85,975,000	$ 116,135,000
	Right of Way Acquisition Cost (click here)	$ 4,177,353	$ 4,325,805
	CONSTRUCTION COST (w/ROW)	**$ 434,052,000**	**$ 585,002,000**
	ANNUAL COSTS (click here)	**$ 3,819,050**	**$ 4,978,178**

OPINION OF PROBABLE COST
"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 4 "GDU Import to Sheyenne River"

SCENARIO 1:

	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
Biota WTP														$1,588,154
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$169,660	$170,432
GDU - Assigned Costs Related to Principal Supply Works														$70,122
GFTWD Interconnection with Grand Forks	$5,272,346		$706,546		$791		$3,533					$19,533	$114,770	$138,627
McClusky Canal to Lake Ashtabula Pipeline	$247,877,558	$2,541,702		$1,179,860	$37,182	$381		$5,899	12,847		$942,337			$998,646
Pipeline to serve Industries in Southeastern North Dakota	$31,977,196		$601,040		$4,797		$3,005		4,557			$30,918		$43,277
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$22,362		$29,793
Water Conservation														$780,000
TOTALS					$43,567	$582	$13,742	$5,899	$17,404	$0	$942,337	$72,813	$284,430	***$3,819,050***

SCENARIO 2:

	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
Biota WTP														$2,262,525
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$389,220	$389,992
GDU - Assigned Costs Related to Principal Supply Works														$109,707
GFTWD Interconnection with Grand Forks	$6,212,917		$1,009,351		$932		$5,047					$29,891	$279,440	$315,309
McClusky Canal to Lake Ashtabula Pipeline	$343,121,952	$3,976,533		$1,845,910	$51,468	$596		$9,230	$12,847		$942,337			$1,016,478
Pipeline to serve Industries in Southeastern North Dakota	$38,480,251		$1,065,622		$5,772		$5,328		$4,557			$50,574		$66,231
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$30,504		$37,935
Water Conservation														$780,000
TOTALS					$58,970	$797	$17,579	$9,230	$17,404	$0	$942,337	$110,969	$668,660	***$4,978,178***

OPINION OF PROBABLE COST

Draft: 10/30/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 5
"GDU Import Pipeline"

"SUPPLY FEATURES"

Feature No.	Feature Name	Scenario 1		Scenario 2	
5.1	GDU - Assigned Costs Related to Principal Supply Works	$	6,127,993	$	7,736,591
5.2	McClusky Canal Intake, Screens and Pump Station	$	6,861,808	$	7,674,448
5.3	Biota Treatment Plant	$	25,304,742	$	31,763,977
5.4	BiotaTreated Water Primary Pump Station Near Hoffer Lake	Included in 5.3 costs above			
5.5	Pipeline - Hoffer Lake Pump Station to Goodrich Resevoir	$	18,890,752	$	23,727,981
5.6	Goodrich Resevoir	$	3,446,784	$	4,351,565
5.7	Pipeline - Goodrich Resevoir to PRV Station E. of Bowden	$	51,519,445	$	64,711,686
5.8	PRV Station E. of Bowden	$	1,600,000	$	2,020,000
5.9	Pipeline - PRV Station E. of Bowden to Resevoir E. of Cooperstown	$	174,990,981	$	204,453,681
5.10	Resevoir E. of Cooperstown	$	3,446,784	$	4,351,565
5.11	Pipeline - Resevoir E. of Cooperstown to PRV Near Hope	$	15,321,543	$	19,244,829
5.12	PRV Station near Hope	$	1,600,000	$	2,020,000
5.13	Pipeline - PRV near Hope to Hillsboro Tee	$	43,463,164	$	54,592,487
5.14	Pipeline - Hillsboro Tee to PRV near Reynolds	$	13,897,708	$	13,897,708
5.15	PRV Station near Reynolds	$	534,000	$	567,000
5.16	Pipeline - Reynolds PRV to Grand Forks	$	15,621,152	$	15,685,245
5.17	Pipeline - East Grand Forks	$	1,236,618	$	1,435,946
5.18	Pipeline - Hillsboro Tee to Pump Station N. of Fargo/Moorhead	$	27,868,049	$	29,909,440
5.19	Pump Station N. of Fargo/Moorhead	$	4,254,290	$	6,506,634
5.20	Pipeline - Pump Station to Fargo	$	49,672,894	$	52,724,964
5.21	Pump Station - Fargo to Wahpeton	$	601,040	$	1,065,622
5.22	Pipeline - Fargo to Wahpeton	$	16,808,180	$	20,226,382
5.23	Pump Station - G.F. to G.F. Trail Booster	$	185,640	$	265,200
5.24	Pipeline - G.F. to G.F. Trail Booster	$	1,663,787	$	1,960,601
5.25	G.F. Trail Booster	$	185,640	$	265,200
5.26	Pipeline - G.F. Trail Booster to G.F. Trail Rural Water Users	$	1,106,758	$	1,304,200
5.27	Improvement of Red River Intake for Grafton	$	1,550,572	$	1,550,572
5.28	Electrical Infrastucture	$	995,006	$	995,006
5.29	CRWUD Interconnection with Fargo	$	2,705,865	$	2,705,865
5.30	SCADA control of main delivery pipeline system	$	9,936,000	$	9,936,000
	SUBTOTAL (Direct Costs)	**$**	**501,397,000**	**$**	**587,650,000**
	Contractor OH,&P (30%)	$	150,419,000	$	176,295,000
	Contractor Costs (15%)	$	75,210,000	$	88,148,000
	SUBTOTAL (Burdened Costs including mobilization)	**$**	**727,026,000**	**$**	**852,093,000**
	Unlisted Items (5% of Sub-total)	$	36,351,000	$	42,605,000
	CONTRACT COST	**$**	**763,377,000**	**$**	**894,698,000**
	Contingency (25% of Contract Cost)	$	190,844,000	$	223,675,000
	FIELD COST	**$**	**954,221,000**	**$**	**1,118,373,000**
	Non-Contract Costs (25% of Field Cost)	$	238,555,000	$	279,593,000
	Right of Way Acquisition Cost (click here)	$	9,471,684	$	9,755,397
	CONSTRUCTION COST (w/ROW)	**$**	**1,202,248,000**	**$**	**1,407,721,000**
	ANNUAL COST (click here)	**$**	**5,329,890**	**$**	**6,309,599**

OPINION OF PROBABLE COST
"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 5 "GDU Import Pipeline"

SCENARIO 1:

	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
Biota WTP														$2,465,000
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$169,660	$170,432
GDU - Assigned Costs Related to Principal Supply Works														$180,960
GFTWD Interconnection with Grand Forks	$5,272,346		$706,546		$791		$3,533					$19,533	$114,770	$138,627
McClusky Canal to Fargo and Grand Forks Pipeline	$784,953,830	$13,118,460	$8,095,914	$7,105,802	$117,743	$1,968	$40,480	$35,529	$24,931		$1,157,554	$143,596		$1,521,801
Pipeline to serve Industries in Southeastern North Dakota	$31,977,196		$601,040		$4,797		$3,005		$4,559			$30,918		$43,278
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$22,362		$29,793
Water Conservation														$780,000
TOTALS					$124,129	$2,169	$54,222	$35,529	$29,489	$0	$1,157,554	$216,409	$284,430	***$5,329,890***

SCENARIO 2:

	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
Biota WTP														$2,731,000
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$389,220	$389,992
GDU - Assigned Costs Related to Principal Supply Works														$228,462
GFTWD Interconnection with Grand Forks	$6,212,917		$1,009,351		$932		$5,047					$29,891	$279,440	$315,309
McClusky Canal to Fargo and Grand Forks Pipeline	$914,170,689	$16,562,056	$12,382,124	$8,767,121	$137,126	$2,484	$61,911	$43,836	$24,931		$1,157,554	$332,828		$1,760,669
Pipeline to serve Industries in Southeastern North Dakota	$38,480,251		$1,065,622		$5,772		$5,328		$4,559			$50,574		$66,233
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$30,504		$37,935
Water Conservation														$780,000
TOTALS					$144,628	$2,685	$79,490	$43,836	$29,489	$0	$1,157,554	$443,796	$668,660	***$6,309,599***

OPINION OF PROBABLE COST

Draft: 10/30/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 6
"Missouri River Import to Red River Valley"

"SUPPLY FEATURES"

Feature No.	Feature Name		Scenario 1		Scenario 2
6.1	Intake and Pump Station for Missouri River	$	7,549,660	$	10,984,908
6.2	Biota Treatment Plant	$	7,209,501	$	10,165,422
6.3	Pump Station Near Bismarck		Included in 6.2 above		
6.4	Pipeline - Bismarck Pump Station to Sterling Pump Station/Reservoir	$	16,085,914	$	20,716,052
6.5	Pump Station/Reservoir Near Sterling	$	3,543,072	$	5,361,621
6.6	Pipeline - Sterling Pump Station/Reservoir to Cleveland Reservoir	$	57,929,209	$	63,244,502
6.7	Reservoir Near Cleveland	$	947,866	$	1,357,171
6.8	Pipeline - Reservoir Near Cleveland to PRV Near Jamestown	$	7,020,613	$	8,486,860
6.9	PRV Near Jamestown	$	440,000	$	630,000
6.10	Pipeline - PRV Near Jamestown to Reservoir S.E of Valley City	$	41,161,963	$	49,169,719
6.11	Reservoir S.E of Valley City	$	947,866	$	1,357,171
6.12	Pipeline - Reservoir S.E. Valley City to PRV Near Oriska	$	4,343,331	$	5,024,470
6.13	PRV Near Oriska	$	440,000	$	630,000
6.14	Pipeline - PRV Near Oriska to Fargo/Grand Forks Tee	$	24,311,475	$	28,162,007
6.15	Pipeline - Fargo/Grand Forks Tee to Fargo	$	8,311,446	$	10,180,580
6.16	Pipeline - Fargo/Grand Forks Tee to Booster Pump Near Arthur	$	9,660,781	$	9,660,781
6.17	Booster Pump Near Arthur	$	1,508,747	$	1,508,747
6.18	Pipeline - Booster Pump near Arthur to Grand Forks	$	31,211,945	$	31,211,945
6.19	Pipeline - Lake Ashtabula Feeder	$	7,616,714	$	9,329,611
6.20	Discharge Structure Lake Ashtabula	$	100,000	$	171,000
6.21	Improvement of Red River Intake for Grafton	$	1,550,572	$	1,550,572
6.22	Improvements to the Moorhead and Buffalo Aquifers for Moorhead	$	1,146,392	$	1,708,392
6.23	ASR Moorhead	$	688,970	$	688,970
6.24	ASR West Fargo North Aquifer	$	22,124,478	$	22,124,478
6.25	ASR West Fargo South Aquifer	$	20,166,538	$	22,022,618
6.26	SE Aquifer Well System and Conveyance Pipeline for SE Industrial Needs	$	23,303,006	$	38,665,281
6.27	Elk Valley Aquifer Well System and Conveyance Pipeline	$	31,870,476	$	31,870,476
6.28	Storage Reservoirs in Northern Red River Valley	$	12,000,000	$	15,200,000
6.29	Electrical Infrastucture	$	645,250	$	645,250
6.30	CRWUD Interconnection with Fargo	$	2,705,865	$	2,705,865
6.31	SCADA control of main delivery pipeline system	$	9,593,000	$	9,593,000
	SUBTOTAL (Direct Costs)	**$**	**356,135,000**	**$**	**414,127,000**
	Contractor OH,&P (30%)	$	106,841,000	$	124,238,000
	Contractor Costs (15%)	$	53,420,000	$	62,119,000
	SUBTOTAL (Burdened Costs including mobilization)	**$**	**516,396,000**	**$**	**600,484,000**
	Unlisted Items (5% of Sub-total)	$	25,820,000	$	30,024,000
	CONTRACT COST	**$**	**542,216,000**	**$**	**630,508,000**
	Contingency (25% of Contract Cost)	$	135,554,000	$	157,627,000
	FIELD COST	**$**	**677,770,000**	**$**	**788,135,000**
	Non-Contract Costs (25% of Field Cost)	$	169,443,000	$	197,034,000
	Right of Way Acquisition Cost (click here)	$	28,164,854	$	28,781,965
	CONSTRUCTION COST (w/ROW)	**$**	**875,378,000**	**$**	**1,013,951,000**
	ANNUAL COSTS (click here)	**$**	**9,897,122**	**$**	**10,990,870**

OPINION OF PROBABLE COST
"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 6 "Missouri River Import to Red River Valley"

SCENARIO 1:

Features	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
Biota WTP														$2,500,000
Bismarck to Fargo Pipeline	$395,164,400	$3,607,576	$9,613,611	$1,674,640	$59,275	$541	$48,068	$8,373	$28,726		$1,157,554	$1,022,140		$2,324,677
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$169,660	$170,432
Moorhead ASR										$12,175	$54,827	$6,528	$54,000	$127,529
Moorhead Peak Day - Expanded Use of Buffalo Aquifer										$5,594	$54,827	$4,600		$65,021
New Groundwater to Serve Industries	$19,678,322		$2,397,780		$2,952		$11,989		$304,390	$84,047	$400,414	$52,521		$856,312
Peak Day Water Demand using Storage		$22,836,000				$3,425					$54,827			$58,252
Purchase Elk Valley Aquifer Water Rights	$23,697,554		$5,994,450		$3,555		$29,972		$2,362	$153,379	$649,074	$36,448		$874,789
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$22,362		$29,793
Water Conservation														$780,000
West Fargo North ASR	$6,096,802				$915				$525	$221,164	$530,594	$38,786	$309,380	$1,101,363
West Fargo South ASR	$290,324				$44				$25	$173,588	$530,594	$50,213	$254,490	$1,008,954
TOTALS					$67,537	$4,167	$97,233	$8,373	$336,027	$649,947	$3,432,709	$1,233,598	$787,530	***$9,897,122***

SCENARIO 2:

Features	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
Biota WTP														$2,842,000
Bismarck to Fargo Pipeline	$447,559,961	$5,165,394	$13,074,310	$2,397,780	$67,134	$775	$65,372	$11,989	$28,726		$1,157,554	$1,160,787		$2,492,336
CRWUD Interconnection with Fargo	$3,810,453	$1,338,808			$572	$201							$389,220	$389,992
Moorhead ASR										$12,175	$54,827	$6,947	$58,500	$132,448
Moorhead Peak Day - Expanded Use of Buffalo Aquifer										$16,288	$54,827	$9,420		$80,535
New Groundwater to Serve Industries	$19,678,322		$3,596,670		$2,952		$17,983		$304,390	$128,478	$400,414	$88,119		$942,336
Peak Day Water Demand using Storage		$28,925,600				$4,339					$54,827			$59,166
Purchase Elk Valley Aquifer Water Rights	$23,697,554		$5,994,450		$3,555		$29,972		$2,362	$153,379	$649,074	$39,252		$877,593
Relocation of Grafton River Intake	$1,509,935		$1,440,803		$226		$7,204					$30,504		$37,935
Water Conservation														$780,000
West Fargo North ASR	$6,096,802				$915				$525	$221,164	$530,594	$48,525	$459,080	$1,260,802
West Fargo South ASR	$290,324				$44				$25	$199,809	$530,594	$60,866	$304,390	$1,095,727
TOTALS					$75,397	$5,314	$120,531	$11,989	$336,027	$731,293	$3,432,709	$1,444,420	$1,211,190	***$10,990,870***

OPINION OF PROBABLE COST

Draft: 10/30/2005

"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 7
"GDU Water Supply Replacement Pipeline"

"SUPPLY FEATURES"

Feature No.	Feature Name		Scenario 1		Scenario 2
7.1	GDU - Assigned Costs Related to Principal Supply Works	$	13,060,284	$	15,741,281
7.2	McClusky Canal Intake, Screens and Pump Station	$	10,762,895	$	12,217,413
7.3	SDWA Compliant Water Treatment Plant with Softening	$	121,352,143	$	143,578,482
7.4	Treated Water (SDWA compliant) Primary Pump Station Near Hoffer Lake		Included in 7.3 costs above		
7.5	Pipeline - Hoffer Lake Pump Station to Goodrich Resevoir	$	27,712,108	$	31,215,208
7.6	Goodrich Resevoir	$	7,353,283	$	8,841,001
7.7	Pipeline - Goodrich Resevoir to PRV Station E. of Bowden	$	78,282,647	$	89,473,774
7.8	PRV Station E. of Bowden	$	3,413,400	$	4,104,000
7.9	Pipeline - PRV Station E. of Bowden to Resevoir E. of Cooperstown	$	289,007,892	$	318,958,060
7.10	Resevoir E. of Cooperstown	$	7,220,582	$	8,664,353
7.11	Pipeline - Resevoir E. of Cooperstown to PRV Near Hope	$	30,154,459	$	34,052,464
7.12	PRV Station near Hope	$	2,098,700	$	2,550,000
7.13	Pipeline - PRV near Hope to Buffalo Reservoir	$	54,242,838	$	61,945,626
7.14	Buffalo Reservoir	$	4,499,130	$	5,465,953
7.15	Pipeline - Buffalo Reservoir to Fargo	$	65,436,496	$	78,353,392
7.16	Pipeline - Cass Rural Water Phase 1	$	711,251	$	838,136
7.17	Pipeline - Moorhead	$	11,396,147	$	11,846,261
7.18	Pipeline - Fargo/G.F. Tee to PRV SW of Larimore	$	44,365,522	$	45,656,973
7.19	PRV SW of Larimore	$	957,800	$	1,124,000
7.20	Pipeline - PRV SW of Larimore to Reservoir near G.F. Trail Rural Water	$	10,103,803	$	10,570,531
7.21	Reservoir near G.F. Trail Rural Water	$	1,960,358	$	2,295,343
7.22	Pipeline - Reservoir near G.F. Trail Rural Water to G.F.	$	23,274,205	$	28,631,262
7.23	Pipeline - East Grand Forks	$	2,483,351	$	3,117,302
7.24	Pump Station at Buffalo	$	2,001,730	$	2,458,018
7.25	Pipeline - Pump Station at Buffalo to Enderlin	$	16,137,503	$	16,995,056
7.26	Pipeline - Enderlin to Whapeton	$	35,749,293	$	39,149,159
7.27	Pipeline - Whapeton to Breckenridge	$	2,964,513	$	3,248,891
7.28	Pipeline - Enderlin to Lisbon	$	1,677,474	$	1,677,474
7.29	Pump Station at Lisbon	$	26,255	$	50,097
7.30	Pipeline - Lisbon to Gwinner	$	1,620,974	$	1,620,974
7.31	Pipeline - Tee NW of Northwood to Larimore PRV	$	2,794,658	$	2,941,772
7.32	Larimore PRV	$	220,000	$	260,000
7.33	Pipeline - Larimore PRV to Inkster Reservoir	$	10,912,235	$	12,245,367
7.34	Inkster Reservoir	$	277,466	$	302,455
7.35	Pipeline - Inkster Reservoir to Grafton	$	11,312,136	$	13,612,633
7.36	Pump Station West of Inkster	$	411,289	$	582,669
7.37	Pipeline - Pump Station West of Inkster to Walsh Rural Water	$	2,085,567	$	2,421,735
7.38	Pipeline - Larimore PRV to Larimore	$	453,580	$	453,580
7.39	Pipeline - Tee West of Cooperstown to Valley City/Barnes Rural Water Tee	$	6,757,988	$	9,657,504
7.40	Pipeline - Valley City/Barnes Rural Water Tee to Valley City	$	1,686,543	$	1,978,942
7.41	Pipeline - Valley City/Barnes Rural Water Tee to Barnes Rural Water	$	1,582,765	$	2,188,486
7.42	Pipeline - Tee (2) West of Cooperstown to Dakota Rural Water (North)	$	1,147,398	$	938,780
7.43	Pipeline - Fargo/G.F. Tee to Trail Rural Water	$	2,961,652	$	2,961,652
7.44	PRV North of Hope	$	74,800	$	86,900
7.45	PRV for Dakota RW North	$	7,900	$	6,000
7.46	PRV for Valley City Supply	$	53,700	$	75,700
7.47	Electrical Infrastucture	$	235,083	$	235,083
7.48	SCADA control of main delivery pipeline system	$	16,310,000	$	16,310,000
	SUBTOTAL (Direct Costs)	**$**	**929,312,000**	**$**	**1,051,700,000**
	Contractor OH,&P (30%)	$	278,794,000	$	315,510,000
	Contractor Costs (15%)	$	139,397,000	$	157,755,000
	SUBTOTAL (Burdened Costs including mobilization)	**$**	**1,347,503,000**	**$**	**1,524,965,000**
	Unlisted Items (5% of Sub-total)	$	67,375,000	$	76,248,000
	CONTRACT COST	**$**	**1,414,878,000**	**$**	**1,601,213,000**
	Contingency (25% of Contract Cost)	$	353,720,000	$	400,303,000
	FIELD COST	**$**	**1,768,598,000**	**$**	**2,001,516,000**
	Non-Contract Costs (25% of Field Cost)	$	442,150,000	$	500,379,000
	Right of Way Acquisition Cost (click here)	$	15,919,492	$	16,127,637
	CONSTRUCTION COST (w/ROW)	**$**	**2,226,667,000**	**$**	**2,518,023,000**
	ANNUAL COSTS (click here)	**$**	**25,434,896**	**$**	**31,674,350**

OPINION OF PROBABLE COST

"RED RIVER VALLEY WATER SUPPLY PROJECT"
Design Alternative 7 "GDU Water Supply Replacement Pipeline"

SCENARIO 1:

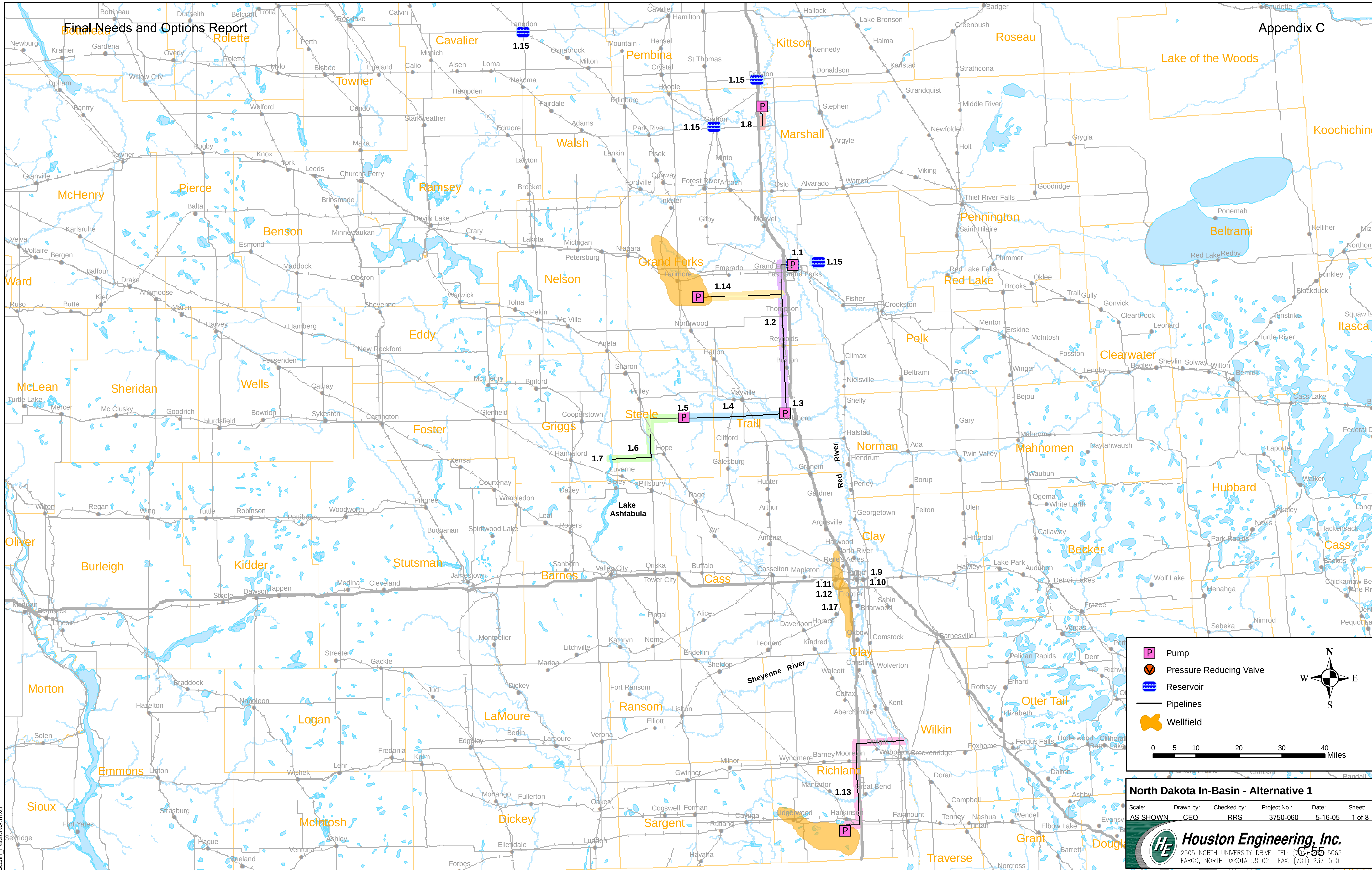
	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
Biota WTP														$22,395,000
GDU - Assigned Costs Related to Principal Supply Works														$385,671
Replacement Pipeline	$1,402,539,541	$40,554,489	$4,641,937	$12,990,449	$210,381	$6,083	$23,210	$64,952	$46,302		$1,322,037	$201,260		$1,874,225
Water Conservation														$780,000
TOTALS					$210,381	$6,083	$23,210	$64,952	$46,302	$0	$1,322,037	$201,260	$0	***$25,434,896***

SCENARIO 2:

	Field Cost				Annual Facility Cost						Annual Equipment & Labor	Annual Power	Annual Water Treatment	Total Annual OM&R
Features	Pipelines	Reservoirs	Pump Stations	PRVs	Pipelines	Reservoirs	Pump Stations	PRVs	Corrosion Protection	Wellfields				
Biota WTP														$28,445,000
GDU - Assigned Costs Related to Principal Supply Works														$464,841
Replacement Pipeline	$1,573,307,143	$48,658,008	$5,881,761	$15,617,160	$235,996	$7,299	$29,409	$78,086	$48,712		$1,322,037	$262,970		$1,984,509
Water Conservation														$780,000
TOTALS					$235,996	$7,299	$29,409	$78,086	$48,712	$0	$1,322,037	$262,970	$0	***$31,674,350***

Appendix C – Attachment 4

Option Drawings Showing Feature Numbers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Reservoir
Pipelines
Wellfield
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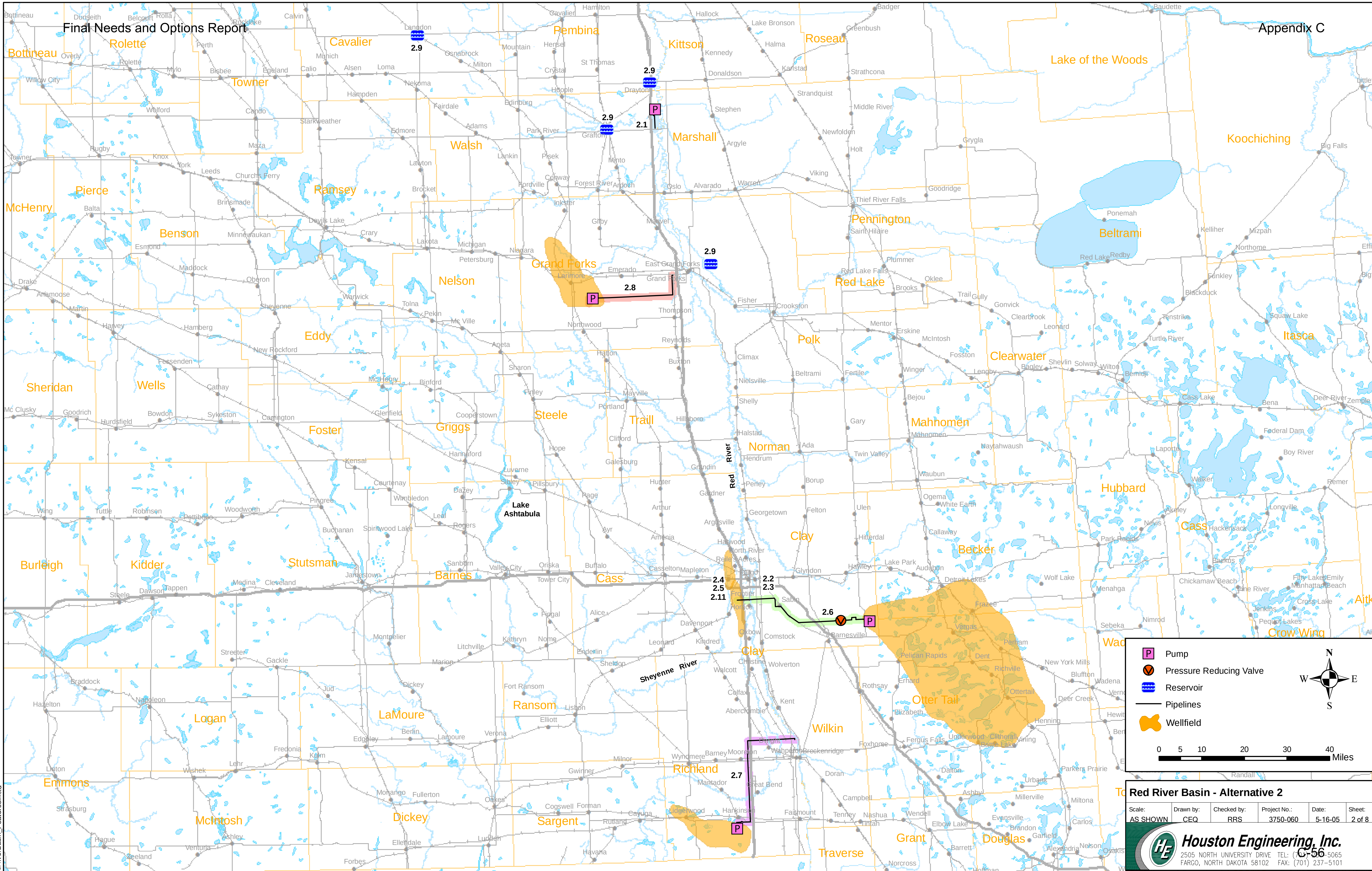
North Dakota In-Basin - Alternative 1
Scale: AS SHOWN
Drawn by: CEQ
Checked by: RRS
Project No.: 3750-060
Date: 5-16-05
Sheet: 1 of 8
Houston Engineering, Inc.
2505 NORTH UNIVERSITY DRIVE FARGO, NORTH DAKOTA 58102
TEL: (701) 237-5065 FAX: (701) 237-5101
Lake Ashtabula
Sheyenne River
Red River
INBasin_Features.mxd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Reservoir
Pipelines
Wellfield
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Miles
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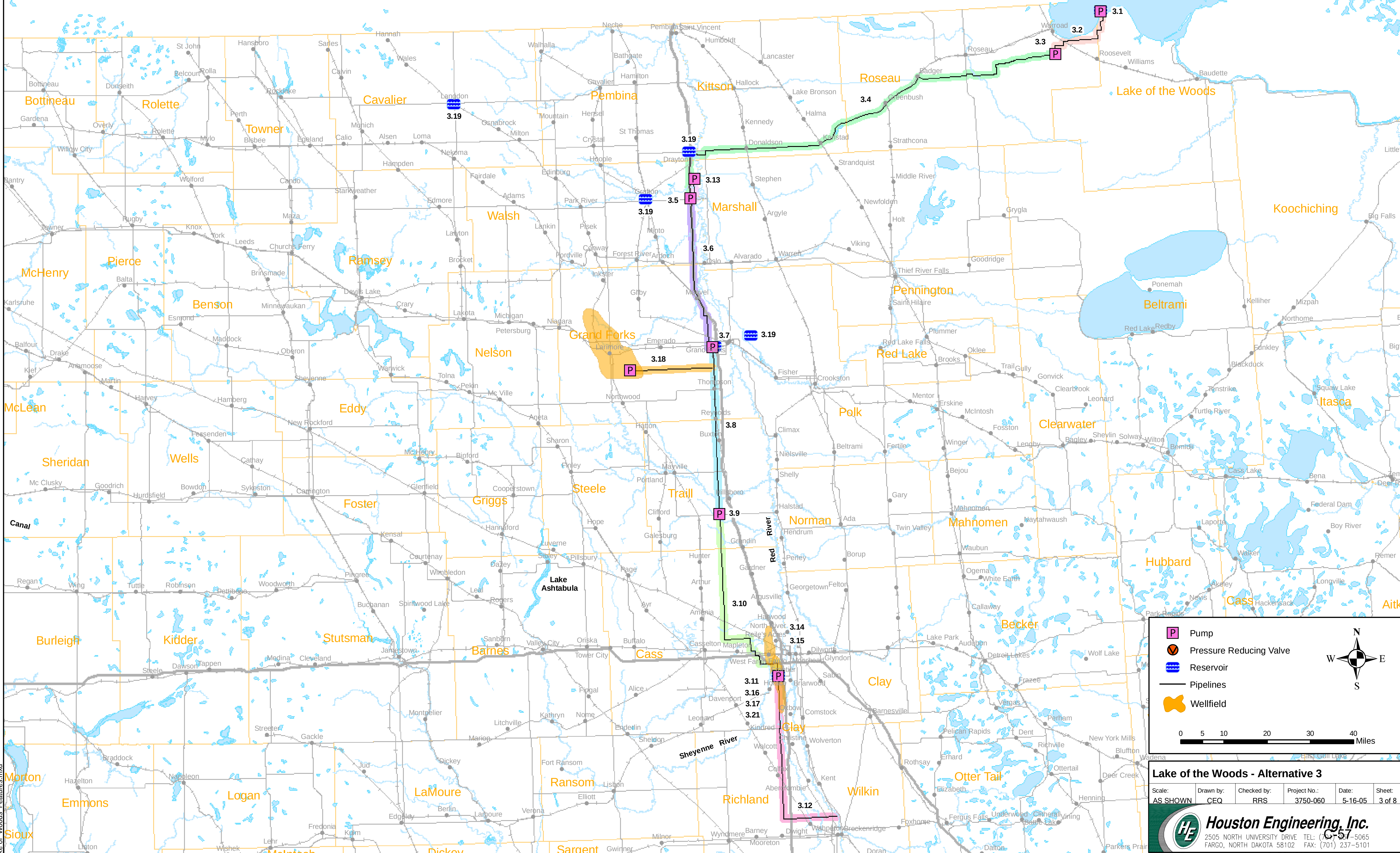
Scale: AS SHOWN
Drawn by: CEQ
Checked by: RRS
Project No.: 3750-060
Date: 5-16-05
Sheet: 2 of 8
Houston Engineering, Inc.
2505 NORTH UNIVERSITY DRIVE
FARGO, NORTH DAKOTA 58102
FAX: (701) 237-5101
Lake Ashtabula
Red River
Sheyenne River
RedRiverBasin_Features.mxd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3.1
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Roseau
Lake of the Woods
Kittson
Pembina
Cavalier
Bottineau
Rolette
Towner
Marshall
Walsh
Ramsey
Pierce
McHenry
Benson
Koochiching
Pennington
Beltrami
Grand Forks
Nelson
Red Lake
Polk
Eddy
McLean
Clearwater
Itasca
Sheridan
Wells
Foster
Griggs
Steele
Traill
Norman
Mahnomen
Hubbard
Cass
Becker
Clay
Aitkin
Burleigh
Kidder
Stutsman
Barnes
Wilkin
Otter Tail
Richland
Ransom
Sargent
LaMoure
Logan
Emmons
Morton
Sioux
McIntosh
Dickey
Lake Ashtabula
Red River
Sheyenne River
Canal
Pump
Pressure Reducing Valve
Reservoir
Pipelines
Wellfield
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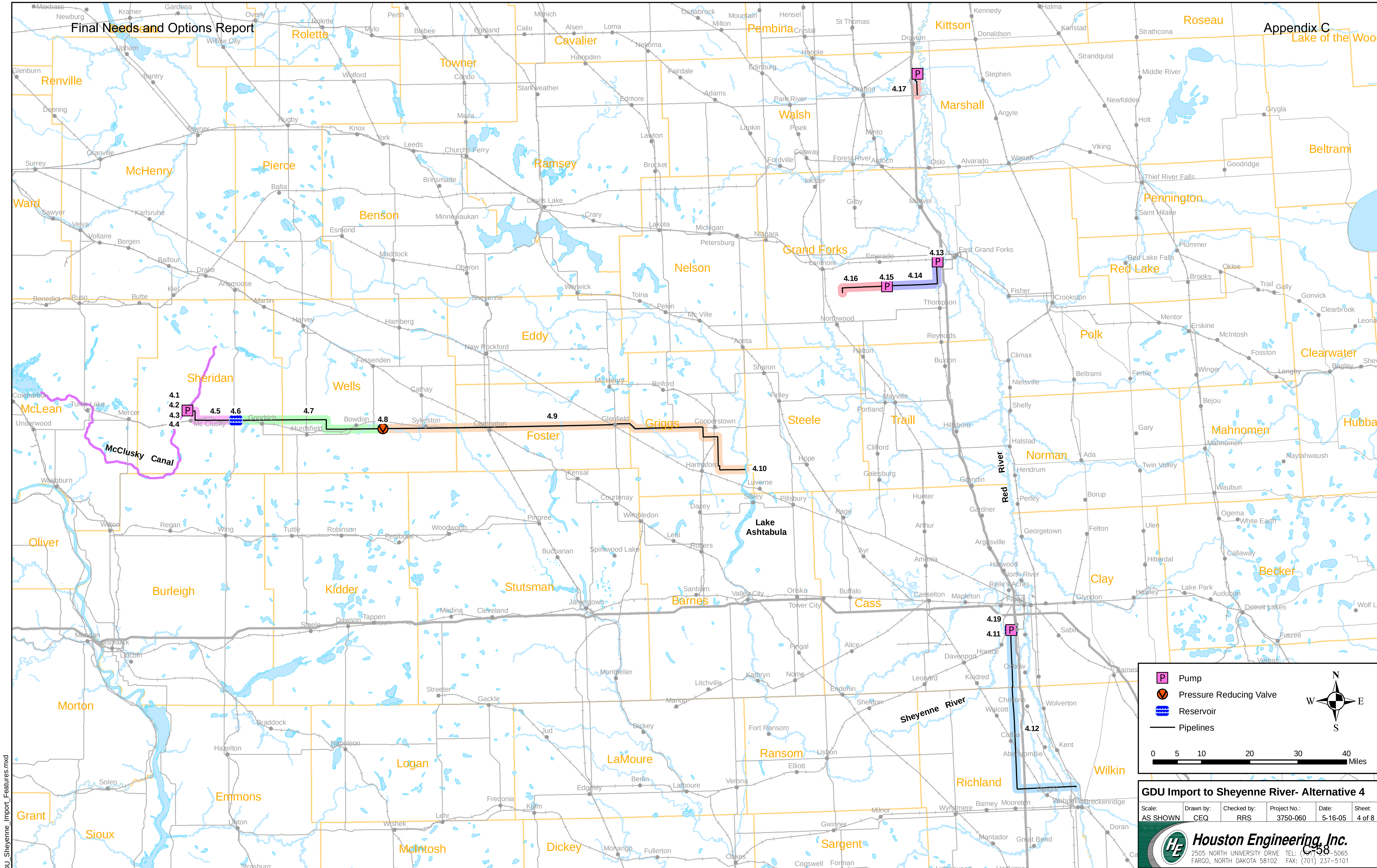
0 5 10 20 30 40 Miles
Lake of the Woods - Alternative 3
Scale: AS SHOWN
Drawn by: CEO
Checked by: RRS
Project No.: 3750-060
Date: 5-16-05
Sheet: 3 of 8
Houston Engineering, Inc.
2505 NORTH UNIVERSITY DRIVE
FARGO, NORTH DAKOTA 58102
TEL: (701) 237-5065
FAX: (701) 237-5101
Lake of Woods Features.mxd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Pressure Reducing Valve
Reservoir
Pipelines
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Drawn by: CEQ
Checked by: RRS
Project No.: 3750-060
Date: 5-16-05
Sheet: 4 of 8
Houston Engineering, Inc.
2505 NORTH UNIVERSITY DRIVE FARGO, NORTH DAKOTA 58102
TEL: (701) 237-5065 FAX: (701) 237-5101
C-58
GDU_Sheyenne_Import_Features.mxd
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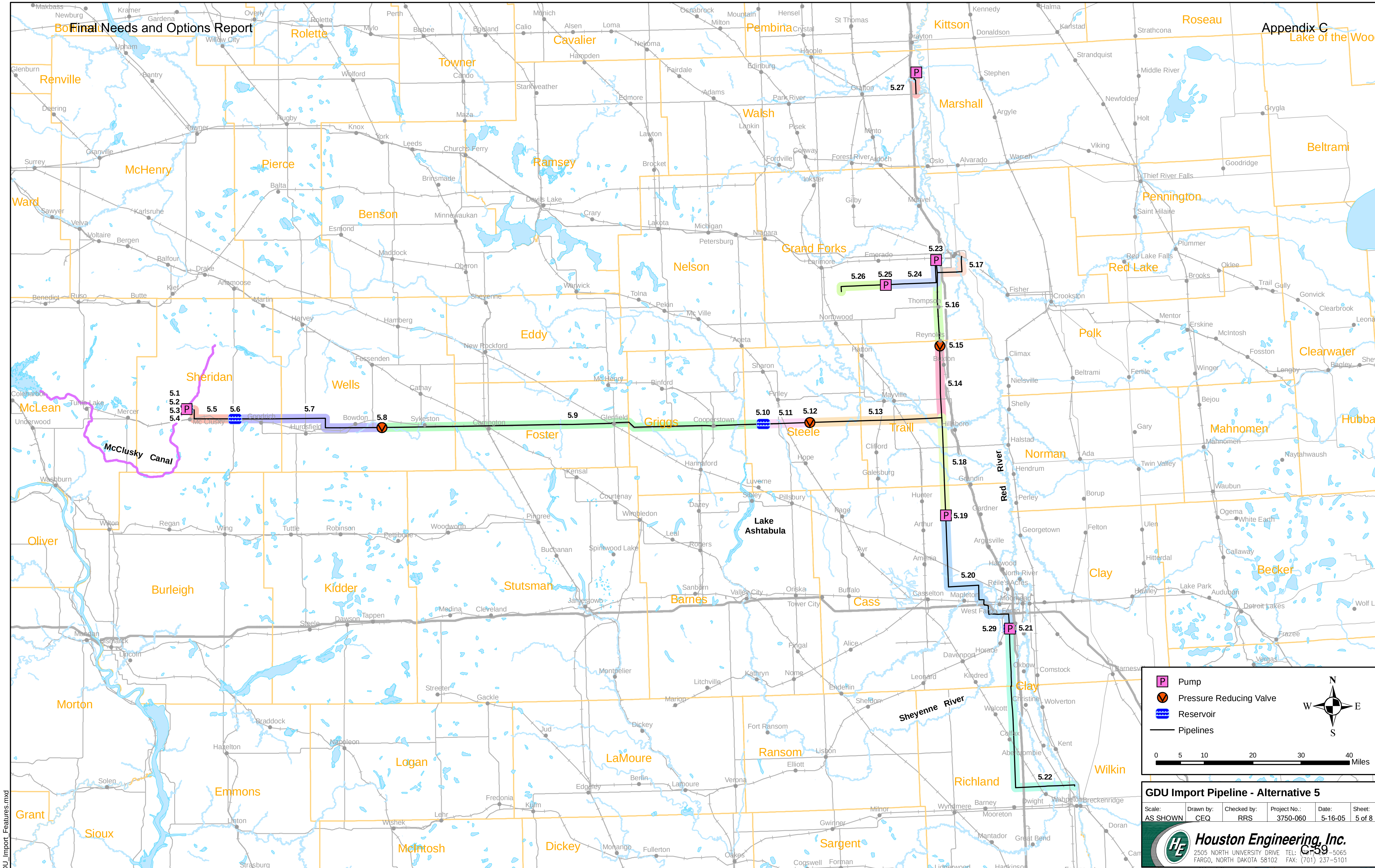
McClusky Canal
Lake Ashtabula
Red River
Sheyenne River
Renville
McHenry
Ward
McLean
Sheridan
Pierce
Rolette
Towner
Cavalier
Pembina
Kittson
Roseau
Lake of the Woods
Marshall
Walsh
Ramsey
Benson
Wells
Eddy
Nelson
Grand Forks
Pennington
Red Lake
Beltrami
Polk
Clearwater
Foster
Griggs
Steele
Traill
Norman
Mahnomen
Hubbard
Oliver
Burleigh
Kidder
Stutsman
Barnes
Cass
Clay
Becker
Morton
Logan
LaMoure
Ransom
Richland
Wilkin
Emmons
Grant
Sioux
McIntosh
Dickey
Sargent


McClusky Canal
Lake Ashtabula
Red River
Sheyenne River
Pump
Pressure Reducing Valve
Reservoir
Pipelines
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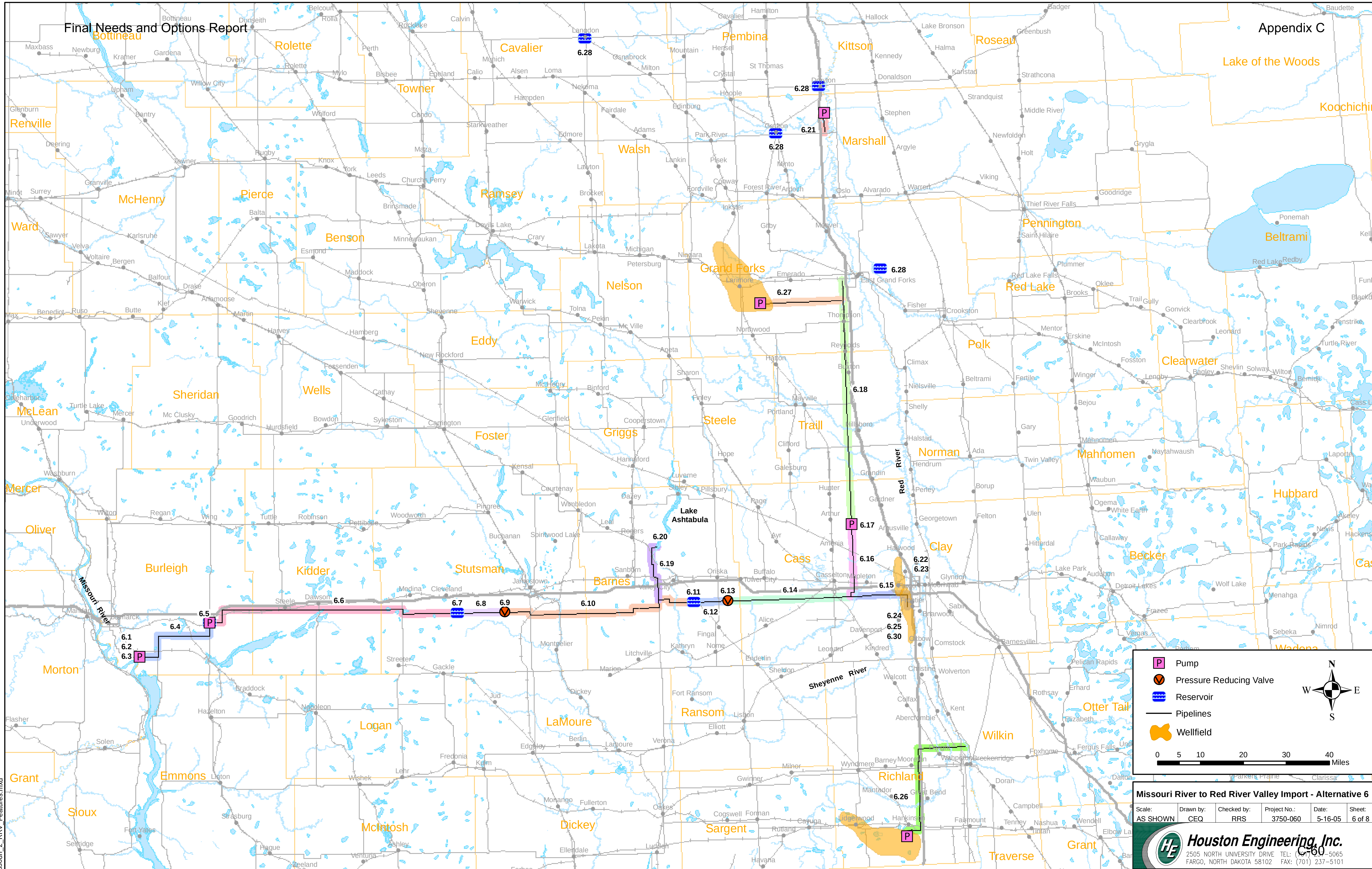
GDU Import Pipeline - Alternative 5
Scale: AS SHOWN
Drawn by: CEQ
Checked by: RRS
Project No.: 3750-060
Date: 5-16-05
Sheet: 5 of 8
Houston Engineering, Inc.
2505 NORTH UNIVERSITY DRIVE FARGO, NORTH DAKOTA 58102
FAX: (701) 237-5101
GDU_Import_Features.mxd


Missouri River to Red River Valley Import - Alternative 6
Pump
Pressure Reducing Valve
Reservoir
Pipelines
Wellfield
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0 5 10 20 30 40
Miles
Scale: AS SHOWN
Drawn by: CEQ
Checked by: RRS
Project No.: 3750-060
Date: 5-16-05
Sheet: 6 of 8
Houston Engineering, Inc.
2505 NORTH UNIVERSITY DRIVE
FARGO, NORTH DAKOTA 58102
Missouri River
Red River
Sheyenne River
Lake Ashtabula
Burleigh
Kidder
Stutsman
Barnes
Cass
Grand Forks
Traill
Richland
Clay
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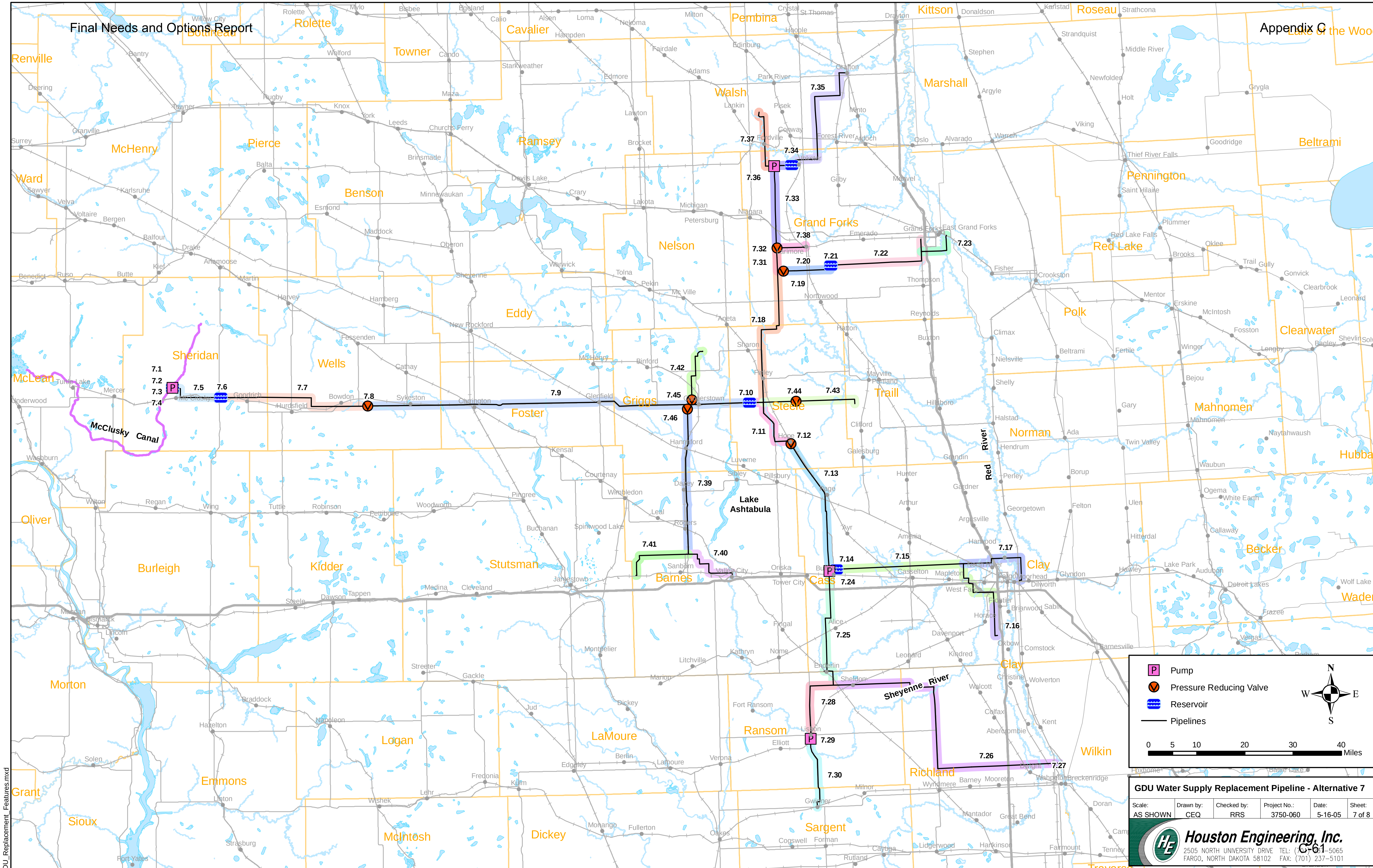
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Lake Ashtabula
Sheyenne River
Red River
Pump
Pressure Reducing Valve
Reservoir
Pipelines
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GDU Water Supply Replacement Pipeline - Alternative 7
Scale: AS SHOWN
Drawn by: CEQ
Checked by: RRS
Project No.: 3750-060
Date: 5-16-05
Sheet: 7 of 8
Houston Engineering, Inc.
2505 NORTH UNIVERSITY DRIVE FARGO, NORTH DAKOTA 58102
FAX: (701) 237-5101
GDU_Replacement_Features.mxd

Appendix C – Attachment 5

Groundwater Engineering Reports

T E C H N I C A L   M E M O R A N D U M

MWH

To:	Ed Cryer	**Date:**	May 13, 2005
From:	Pat Naylor	**Reference:**	1690583.011801
Subject:	Moorhead Expansion to Buffalo Aquifer Cost Opinion		

PURPOSE

A preliminary opinion of probable cost has been prepared pertaining to wells and wellsite equipment for expansion of the Moorhead groundwater supply to increase the production from the Buffalo Aquifer near Moorhead, Minnesota. The expanded well system would increase production capacity and would be for potable use by the City of Moorhead. This preliminary opinion of probable cost is very general and has been prepared to help determine whether the expanded wellfield would be an economically viable option.

PROPOSED PROJECT

Wellfield Capacity

Two wellfield expansion scenarios are proposed. Scenario #1 would increase existing production capacity from 6.0 cfs to 7.0 cfs, an increase of 1.0 cfs (449 gpm). Scenario #2 would increase production capacity to 8.3 cfs, an increase of 2.3 cfs (1,033 gpm). Production would supplement the Moorhead municipal supply.

Little information is available about the Buffalo Aquifer; it is assumed that the conditions are similar to those of the Moorhead Aquifer. Under these assumptions, the expanded wellfield system would include one new 500-gpm production well under Scenario #1 and three new 500-gpm production wells under Scenario #2. (It is assumed that 500 gpm represents maximum production capacity; therefore three wells are assumed for Scenario #2 even though two wells would provide most of the required production capacity.) Each new well would be about 260 feet deep. It is assumed that approximately five miles of pipeline would be required to convey flow from the new production well(s) to the Moorhead WTP. Because the well locations have not been previously defined, it is assumed that additional wells for Scenario #2 would be near the main pipeline proposed for Scenario #1, and the additional pipeline costs would be negligible.

COST OPINION

The costs shown have been prepared using various general sources of information, including preliminary (nonbinding) cost estimates from local contractors, cost estimating aids such as RS Means 2004 Cost Estimating Data, on-line equipment catalogs, on-line equipment quotes, and assumptions based on past experience.

The opinion of probable cost is based on assumptions that were made after reviewing information provided by the U.S. Bureau of Reclamation (unpublished groundwater data and unpublished memorandum**,** *Schlag, A.J., 2003, Aquifer Storage and Recovery Prospects for the Moorhead Aquifer*); by Houston Engineers; and by LTP Drilling; as well as from a report prepared by the North Dakota State Water Commission *(Ripley, D.P., 2000, The Water Resource Characteristics of the West Fargo Aquifer System: North Dakota Ground-Water Studies Number 106 – Part II, 233 pp).*

The assumptions developed for this cost opinion for the expansion of production in the Buffalo Aquifer include the following:

- Required increase in wellfield design capacity would be 1.0 cfs (450 gpm) under Scenario #1 and 2.3 cfs (1,030 gpm) under Scenario #2
- Static water level is roughly 100 ft but varies from place to place
- One new production well for Scenario #1 and three new production wells for Scenario #2
- New well screen average length would be 40 ft to allow for vertical aquifer anisotropy
- Average depth to the bottom of the aquifer is about 260 ft
- Average aquifer thickness is about 100 ft

From these assumptions and the information provided, it is estimated that a wellfield in the aquifer system would have the following design criteria:

- Average new well depth would be 260 ft, including 40 ft of screen and 10 ft of tailpipe below bottom of aquifer
- Screen would be stainless steel
- Well design production capacity would be 500 gpm each
- Average required head would be 300 ft per well
- Each well nominal diameter would be 12 inches
- Submersible pump in each production well would each be 60 horsepower and would require 460-V 3-phase power
- Each well would be housed in a new pump house
- Well pump system would be managed with a SCADA-type central control system and individual PLC
- Each new well lot would be approximately ¾ acre (200 ft x 200 ft) to allow for the wellhouse, security fence, minimum wellhead protection setback, and working space
- Each new well to be enclosed in a fenced area

- Pumping to the Moorhead water system would be accomplished using the pumps in each production well; no wellfield reservoir or pump station would be required.
- Approximately five miles of new wellfield pipeline would be required for both scenarios.

The opinion of probable cost does not include water quality testing, although it does include an automated sampler for some basic water quality parameters at the wellhead. It does not include costs for a centralized control system, but does include the local controls and telemetry from each wellhead capable of communicating with the SCADA controller. Because of the relatively small size of the system, no reservoirs are included in this cost opinion; these features are addressed by others.

The cost of each production well is preliminarily estimated to be about $198,000. The preliminary opinion of probable cost for this expanded wellfield is approximately $1.15 million for Scenario #1 and $1.7 million for Scenario #2. These are unburdened costs. The summary of costs for Scenario #1 and #2 are shown in Table 1 and Table 2, respectively. The estimated costs per production well are shown in Attachment 1.

TABLE 1

PRELIMINARY OPINION OF PROBABLE COST
MOORHEAD 1.0 CFS EXPANSION - BUFFALO AQUIFER SYSTEM

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Production Well	1	Each	$281,000	$281,000	See Attachment 1
10-inch PVC Pipe	26,400	Feet	$32.78	$865,392	Quote for RRVWSP Cost Analysis, doubled to allow for urban conditions
Subtotal (Direct Costs)				**$1,146,392**	
Contractor OH&P (30%)				$343,918	
Contractor Costs (15%)				$171,959	
SUBTOTAL (Burdened Costs including mobilization)				**$1,662,268**	
Unlisted Items (5% of Subtotal (Burdened))				$83,113	
CONTRACT COST				**$1,745,382**	
Contingency (25% of Contract Cost)				$436,345	
FIELD COST				**$2,181,727**	
Non-Contractor Costs (25% of Field Costs)				$545,432	
CONSTRUCTION COST (w/o ROW)				**$2,727,159**	

TABLE 2

PRELIMINARY OPINION OF PROBABLE COST
MOORHEAD 2.3 CFS EXPANSION - BUFFALO AQUIFER SYSTEM

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Production Well	3	Each	$281,000	$843,000	See Attachment 1
10-inch PVC Pipe	26,400	Feet	$32.78	$865,392	Quote for RRVWSP Cost Analysis, doubled to allow for urban conditions
Subtotal (Direct Costs)				**$1,708,392**	
Contractor OH&P (30%)				$512,518	
Contractor Costs (15%)				$256,259	
SUBTOTAL (Burdened Costs including mobilization)				**$2,477,168**	
Unlisted Items (5% of Subtotal (Burdened))				$123,858	
CONTRACT COST				**$2,601,027**	
Contingency (25% of Contract Cost)				$650,257	
FIELD COST				**$3,251,284**	
Non-Contractor Costs (25% of Field Costs)				$812,821	
CONSTRUCTION COST (w/o ROW)				**$4,064,104**	

ATTACHMENT 1
PRELIMINARY OPINION OF PROBABLE COST
MOORHEAD EXPANSION - BUFFALO AQUIFER
COSTS PER PRODUCTION WELL

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$54,710	Each	1	$54,710	Quote, see attached
Column Pipe (6")	$69	Lin. Ft.	220	$15,180	Means 15107.620.1410
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Outflow Meter with Totalizer	$9,050	Each	1	$9,050	Means 15120.940.1180
Sampling Port	$500	Each	1	$500	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Pump (60 hp Submersible)	$17,000	Each	1	$17,000	Assumed based on experience
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Pump House	$20,000	Each	1	$20,000	Assumed based on experience
Chain-Link Fence	$23	Lin. Ft.	800	$18,400	Means 02820.130.0800
Miscellaneous		Each	1	$18,024	10% of costs
TOTAL				**$198,264**	

TECHNICAL MEMORANDUM

MWH

To:	Ed Cryer	**Date:**	May 6, 2005
From:	Pat Naylor	**Reference:**	1690683.011801
Subject:	Elk Valley Aquifer Wellfield Discussion and Cost Opinion		

PURPOSE

A proposal is under consideration within the U.S. Bureau of Reclamation (USBR) for transferring groundwater from the Elk Valley Aquifer to the Grand Forks, ND area for municipal use. Groundwater from the aquifer currently is used by the Grand Forks – Traill Water Users, primarily for irrigation and rural water use. A general discussion of the concepts of this proposal was presented in an unpublished report by Schlag (2005).

This memorandum presents a preliminary evaluation of some of the technical issues costs of the wellfield proposal, as well as a preliminary opinion of probable cost. A discussion of the nontechnical issues, such as water right transfers, public input, environmental impacts, etc. is beyond the scope of this evaluation.

GEOLOGY AND HYDROGEOLOGY

The Elk Valley Aquifer is about 20 to 25 miles west of Grand Forks in the Lake Agassiz Plain. The general location is shown in Figure 1. The aquifer is part of the Elk Valley delta, a glacial outwash deposit resulting from glacial lake and meltwater runoff that flowed from north to south (Kelly and Paulson, 1970). The deltaic deposits include coarser sand and gravel material in the northern portion of the aquifer near the outwash source, with fine sands, silts, and clays in the southern part of the aquifer (Hansen and Kume, 1970). These fine sand deposits to the south, interbedded with silt and clay layers, constitute the aquifer in this area with a maximum combined thickness of up to 65 feet but average about 23 feet thick (Downey and Armstrong, 1977). The southern part of the aquifer typically produces low yields, generally less than 10 gpm (Jensen and Klausing, 1971; Bartelson and Goven, 1998). The northern part of the aquifer consists of sand and gravel interbedded with silt and clay, with production zones ranging from a few feet in thickness up to 61 feet, with an average thickness of about 34 feet. (Kelly and Paulson, 1970). Production capacity from wells in the central and northern portions of the aquifer may be up to 1,000 gpm but typically is about 250 gpm (Schlag, 2005). The static water level is approximately 10 feet below land surface. The total aquifer encompasses an area of about 210 square miles (Bartelson and Goven, 1998).

Water quality in the Elk Valley Aquifer is considered vulnerable and is known to have zones of water quality concern, particularly associated with pesticides and nitrates (NDDH, 1999). Water quality data for 88 samples collected from 83 wells in the late 1990s identified 13 samples in excess of 1 mg/L nitrate concentration, with four samples in excess of the Maximum Contaminant Level for drinking water of 10 mg/L. Sulfates, turbidity, and total dissolved solids also exceed drinking water standards in many wells. Because the aquifer is shallow, unconfined, and recharged directly from surface infiltration, and is located in an agricultural area, it is very susceptible to contamination from fertilizer nutrients such as nitrates, pesticides, fuel spills, and other contaminants.

The elevation of the ground surface in the vicinity of the Elk Valley Aquifer is approximately 1,100 to 1,150 feet above MSL. At Grand Forks, the proposed destination of the water to be transferred, the elevation is about 820 to 840 feet above MSL, a difference of approximately 300 feet on average.

PROPOSED PROJECT

Assumptions

The wellfield and collection system were developed using the following assumptions and information:

- Average depth to top of aquifer is less than 20 feet
- Average depth to bottom of aquifer is less than 60 feet
- Static water level is less than 10 feet below ground level
- Average design production capacity is 250 gpm per well
- Total wellfield production capacity would be 27.1 cfs (12,160 gpm) under Scenario #1 and 28.7 cfs (12,900 gpm) under Scenario #2. Because the difference is small, for cost opinion purposes only Scenario #2 is considered here
- 54 wells at 27 locations (Scenario #2; includes two backup wells), two wells at each of the 27 locations, spaced approximately 500 feet apart at each location (see Figure 2 for well locations; note that 31 well locations are shown rather than 27. It is not known which of the locations would be eliminated if the wellfield is developed, so all are shown. Only 27 locations were used for costing, and it was assumed that the four eliminated locations were lateral wells near the south (downstream) end of the collection pipeline)
- Well screen average length would be 20 feet

Preliminary Design Criteria

Using the assumptions and requirements identified, I estimated that the Elk Valley Aquifer wellfield system would have the following design criteria:

- 54 production wells at 27 locations, two wells per location
- Wells would be 500 feet apart at each location

- Average well depth would be 65 feet, including 20 ft of screen and 5 ft of tailpipe at bottom of well
- Screen would be stainless steel
- Average well production capacity would be 250 gpm
- Average required head would be 200 ft
- Each well nominal diameter would be 8 inches
- Submersible pump in each well would be 20 horsepower and would require 460-V 3-phase power
- Each well would have a flow meter
- Each well would be housed in an HVAC-regulated pump house
- Each pump system would be managed with an existing SCADA-type central control system and individual PLC
- Each well lot would be approximately ¾ acre (200 ft by 200 ft) to allow for the wellhouse, security fence, minimum wellhead protection setback, and working space
- One collection reservoir would be located just downstream of the last production well to facilitate variations in demand, to provide storage in the event of well or pump down time, and to maintain constant pressure
- Pumping to the reservoir would be accomplished using pumps in the individual wells
- Failed pump or similar equipment problems would take no more than 24 hours to repair or replace
- Reservoir would be designed to contain enough storage capacity to accommodate the production from about ten percent of the production wells (i.e. five total wells) out of service for 24 hours (at 250 gpm for five wells, reservoir would hold about 1.8 million gallons)
- Reservoir would be a buried concrete tank.

A pipeline to convey water from the wellfield reservoir to Grand Forks is not included in this evaluation. Downstream storage, treatment, and pump requirements also are not included.

OPINION OF PROBABLE COSTS

A preliminary opinion of probable costs for this project is shown in Table 1. These are unburdened costs. The summary of costs per well shown in Table 1 include both unburdened costs and an itemized opinion of burdened construction costs. These are "ballpark" costs for the wells, pipelines, reservoir, and pump station. It was assumed that 27 well locations would be used; of the 31 locations shown in Figure 2, four would not be included. The four well locations disregarded in the cost opinion were conservatively assumed to be sites near the south (downstream) end of the wellfield pipeline with 6-inch diameter laterals. The cost per individual production well, including pump, controls, housing, valves, etc. is estimated to be approximately $137,000. The preliminary opinion of probable cost for this wellfield is approximately $17.3 million for a 28.7 cfs (12,900 gpm) capacity wellfield for Scenario #2; Scenario #1 is similar in magnitude and would cost only slightly less. It does not include conveyance from the reservoir to Grand Forks, water treatment, permitting, environmental impact assessments, recharge area buffer zone purchases, or some other costs that are likely to be incurred in the project.

The opinion of probable cost does not include water quality testing, although it does include an automated sampler for some basic water quality parameters at the wellhead. It does not include costs for a centralized control system, but does include the local controls and telemetry from each wellhead capable of communicating with the SCADA controller. The cost opinion does include a wellfield reservoir located just downstream of the wellfield. The cost includes pipelines for collection of water from the wells to the wellfield reservoir, but it does not include the pipeline from the wellfield reservoir to a central reservoir at Grand Forks, and it does not include the cost of a central reservoir.

REFERENCES

Anderson, K.A., 1993. Ground Water Handbook. National Ground Water Association, Dublin, OH, 401 pp.

Bartelson, N., and G. Goven, 1998. North Dakota Groundwater Monitoring Program, 1998 Report. North Dakota Department of Health, Division of Water Quality, 141 pp.

Downey, J.S., and C.A. Armstrong, 1977. Ground-Water Resources of Griggs and Steele Counties, North Dakota. North Dakota Geological Survey Bulletin B-64, Part III, 33 pp.

Hansen, D.E., and J. Kume, 1970. Geology and ground water resources of Grand Forks County, part I, Geology: North Dakota Geological Survey Bulletin 53 and North Dakota State Water Commission County Ground Water Studies 13, 76 p.

Jensen, H.M., and R.L. Klausing, 1971. Geology and ground water resources of Trail County, part 3, Ground water resources: North Dakota Geological Survey Bulletin 49 and North Dakota State Water Commission County Ground Water Studies 10, 40 p.

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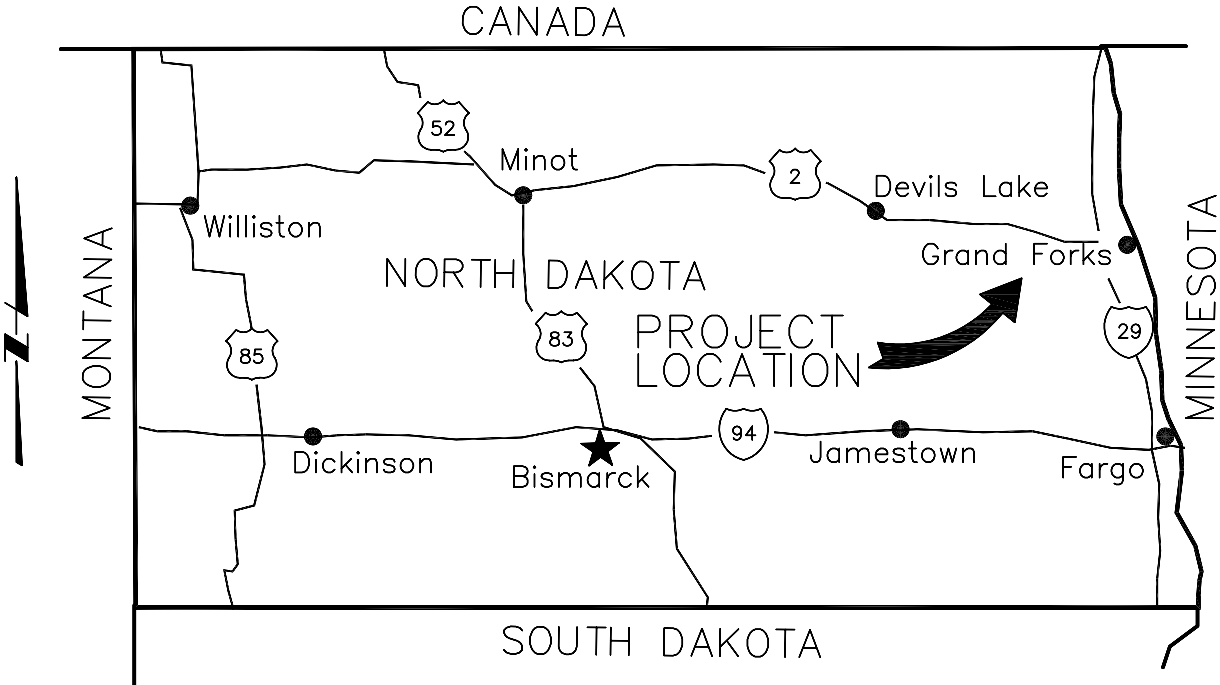
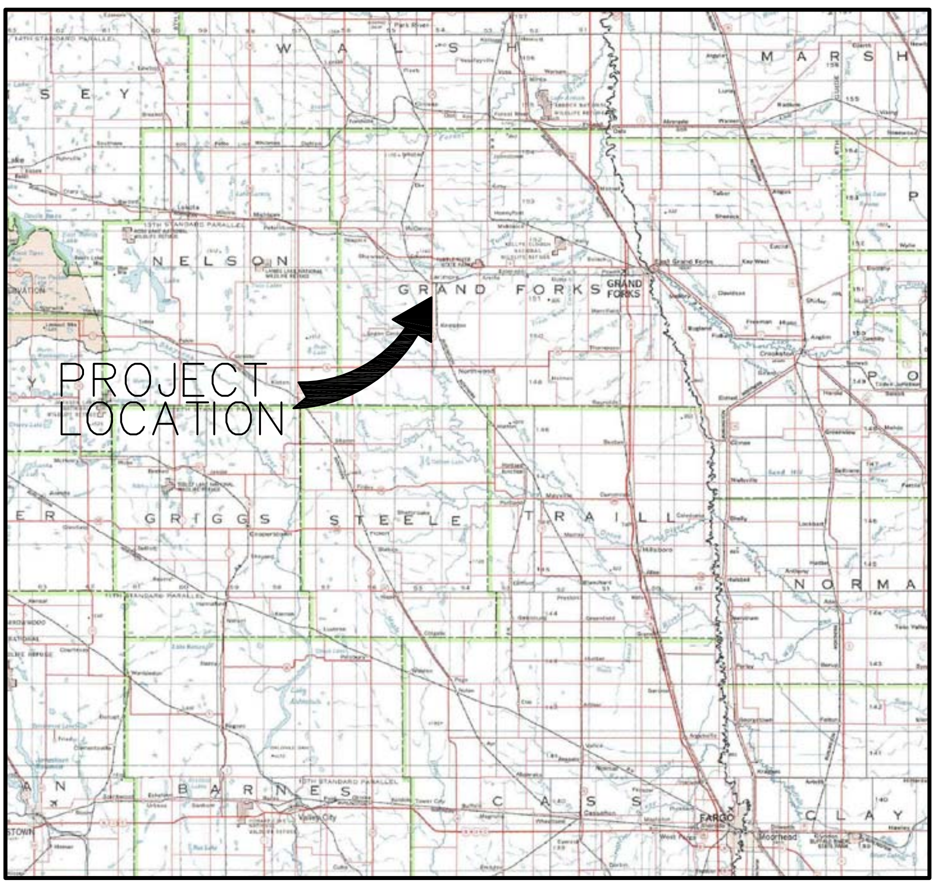
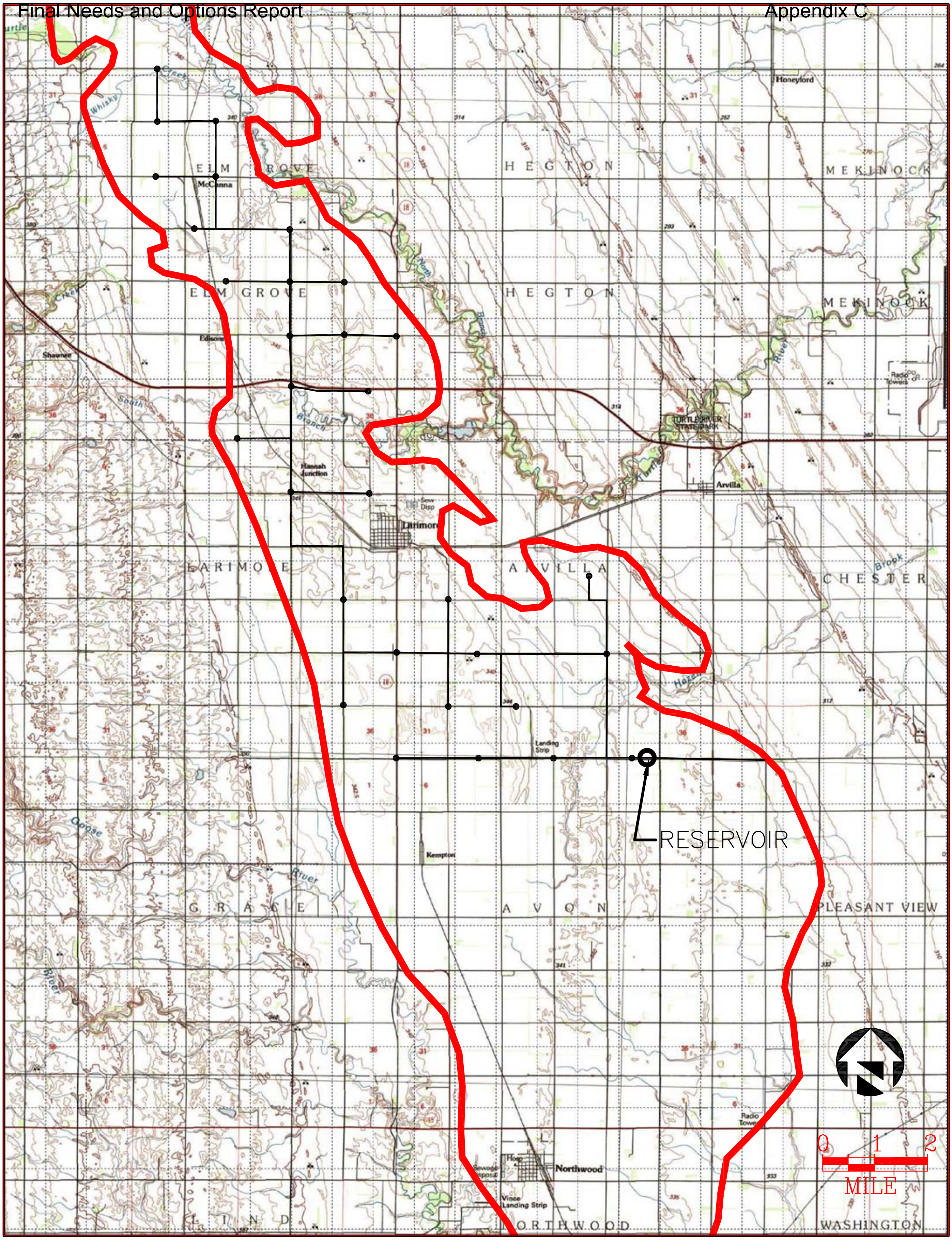


LOCATION MAP



VICINITY MAP

ELK VALLEY AQUIFER
LOCATION MAP
Figure 1



ELK VALLEY AQUIFER
PROPOSED WELL FIELD
Figure 2

MWH

ATTACHMENT 1
PRELIMINARY OPINION OF PROBABLE COST
ELK VALLEY AQUIFER WELLFIELD
COSTS PER PRODUCTION WELL

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$200	Lin. Ft.	65	$13,000	Estimate based on typ. 10" well costs
Column Pipe (4")	$39	Lin. Ft.	220	$8,580	Means 15107.620.1400
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Outflow Meter with Totalizer	$9,050	Each	1	$9,050	Means 15120.940.1180
Sampling Port	$500	Each	1	$500	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Pump (20 hp Submersible)	$10,000	Each	1	$10,000	Grundfos 7/1/04 price list, plus starter
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Pump House	$20,000	Each	1	$20,000	Assumed based on experience
Chain-Link Fence	$23	Lin. Ft.	800	$18,400	Means 02820.130.0800
Miscellaneous		Each	1	$12,493	10% of costs
TOTAL				**$137,423**	

TABLE 1

PRELIMINARY OPINION OF PROBABLE COST
ELK VALLEY WELLFIELD, RESERVOIR, PUMP STATION, AND PIPELINE

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Production Well	54	Each	$137,000	$7,398,000	See Attachment 1
Wellfield Piping:					
6-inch PVC Pipe	69,520	Feet	$10.93	$759,854	Quote for RRVWSP Cost Analysis
8-inch PVC Pipe	13,640	Feet	$13.41	$182,912	Quote for RRVWSP Cost Analysis
10-inch PVC Pipe	10,560	Feet	$16.39	$173,078	Quote for RRVWSP Cost Analysis
14-inch PVC Pipe	17,600	Feet	$20.46	$360,096	Quote for RRVWSP Cost Analysis
18-inch PVC Pipe	5,280	Feet	$24.11	$127,301	Quote for RRVWSP Cost Analysis
20-inch PVC Pipe	31,680	Feet	$32.85	$1,040,688	Quote for RRVWSP Cost Analysis
24-inch DI Pipe	42,240	Feet	$77.82	$3,287,117	Quote for RRVWSP Cost Analysis
30-inch DI Pipe	3,500	Feet	$160.77	$562,695	Quote for RRVWSP Cost Analysis
Reservoir and Pump Station	1,800,000	Gallons	$1.75	$3,150,000	Assumes storage for 5 wells/24 hrs and high head/hp pump station; unit cost from experience
Pressure Control Station	1	Each	$250,000	$250,000	Pressure regulation to maintain high/low pressures; unit cost based on experience
Pump Station Electrical	1	Each	$20,000	$20,000	Assumed based on experience
Subtotal (Direct Costs)				**$17,311,741**	

Contractor OH&P (30%)	**$5,193,522**
Contractor Costs (15%)	$2,596,761
SUBTOTAL (Burdened Costs including mobilization)	**$25,102,024**
Unlisted Items (5% of Subtotal (Burdened))	$1,255,101
CONTRACT COST	**$26,357,126**
Contingency (25% of Contract Cost)	$6,589,281
FIELD COST	**$32,946,407**
Non-Contractor Costs (25% of Field Costs)	$8,236,602
CONSTRUCTION COST (w/o ROW)	**$41,183,009**

TECHNICAL MEMORANDUM

MWH

To: Ed Cryer **Date:** May 6, 2005

From: Pat Naylor **Reference:** 1690583.011801

Subject: Central Minnesota Wellfield Cost Opinion

PURPOSE

A preliminary opinion of probable cost has been prepared pertaining to wells and wellsite equipment for production wellfield under consideration for the Ottertail region of central Minnesota. The wellfield would provide water to users in the Red River Valley on the Minnesota - North Dakota boundary. The location of the proposed wellfield is shown in Figure 1. The Minnesota wellfield is one option being evaluated to address future water resource needs in this area. This preliminary opinion of probable cost is very general and has been prepared to help determine whether the wellfield would be an economically viable option. It addresses two scenarios, including a 45 cfs production capacity (Scenario #1) and a 72 cfs production capacity (Scenario #2).

PROPOSED PROJECT

Wellfield Capacity

Scenario #1 would produce 45 cfs (20,200 gpm) from 81 production wells, tapping the Pelican River Sands and Ottertail Outwash aquifers. The proposed locations of the Scenario #1 wells are shown I Figure 2. Scenario #2 would produce 72 cfs (18,000 gpm) from 129 wells, also drawing from the Pelican River Sands and Ottertail Outwash aquifers. Scenario #2 well locations are shown in Figure 3. Each well would be pumped at an average of 250 gpm under both scenarios.

Pipelines

Water pumped from the wells would be conveyed reservoirs in the wellfield. Pipelines 20 inches in diameter or less would be PVC. Pipelines larger than 20 inches in diameter would be ductile iron. Proposed wellfield pipelines are shown in Figure 2 for Scenario #1 and in Figure 3 for Scenario #2. The pipelines follow existing roadways wherever practical, primarily because the area has many lakes, ponds, and wetlands, and using existing roadways is less likely to disturb these features.

Reservoirs

Wellfield reservoirs will be required to facilitate variations in demand, to provide storage, to keep collection system head within reasonable range, and to help regulate delivery pressure. Scenario #1 would require two reservoirs in the wellfield, and Scenario #2 would require three reservoirs in the wellfield. Each reservoir would hold the 24-hour pumping capacity of approximately ten percent of the number of wells upstream of the respective reservoir.

Each reservoir would also be equipped with a pump station and a pressure control station. Water would be conveyed from the reservoir downstream of the entire wellfield to a central reservoir in Fargo, where the water would be treated prior to distribution. The pipeline from the downstream wellfield reservoir to Fargo, the central reservoir in Fargo, and any water treatment requirements are beyond the scope of this evaluation.

COST OPINION

The costs shown have been prepared using various general sources of information, including preliminary (nonbinding) cost estimates from local contractors, cost estimating aids such as RS Means 2004 Cost Estimating Data, on-line equipment catalogs, on-line equipment quotes, and assumptions based on past experience. The locations, depths, and production capacity of each of the wells, and data files pertaining to land use, waterways, wetlands, and roads were provided by the U.S. Bureau of Reclamation. Because of the numerous lakes and wetlands in the wellfields, roadways were selected for pipeline alignments wherever practical. This resulted in longer pipeline alignments than a layout selected solely on the basis of minimizing pipe lengths; however, the use of roadways for pipelines would minimize disturbance of waterways, wetlands, and wildlife habitat, would be easier to permit, and would be easier to construct.

The opinion of probable cost is based on assumptions that were made after reviewing information provided by the U.S. Bureau of Reclamation (unpublished groundwater data and discussion), by Houston Engineers, and by LTP Drilling, as well as from a report prepared by the U.S. Geological Survey *(Lindgren, R.J., 2002. Ground-Water Resources of the Uppermost Confined Aquifers, Southern Wadena County and Parts of Ottertail, Todd, and Cass Counties, Central Minnesota, 1997-2000. U.S. Geological Survey Water Resources Investigations Report 02-4023, 50 pp.)* Additional hydrogeologic information was obtained from the Minnesota Department of Natural Resources *(Eckman, J.C., and J.A. Berg, 2002. Regional Hydrogeologic Assessment, Otter Tail Area, West-Central Minnesota, Surficial Geology. Minnesota Department of Natural Resources, Division of Waters, Regional Hydgrogeologic Assessment Series, RHA-5, Part B, Plate 3.)*

The assumptions developed for this cost opinion for the central Minnesota wellfield include the following:

- Total wellfield design capacity would be 45 cfs (20,200 gpm) for Scenario #1 and 72 cfs (32,300 gpm) for Scenario #2
- Static water level is typically less than 20 ft
- 81 wells for a 45 cfs wellfield and 130 wells for a 72 cfs wellfield

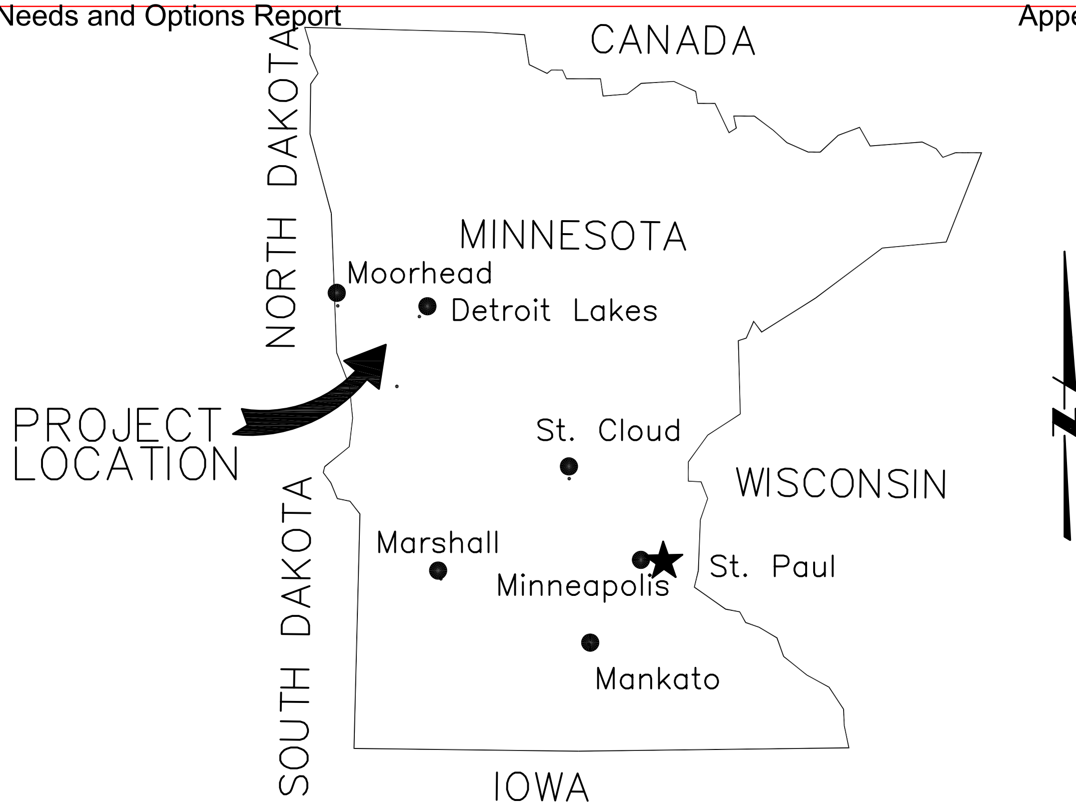
- Well screen average length would be 40 ft to allow for vertical aquifer anisotropy

From these assumptions and the information provided, it is estimated that a wellfield in the aquifer system would have the following design criteria:

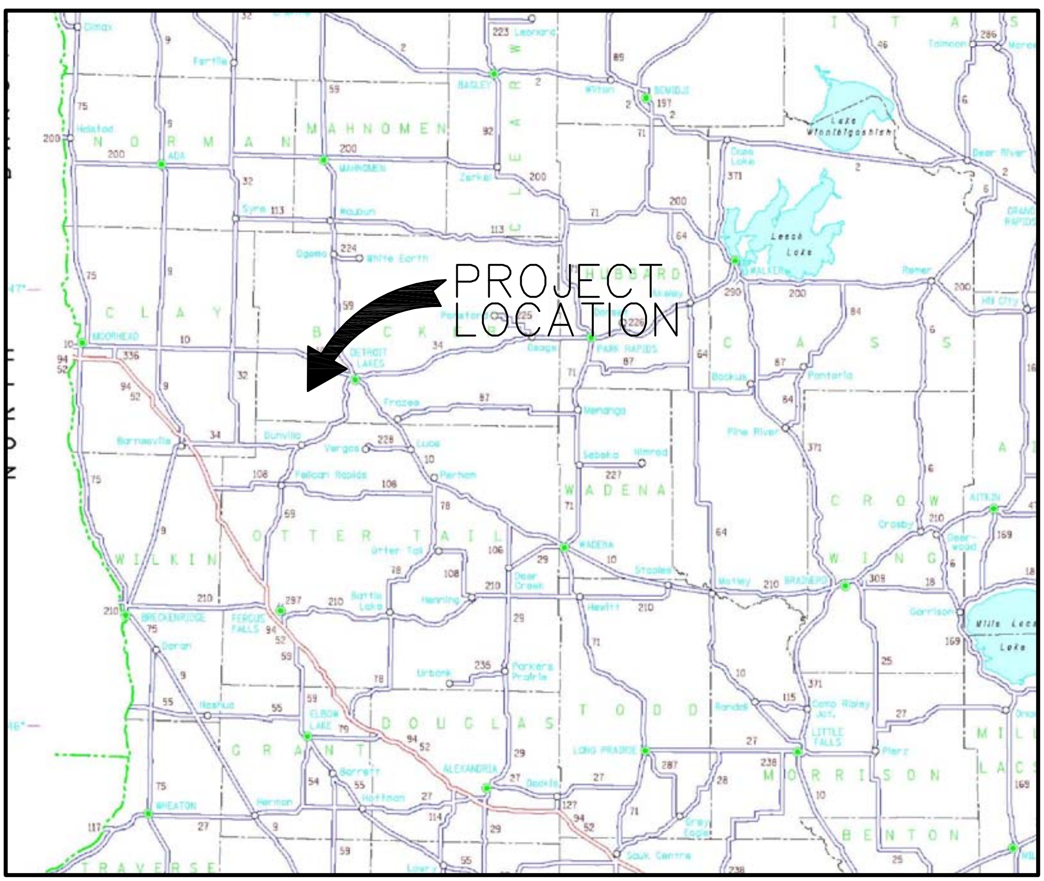
- Average well depth would be 235 ft (approximate average depth for both Scenario #1 and Scenario #2), including 40 ft of screen and 10 ft of tailpipe below bottom of aquifer
- Screen would be stainless steel
- Average well production capacity would be 250 gpm
- Average required head would be 300 ft per well
- Each well nominal diameter would be 12 inches
- Submersible pump in each well would be 30 horsepower and would require 460-V 3-phase power
- Each well would be housed in an HVAC-regulated pump house
- Each pump system would be managed with a SCADA-type central control system and individual PLC
- Each well lot would be approximately ¾ acre (200 ft x 200 ft) to allow for the wellhouse, security fence, minimum wellhead protection setback, and working space
- Two collection reservoirs would be located within the wellfield for Scenario #1 and three reservoirs would be within the wellfield for Scenario #2. The reservoirs would be required to facilitate variations in demand, to provide storage in the event of well or pump down time, and to maintain constant pressure (reservoir locations are shown in Figure 2 for Scenario #1 and in Figure 3 for Scenario #2)
- Pumping to the reservoir would be accomplished using pumps in the individual wells
- A failed pump or similar equipment problem would take no more than 24 hours to repair or replace
- Reservoir would be designed to contain enough storage capacity to accommodate the production capacity from about ten percent of the upstream wells to be out of service for 24 hours:
  1. For Scenario #1, Reservoir #1 would have a capacity for about ten percent of 39 wells (four wells) for 24 hours (1.44 million gallons), and Reservoir #2 would hold about ten percent of 81 wells (eight wells) for 24 hours (2.88 million gallons)
  2. For Scenario #2, Reservoir #1 would have a capacity of about ten percent of 72 wells (seven wells) for 24 hours (2.52 million gallons), Reservoir #2 would have capacity for about ten percent of 109 wells (11 wells) for 24 hours (3.96 million gallons), and Reservoir #3 would hold about ten percent of 130 wells (13 wells) for 24 hours (4.68 million gallons)
- Reservoirs would be buried concrete tanks.

The opinion of probable cost does not include water quality testing, although it does include an automated sampler for some basic water quality parameters at the wellhead. It does not include costs for a centralized control system, but does include the local controls and telemetry from each wellhead capable of communicating with the SCADA controller. The cost opinion does include two wellfield reservoirs and pump stations for the 45 cfs option and three reservoirs and pump stations for the 72 cfs option. The reservoirs and pump stations are required to help equalize demand and delivery, to provide interim storage, and to boost head to offset pipeline headlosses. The cost includes pipelines for collection of water from the wells to the wellfield reservoirs, but it does not include a pipeline from the wellfield to a central reservoir at or near the area of use, and it does not include the cost of a central reservoir.

The average cost per well is preliminarily estimated to be about $175,000. The preliminary opinion of probable cost for this wellfield is approximately $78.3 million for a 45 cfs capacity wellfield and approximately $130.8 million for a 72 cfs capacity wellfield. These are unburdened costs. The summary of costs per well are shown in Table 1 for a 45 cfs wellfield and Table 2 for a 72 cfs wellfield, including an itemized opinion of burdened construction costs.

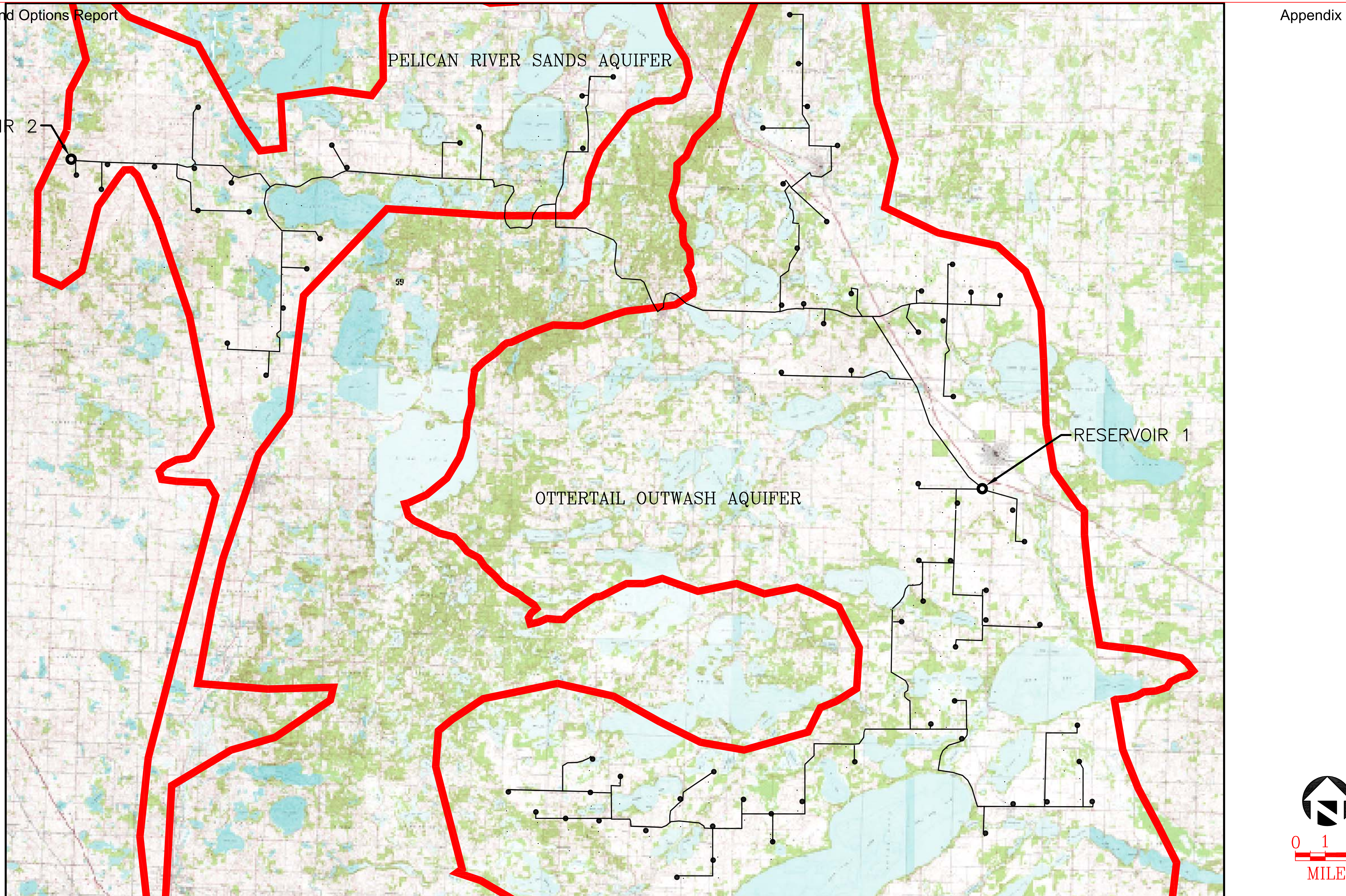


LOCATION MAP



VICINITY MAP

CENTRAL MINNESOTA AQUIFERS
LOCATION MAP
Figure 1



CENTRAL MINNESOTA AQUIFERS
PROPOSED WELL FIELD (45 CFS)
Figure 2

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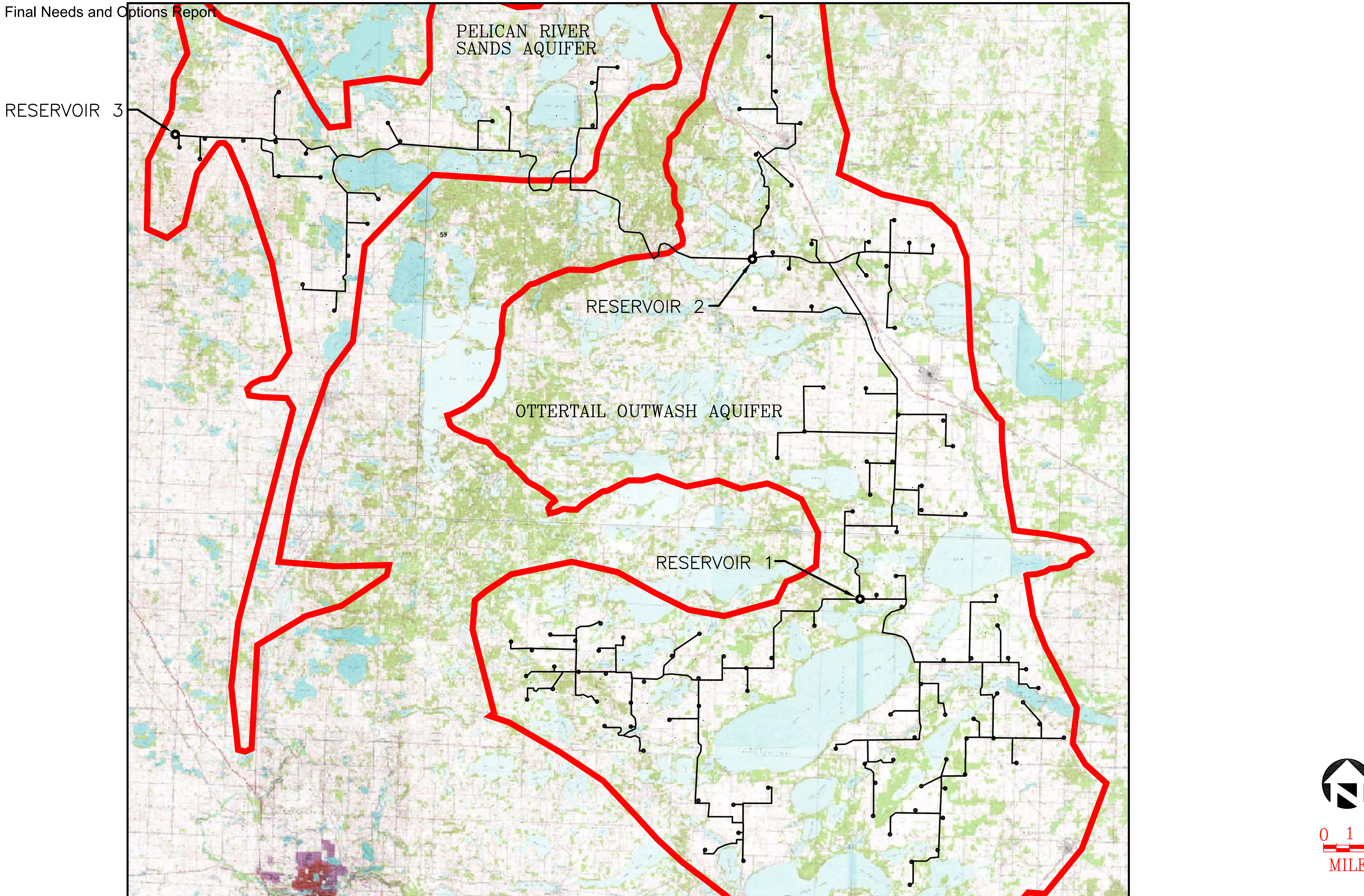

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CENTRAL MINNESOTA AQUIFERS
PROPOSED WELL FIELD (72 CFS)
Figure 3

ATTACHMENT 1
PRELIMINARY OPINION OF PROBABLE COST
CENTRAL MINNESOTA WELLFIELD
COSTS PER PRODUCTION WELL

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$49,375	Each	1	$49,375	Quote, modified, see attached
Column Pipe (4")	$39	Lin. Ft.	150	$5,850	Means 15107.620.1400
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Outflow Meter with Totalizer	$9,050	Each	1	$9,050	Means 15120.940.1180
Sampling Port	$500	Each	1	$500	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Pump (30 hp Submersible)	$16,000	Each	1	$16,000	Grundfos 7/1/04 price list, plus starter
Pump House w/HVAC	$20,000	Each	1	$20,000	Assumed based on experience
Electrical	$5,000	Each	1	$5,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Chain-Link Fence	$23	Lin. Ft.	600	$13,800	Means 02820.130.0800
Miscellaneous		Each	1	$15,898	10% of costs
TOTAL				**$174,873**	

TABLE 1

PRELIMINARY OPINION OF PROBABLE COST
CENTRAL MINNESOTA 45 CFS WELLFIELD, RESERVOIRS, PUMP STATIONS, PRESSURE CONTROL STATIONS, AND PIPELINES

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Production Well	81	Each	$175,000	$14,175,000	See attached
Wellfield Piping:					
6-inch PVC Pipe	295,600	Feet	$10.93	$3,230,908	Quote for RRVWSP Cost Analysis
8-inch PVC Pipe	86,100	Feet	$13.41	$1,154,601	Quote for RRVWSP Cost Analysis
10-inch PVC Pipe	30,200	Feet	$16.39	$494,978	Quote for RRVWSP Cost Analysis
12-inch PVC Pipe	32,900	Feet	$19.90	$654,710	Quote for RRVWSP Cost Analysis
14-inch PVC Pipe	79,000	Feet	$20.46	$1,616,340	Quote for RRVWSP Cost Analysis
16-inch PVC Pipe	25,100	Feet	$24.11	$605,161	Quote for RRVWSP Cost Analysis
18-inch PVC Pipe	6,300	Feet	$28.29	$178,227	Quote for RRVWSP Cost Analysis
20-inch PVC Pipe	48,800	Feet	$32.85	$1,603,080	Quote for RRVWSP Cost Analysis
30-inch DI Pipe	88,300	Feet	$160.77	$14,195,991	Quote for RRVWSP Cost Analysis
36-inch DI Pipe	136,900	Feet	$190.78	$26,117,782	Quote for RRVWSP Cost Analysis
42-inch DI Pipe	28,500	Feet	$215.66	$6,146,310	Quote for RRVWSP Cost Analysis
Reservoir and Pump Station	1,440,000	Gallons	$1.75	$2,520,000	Assumes storage for 4 wells/24 hrs and high head/hp pump station; unit cost from experienc
Reservoir and Pump Station	2,880,000	Gallons	$1.75	$5,040,000	Assumes storage for 8 wells/24 hrs and high head/hp pump station; unit cost from experienc
Pressure Control Station	2	Each	$250,000	$500,000	Pressure regulation to maintain high/low pressures; unit cost based on experience.
Pump Station Electrical	2	Each	$20,000	$40,000	
Subtotal (Direct Costs)				**$78,273,088**	

Contractor OH&P (30%)	$23,481,926
Contractor Costs (15%)	$11,740,963
SUBTOTAL (Burdened Costs including mobilization)	**$113,495,978**
Unlisted Items (5% of Subtotal (Burdened))	$5,674,799
CONTRACT COST	**$119,170,776**
Contingency (25% of Contract Cost)	$29,792,694
FIELD COST	**$148,963,471**
Non-Contractor Costs (25% of Field Costs)	$37,240,868
CONSTRUCTION COST (w/o ROW)	**$186,204,338**

TABLE 2

PRELIMINARY OPINION OF PROBABLE COST
CENTRAL MINNESOTA 72 CFS WELLFIELD, RESERVOIRS, PUMP STATIONS, PRESSURE CONTROL STATIONS, AND PIPELINES

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Production Well	129	Each	$175,000	$22,575,000	See attached
Wellfield Piping:					
6-inch PVC Pipe	456,000	Feet	$10.93	$4,984,080	Quote for RRVWSP Cost Analysis
8-inch PVC Pipe	124,200	Feet	$13.41	$1,665,522	Quote for RRVWSP Cost Analysis
10-inch PVC Pipe	70,800	Feet	$16.39	$1,160,412	Quote for RRVWSP Cost Analysis
12-inch PVC Pipe	8,200	Feet	$19.90	$163,180	Quote for RRVWSP Cost Analysis
14-inch PVC Pipe	120,800	Feet	$20.46	$2,471,568	Quote for RRVWSP Cost Analysis
16-inch PVC Pipe	22,200	Feet	$24.11	$535,242	Quote for RRVWSP Cost Analysis
18-inch PVC Pipe	20,100	Feet	$28.29	$568,629	Quote for RRVWSP Cost Analysis
20-inch PVC Pipe	26,400	Feet	$32.85	$867,240	Quote for RRVWSP Cost Analysis
24-inch DI Pipe	21,100	Feet	$77.82	$1,642,002	Quote for RRVWSP Cost Analysis
30-inch DI Pipe	77,900	Feet	$160.77	$12,523,983	Quote for RRVWSP Cost Analysis
36-inch DI Pipe	17,100	Feet	$190.78	$3,262,338	Quote for RRVWSP Cost Analysis
42-inch DI Pipe	142,600	Feet	$215.66	$30,753,116	Quote for RRVWSP Cost Analysis
48-inch DI Pipe	98,800	Feet	$275.88	$27,256,944	Quote for RRVWSP Cost Analysis
Reservoir and Pump Station	2,520,000	Gallons	$1.75	$4,410,000	Assumes storage for 7 wells/24 hrs and high head/hp pump station; unit cost from experience
Reservoir and Pump Station	3,960,000	Gallons	$1.75	$6,930,000	Assumes storage for 11 wells/24 hrs and high head/hp pump station; unit cost from experience
Reservoir and Pump Station	4,680,000	Gallons	$1.75	$8,190,000	Assumes storage for 13 wells/24 hrs and high head/hp pump station; unit cost from experience
Pressure Control Station	3	Each	$250,000	$750,000	Pressure regulation to maintain high/low pressures; unit cost based on experience.
Pump Station Electrical	3	Each	$20,000	$60,000	
Subtotal (Direct Costs)				**$130,769,256**	

Contractor OH&P (30%)	$39,230,777
Contractor Costs (15%)	$19,615,388
SUBTOTAL (Burdened Costs including mobilization)	**$189,615,421**
Unlisted Items (5% of Subtotal (Burdened))	$9,480,771
CONTRACT COST	**$199,096,192**
Contingency (25% of Contract Cost)	$49,774,048
FIELD COST	**$248,870,240**
Non-Contractor Costs (25% of Field Costs)	$62,217,560
CONSTRUCTION COST (w/o ROW)	**$311,087,800**

T E C H N I C A L   M E M O R A N D U M

MWH

To:	Ed Cryer	**Date:**	May 13, 2005
From:	Pat Naylor	**Reference:**	1690583.011801
Subject:	Moorhead ASR Cost Opinion		

PURPOSE

A preliminary opinion of probable cost has been prepared pertaining to wells and wellsite equipment for an aquifer storage and recovery (ASR) system in the Moorhead Aquifer at Moorhead, Minnesota. The ASR well system would inject treated water from the Moorhead Water Treatment Plant and would be withdrawn for potable use by the City of Moorhead. This preliminary opinion of probable cost is very general and has been prepared to help determine whether the ASR system would be an economically viable option.

PROPOSED PROJECT

Wellfield Capacity

The ASR system would include one new dual-use well, one new injection well, and retrofitting of one existing well for use as a production well. Each new well would be about 260 feet deep. Treated water would be injected into the dual-use well and the injection well well when excess water is available and when demand is low. Production from the dual-use well would occur when demand is high and would supplement the Moorhead municipal supply. The production well would be used as needed. It is anticipated that well pumps would be capable of producing the required system head without additional pump stations.

Pipelines

The retrofitted production well is located in the immediate vicinity of the Moorhead WTP; pipeline costs are assumed to be negligible for the purposes of this cost opinion. The new dual-use well location has not been defined. It is assumed for costing purposes that this well will be located approximately 1,500 feet from the WTP. The new injection well is assumed to be located within the urban area, and the water to be injected is assumed to come directly from the existing potable water distribution system. The pipeline length needed to tie into the injection well from the existing distribution system is assumed to be negligible.

COST OPINION

The costs shown have been prepared using various general sources of information, including preliminary (nonbinding) cost estimates from local contractors, cost estimating aids such as RS Means 2004 Cost Estimating Data, on-line equipment catalogs, on-line equipment quotes, and assumptions based on past experience.

The opinion of probable cost is based on assumptions that were made after reviewing information provided by the U.S. Bureau of Reclamation (unpublished groundwater data and unpublished memorandum, *Schlag, A.J., 2003, Aquifer Storage and Recovery Prospects for the Moorhead Aquifer*); by Houston Engineers; and by LTP Drilling; as well as from a report prepared by the North Dakota State Water Commission *(Ripley, D.P., 2000, The Water Resource Characteristics of the West Fargo Aquifer System: North Dakota Ground-Water Studies Number 106 – Part II, 233 pp).*

The assumptions developed for this cost opinion for the Moorhead ASR system include the following:

- Total wellfield design capacity would be 1.0 cfs (450 gpm)
- Static water level is roughly 100 ft but varies considerably from place to place
- One new dual-use well,one new injection well, and one existing well retrofitted as a production well
- New well screen average length would be 40 ft to allow for vertical aquifer anisotropy
- Average depth to the bottom of the aquifer is about 266 ft
- Average aquifer thickness is about 98 ft
- Pipeline from new dual-use well to the WTP is approximately 1,500 ft
- New pipelines for retrofitted production well and injection well are of negligible length.

From these assumptions and the information provided, it is estimated that a wellfield in the aquifer system would have the following design criteria:

- Average new well depth would be 260 ft, including 40 ft of screen and 10 ft of tailpipe below bottom of aquifer
- Screen would be stainless steel
- Dual-use well and production well design production capacity would be 500 gpm each
- Injection well design production capacity would be 250 to 500 gpm
- Average required head would be 300 ft per well
- Each well nominal diameter would be 12 inches
- Submersible pump in the dual-use well and production well would each be 60 horsepower and would require 460-V 3-phase power
- Each well would be housed in a new pump house
- Well pump system would be managed with a SCADA-type central control system and individual PLC

- Each new well lot would be approximately ¾ acre (200 ft x 200 ft) to allow for the wellhouse, security fence, minimum wellhead protection setback, and working space
- Existing well to be retrofitted would require a new pump house but would not be fenced because it is presumably in a fenced area
- Pumping to the Moorhead water system would be accomplished using the pumps in the dual-use well and production well
- Injection well pumping would be accomplished with the system pressure within the City of Moorhead water system and would not require booster pumps
- .One monitoring well for each dual-use or injection well.

The opinion of probable cost does not include water quality testing, although it does include an automated sampler for some basic water quality parameters at the wellhead. It does not include costs for a centralized control system, but does include the local controls and telemetry from each wellhead capable of communicating with the SCADA controller. Because of the relatively small size of the ASR system, no reservoirs are included in this cost opinion.

The cost of the dual-use well is preliminarily estimated to be about $281,000, and the injection well is preliminarily estimated to cost about $236,000. The retrofit of the existing well as a production well is estimated to cost about $118,000. The preliminary opinion of probable cost for this ASR system is approximately $689,000. These are unburdened costs. The summary of costs are shown in Table 1. The estimated costs per well are shown in Attachments 1, 2, and 3.

ATTACHMENT 1
ASR PRELIMINARY OPINION OF PROBABLE COST
MOORHEAD ASR SYSTEM
DUAL USE WELL COSTS

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$54,710	Each	1	$54,710	Estimate from driller
Column Pipe (6")	$69	Lin. Ft.	220	$15,180	Means 15107.620.1410
Valve (2-way)	$40,000	Each	1	$40,000	Verbal estimate from Baski Valves
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Inflow Meter with Totalizer	$13,000	Each	1	$13,000	Means 15120.940.1220
Outflow Meter with Totalizer	$13,000	Each	1	$13,000	Means 15120.940.1220
Automated Water Quality Monit. (pH, Turb, TDS, T)	$18,000	Each	1	$18,000	Assumed based on experience
Sampling Ports (Injection and Recovery)	$500	Each	2	$1,000	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Pump (60 hp Submersible)	$17,000	Each	1	$17,000	Assumed based on experience
Pump House w/HVAC	$20,000	Each	1	$20,000	Assumed based on experience
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Chain-Link Fence	$23	Lin. Ft.	800	$18,400	Means 02820.130.0800
Miscellaneous		Each	1	$25,569	10% of costs
TOTAL				**$281,259**	

ATTACHMENT 2
ASR PRELIMINARY OPINION OF PROBABLE COST
MOORHEAD ASR SYSTEM
INJECTION WELL COSTS

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$54,710	Each	1	$54,710	Quote, see attached
Column Pipe (5")	$53	Lin. Ft.	180	$9,540	Means 15107.620.1410
Valve (2-way)	$40,000	Each	1	$40,000	Verbal estimate from Baski Valves
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Inflow Meter with Totalizer	$9,050	Each	1	$9,050	Means 15120.940.1180
Automated Water Quality Monit. (pH, Turb, TDS, T)	$18,000	Each	1	$18,000	Assumed based on experience
Sampling Ports (Injection and Recovery)	$500	Each	2	$1,000	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Pump House	$18,000	Each	1	$18,000	Assumed based on experience
Chain-Link Fence	$23	Lin. Ft.	800	$18,400	Means 02820.130.0800
Miscellaneous		Each	1	$21,410	10% of costs
TOTAL				**$235,510**	

ATTACHMENT 3
ASR PRELIMINARY OPINION OF PROBABLE COST
MOORHEAD ASR SYSTEM
EXISTING PRODUCTION WELL RETROFIT

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Column Pipe (6")	$69	Lin. Ft.	220	$15,180	Means 15107.620.1410
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Outflow Meter with Totalizer	$9,050	Each	1	$9,050	Means 15120.940.1180
Sampling Port	$500	Each	1	$500	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Pump (60 hp Submersible)	$17,000	Each	1	$17,000	Assumed based on experience
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Pump House	$20,000	Each	1	$20,000	Assumed based on experience
Miscellaneous		Each	1	$10,713	10% of costs
TOTAL				**$117,843**	

TABLE 1

PRELIMINARY OPINION OF PROBABLE COST
MOORHEAD ASR SYSTEM

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Dual Use Well	1	Each	$281,000	$281,000	See Attachment 1
Injection Well	1	Each	$236,000	$236,000	See Attachment 2
Production Well Retrofit	1	Each	$118,000	$118,000	See Attachment 3
Monitoring Well	320	Feet	$15	$4,800	Unit cost estimate from LTP Drilling; 1 for each dual use or injection well, same depth
10-inch PVC Pipe	1,500	Feet	$32.78	$49,170	Quote for RRVWSP Cost Analysis, doubled to allow for urban conditions
Subtotal (Direct Costs)				**$688,970**	
Contractor OH&P (30%)				$206,691	
Contractor Costs (15%)				$103,346	
SUBTOTAL (Burdened Costs including mobilization)				**$999,007**	
Unlisted Items (5% of Subtotal (Burdened))				$49,950	
CONTRACT COST				**$1,048,957**	
Contingency (25% of Contract Cost)				$262,239	
FIELD COST				**$1,311,196**	
Non-Contractor Costs (25% of Field Costs)				$327,799	
CONSTRUCTION COST (w/o ROW)				**$1,638,995**	

TECHNICAL MEMORANDUM

MWH

To:	Ed Cryer	**Date:**	May 6, 2005
From:	Pat Naylor	**Reference:**	1690583.011801
Subject:	Southeast North Dakota Wellfield		

PURPOSE

A proposal is under consideration within the U.S. Bureau of Reclamation (USBR) for supplementing existing surface and groundwater supplies for the City of Wahpeton, in southeastern North Dakota. Wahpeton currently uses surface water from the Red River and groundwater from the Wahpeton Buried Valley aquifer. Currently, in normal to wet water years, Wahpeton is able to meet its municipal and industrial water demands using existing resources and facilities. However, projected demand for municipal and industrial growth indicates that existing capacity probably will be exceeded in the future under drought conditions. Although surface water can be acquired to meet water demand in most years, it is anticipated that limitations on appropriated water and low-flow surface water conditions during extended drought will result in shortfalls. The USBR has proposed consideration of a wellfield that draws from other regional aquifers as a supplemental groundwater supply. A conceptual evaluation of aquifer and wellfield options was presented in an unpublished paper (USBR, 2005).

This memorandum presents a preliminary evaluation of some of the technical issues and costs of the wellfield proposal. A discussion of the nontechnical issues, such as water right transfers, public input, environmental impacts, etc. is beyond the scope of this evaluation.

GEOLOGY AND HYDROGEOLOGY

The proposed wellfield would produce primarily from the Brightwood and Spiritwood aquifers, with additional production from the Gwinner and Milnor Channel aquifers. The wellfield would be located across a 40-mile by 9-mile area that starts approximately 21 miles west of Wahpeton in far southeastern North Dakota. The elevations of wells would be between about 1,300 feet above MSL at the far western end of the wellfield, to an elevation of about 970 feet at the eastern end of the wellfield. The City of Wahpeton is at an elevation of about 965 feet.

The locations of the proposed wellfield and the associated aquifers are shown in Figure 1. Significant additional regional aquifers include the Sheyenne Delta and Hankinson aquifers; the groundwater from these other aquifers is well developed and thought to be appropriated at or near sustainable yield.

Each of the aquifers is associated with Pleistocene glaciers, either directly or indirectly. A brief discussion of conditions in each aquifer is presented below.

Brightwood Aquifer

The Brightwood aquifer consists of glacial outwash encompassing more than 60 square miles. The aquifer thickness ranges from 70 to 130 feet, with an average thickness of about 100 feet. The aquifer material is comprised of mostly well-sorted sands and medium-grained gravels. The aquifer is capped with glacial till over much of the surface, although it generally shows characteristics of an unconfined aquifer. Recharge is believed to occur from direct precipitation. The groundwater hydraulic gradient is eastward, and the aquifer discharges to various lakes and to the Milnor Channel Aquifer. The aquifer is largely undeveloped but is believed to have relatively good production capacity (USBR, 2005).

Groundwater in the Brightwood aquifer is of the calcium bicarbonate to calcium sulfate type and is very hard. It is high in iron and manganese, sulfate, and total dissolved solids. Nitrate commonly occurs in concentrations of 1 mg/L or less and occasionally is found at concentrations of four to five mg/L (NDSWC, 2005).

Spiritwood Aquifer

The Spiritwood aquifer is part of a large glaciofluvial buried valley complex. The aquifer extends in a more-or-less linear fashion across much of southeastern North Dakota and into northeastern South Dakota. The aquifer is encountered from the surface to depths of 180 feet below ground surface in thicknesses of 14 to 98 feet (Thompson, 2001). In the Wahpeton area, the aquifer consists of sand and gravel interbedded with silt and clay layers, with an average thickness of approximately 33 feet. The aquifer is overlain in places by glacial till and overlies various bedrock formations. It generally behaves like a confined aquifer. Recharge occurs from surface infiltration of precipitation where the aquifer is near the surface, and primarily from adjacent formations by leakage where it is deeper (Thompson, 2001). The aquifer exceeds 320 miles in overall areal extent (Kelly, 1964). Production wells from this aquifer can produce as much as 500 to 1,000 gpm in some instances (USBR, 2005).

Water quality sampling in the Spiritwood aquifer indicates that groundwater is a sodium bicarbonate type. The water is generally very hard and high in total dissolved solids. It is also high in sodium, sulfate, fluoride, iron and manganese, and moderately high in chloride. Nitrate detections are common in water quality samples; Thompson (2001) reported an average concentration of 1.2 mg/L, although no samples were reported to exceed the MCL of 10 mg/L.

Gwinner Aquifer

The Gwinner aquifer consists of alluvial deposits in a buried depression of glacial till. It is about 22 miles long and about one-half mile to four miles wide. It is up to 109 feet thick with an average thickness of 55 feet. It is recharged primarily from adjacent glacial drift (USBR, 2005). The top of the aquifer is about 130 to 150 feet below ground surface (NDSWC, 2005).

Gwinner aquifer water quality is of the calcium-sodium bicarbonate to calcium-sodium sulfate type. It is very hard and high in sodium, sulfate, iron, manganese, and total dissolved solids. Nitrate has been detected in some wells at concentrations of four to five mg/L but some of these wells have shown a decline to concentrations of less than one mg/L over time (NDSWC, 2005).

Milnor Channel Aquifer

The Milnor Channel aquifer is believed to be terrace deposits, glacial outwash and fluvial deposits in a glacial meltwater trench associated with a glacier margin, probably a now-abandoned channel of the Sheyenne River (Bartelson and Goven, 1999). The aquifer material is predominantly sand and gravel with interbedded layers of silt and clay (Armstrong, 1982). The deposits are from eight to 66 feet thick, and is about 40 feet thick on average (Baker and Paulson, 1967). The aquifer is unconfined, and the water table is typically within 10 feet of the surface, and ranges from ground surface up to about 33 feet (Bartelson and Goven, 1999). The saturated thickness of the aquifer is from one to 58 feet thick, with an average of approximately 35 feet. The aquifer width is from one to three miles and its length is about 50 miles. It has an areal extent of about 85 square miles. The aquifer is known to interact with lakes, ponds, rivers, and wetlands. Recharge occurs primarily from direct infiltration of precipitation, with additional recharge from the Brightwood aquifer (Baker and Paulson, 1967).

Water quality sampling in the Milnor Channel aquifer has shown that the groundwater is a calcium bicarbonate type, with high very iron, manganese, and sulfate, high sodium, and moderate to high hardness. Pesticides have been detected in about 10 percent of the wells sampled by the North Dakota Department of Health in 1999, and about 18 percent of the sampled wells had detectable concentrations of nitrate, although most were below one mg/L and none exceeded the 10 mg/L MCL. The presence and concentrations of nitrate appear to be stable, with no discernible upward or downward trend (Bartelson and Goven, 1999).

PROPOSED PROJECT

Wellfield Capacity

Two scenarios are considered under the current proposal. Scenario #1 would provide 11.7 cfs (5,250 gpm) at peak capacity from 21 wells, primarily from the Spiritwood Aquifer, with additional production from the Gwinner and Milnor Channel aquifers. The locations of these wells are shown in Figure 2. Scenario #2 would require 30 wells to produce up to 16.7 cfs (7,500 gpm), including all of the wells in Scenario #1 and an additional nine wells in the Brightwood Aquifer. The locations of the wells for Scenario #2 are shown in Figure 3. The average individual well capacity for both scenarios would be about 250 gpm, or 403.3 ac-ft/yr. Note that for each well the projected maximum one-year use would require about 176 gpm or 283.9 ac-ft/yr. on average; it is assumed for the purposes of this preliminary evaluation that the design capacity will be required to meet peak demands. Therefore the wellfield conveyance system must have the capacity to transfer peak demand with all wells at full capacity (i.e. 11.7 cfs for Scenario #1 and 16.7 cfs for Scenario #2).

Wellfield Collection System

The wells would be pumped through a pipeline collection system to one wellfield reservoir for Scenario #1. Two wellfield reservoirs would be required for Scenario #2, with the first reservoir collecting about two-thirds of the flow and then pumping it by means of a pump station to the second reservoir, which also would collect the flow pumped from the remaining wells. The downstream reservoir would then transfer wellfield flow by means of another pump station to a central reservoir at Wahpeton. The pipeline from the last reservoir wellfield and the central reservoir are not included in this evaluation for either scenario. The pipe collection system and reservoir are shown in Figure 2 for Scenario #1 and in Figure 3 for Scenario #2.

Assumptions and Criteria

The assumptions developed for this cost opinion for the wellfield include the following:

- Average well depth is about 250 ft
- Average design production capacity would be 250 gpm per well
- Wells would be placed at locations selected by USBR in the Spiritwood, Brightwood, and Milnor Channel aquifers for Scenario #1, with additional wells in the Gwinner Aquifer for Scenario #2
- Total wellfield design inflow and outflow would be 11.7 cfs (5,250 gpm) for Scenario #1 and 16.7 cfs (7,500 gpm) for Scenario #2
- Pumping level is 180 feet or less (conservative)
- 21 wells for Scenario #1 and 30 wells for Scenario #2
- Well screen average length would be 40 feet (shorter screen may be possible, but a longer screen is preferred to minimize entrance velocities and to allow for the effects of aquifer anisotropy)

Using these assumptions, I estimated that the wellfield for Scenarios #1 and #2 would have the following design criteria:

- Average well depth would be 250 ft, including 40 ft of screen and 10 ft of tailpipe below bottom of aquifer (depth at direction of USBR)
- Screen would be stainless steel
- Well production capacity would be 250 gpm
- Average required pumping head would be 280 ft
- Each well nominal diameter would be ten inches
- Submersible pump in each well would be 30 horsepower and would require 460-V 3-phase power
- Each well would be housed in a well pump and control house
- Each pump system would be managed with a SCADA-type central control system and individual PLC
- Each well lot would require approximately ¾ acre (200 ft x 200 ft) to allow for the wellhouse, security fence, minimum wellhead protection setback, and working space
- One collection reservoir would be located just downstream of the last collector well in Scenario #1, and two reservoirs would be located in the wellfield in Scenario #2, to

facilitate variations in demand, to provide storage in the event of well or pump down time, and to maintain constant pressure

- Pumping to the reservoirs would be accomplished using pumps in the individual wells
- Failed pump or similar equipment problems we have assumed would take no more than 24 hours to repair or replace
- Each reservoir would be designed to contain enough storage capacity to accommodate the production capacity from about ten percent of the wells upstream of the reservoir
- Reservoir(s) would consist of a buried concrete tank.

OPINION OF PROBABLE COST

The average cost per production well is estimated at about $180,000. The preliminary opinion of probable cost for this wellfield is approximately $12.0 million for Scenario #1 and $27.1 million for Scenario #2. Much of the large cost differential between Scenario #1 and Scenario #2 reflects the difference in the required lengths of large-diameter wellfield piping. Scenario #1 has only one reservoir, and it is located further from Wahpeton than the downstream reservoir in Scenario #2. However, some of the cost of this piping, although not included in the wellfield cost opinion shown here, will be incurred in the increased distance of the conveyance pipeline from the wellfield reservoir to Wahpeton. These are unburdened costs. The summary of costs per well are shown in Table 1 for an 11.7 cfs wellfield and Table 2 for a 16.7 cfs wellfield, including an itemized opinion of burdened construction costs.

The opinion of probable cost does not include water quality testing, although it does include an automated sampler for some basic water quality parameters at the wellhead. It does not include costs for a centralized control system, but does include the local controls and telemetry from each wellhead capable of communicating with the SCADA controller. The cost includes pipelines for collection of water from the wells to the wellfield reservoir(s), but it does not include the cost of a central reservoir or of the pipeline to convey water from the wellfield reservoirs to the central reservoir. It also does not include permitting, environmental impact assessments, recharge area buffer zone purchases, or other costs that are likely to be incurred in the project. These costs would be substantial. The costs presented here should be assumed to have an accuracy of plus 25 percent to minus 30 percent.

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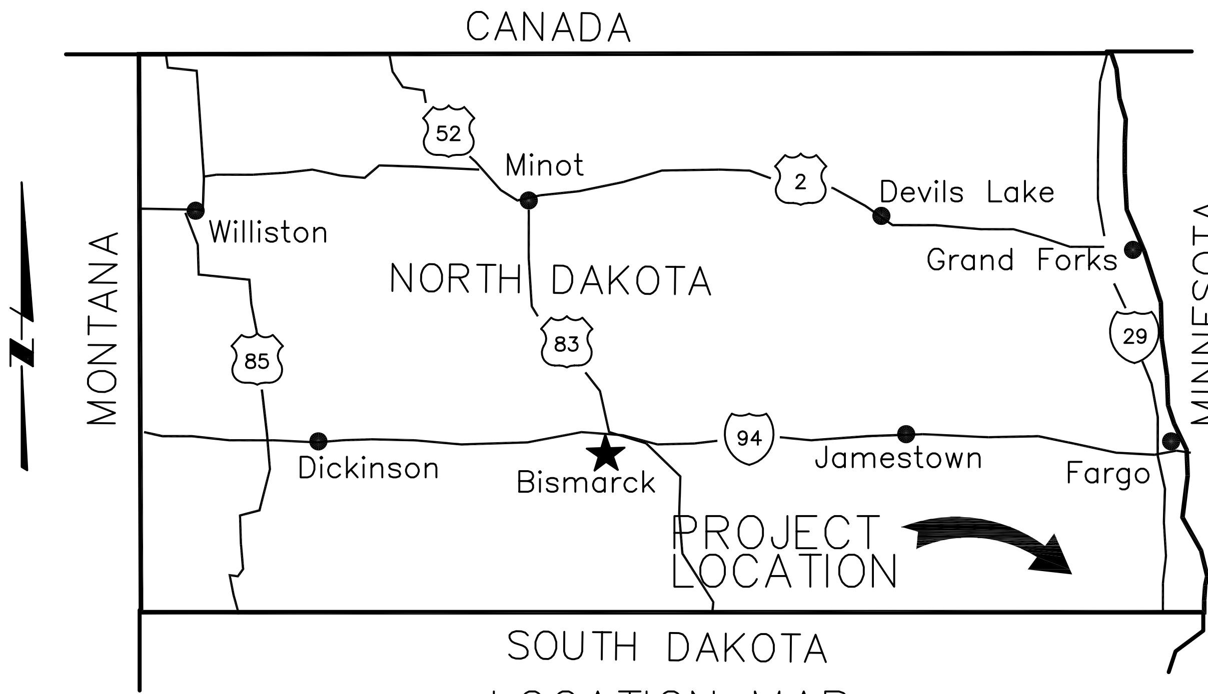
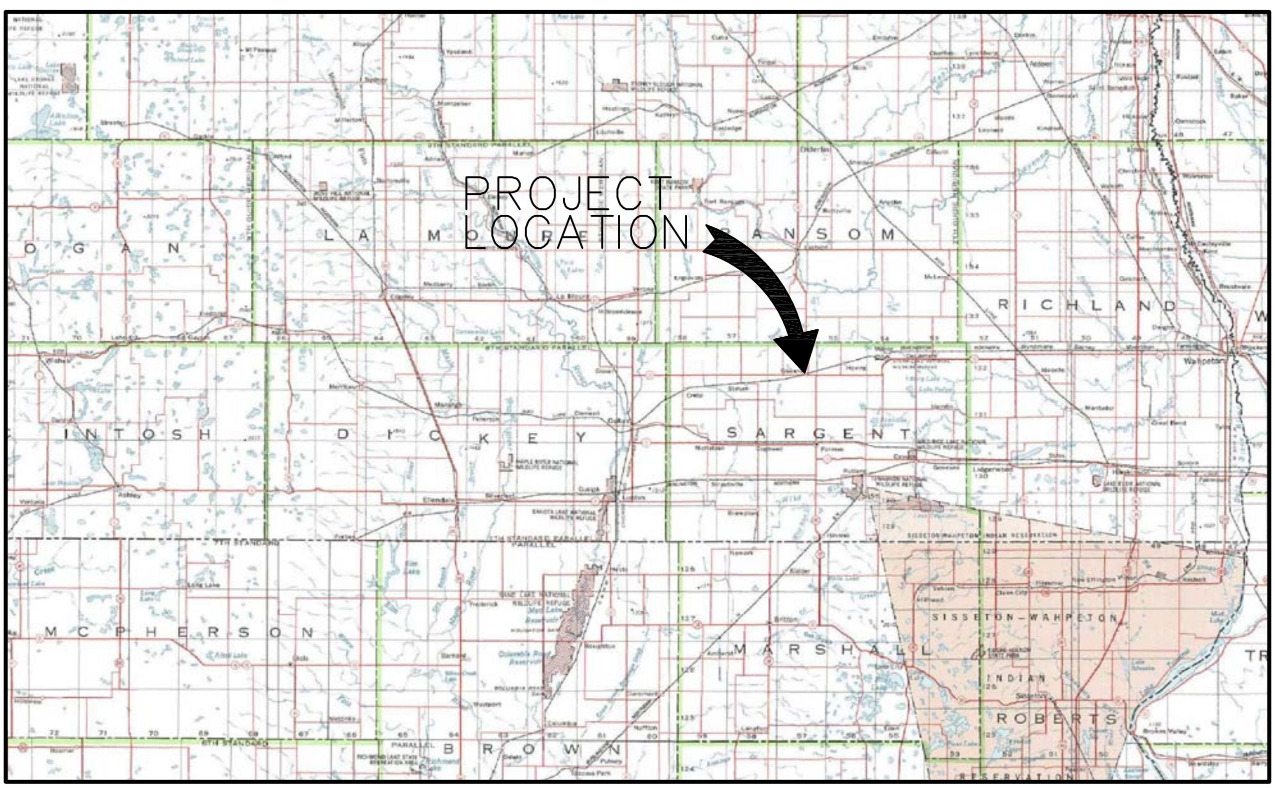


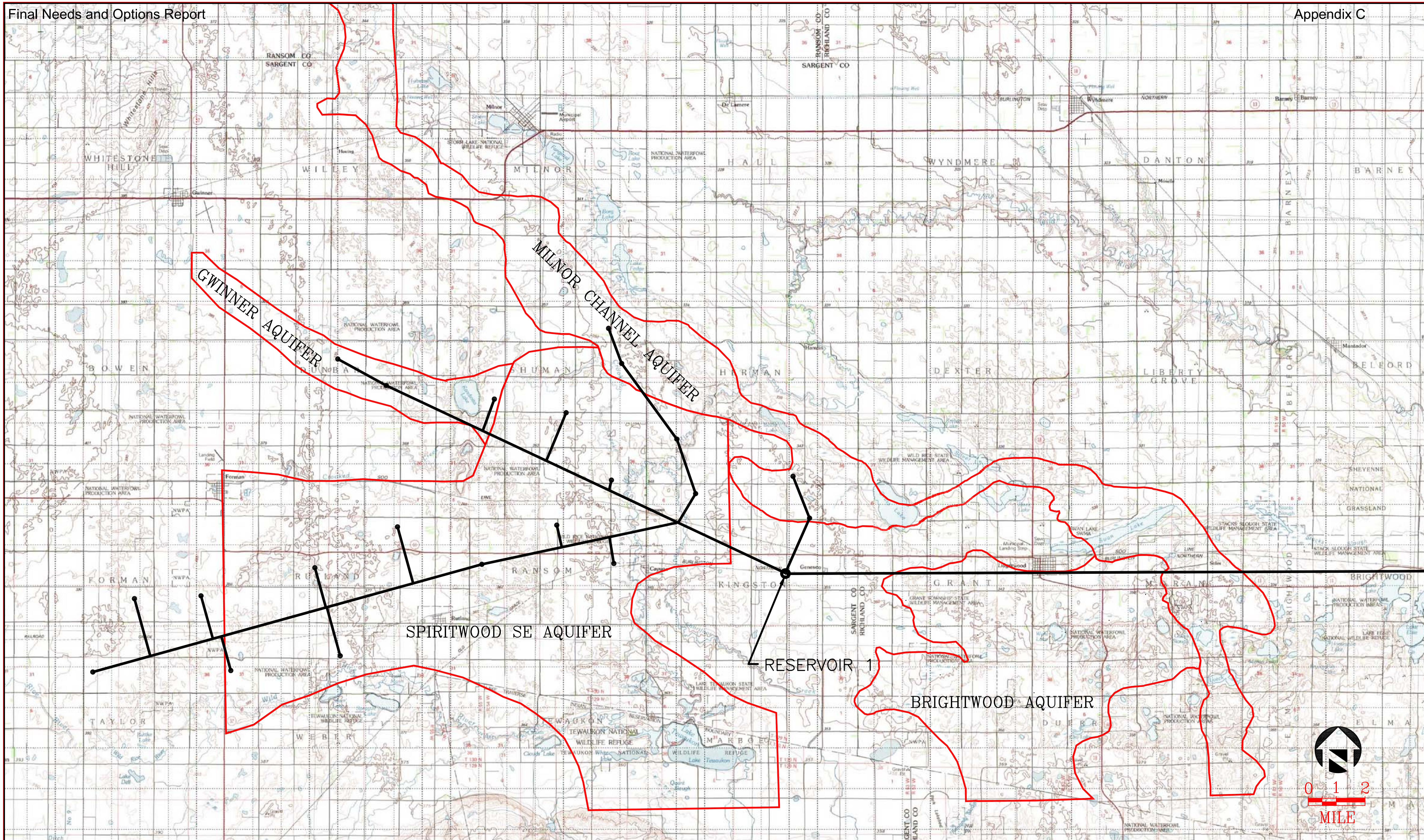
LOCATION MAP



VICINITY MAP

SOUTHEASTERN NORTH DAKOTA AQUIFERS
LOCATION MAP
Figure 1

MWH



SOUTHEASTERN NORTH DAKOTA AQUIFERS
PROPOSED WELLFIELD (11.7 CFS CAPACITY)
Figure 2

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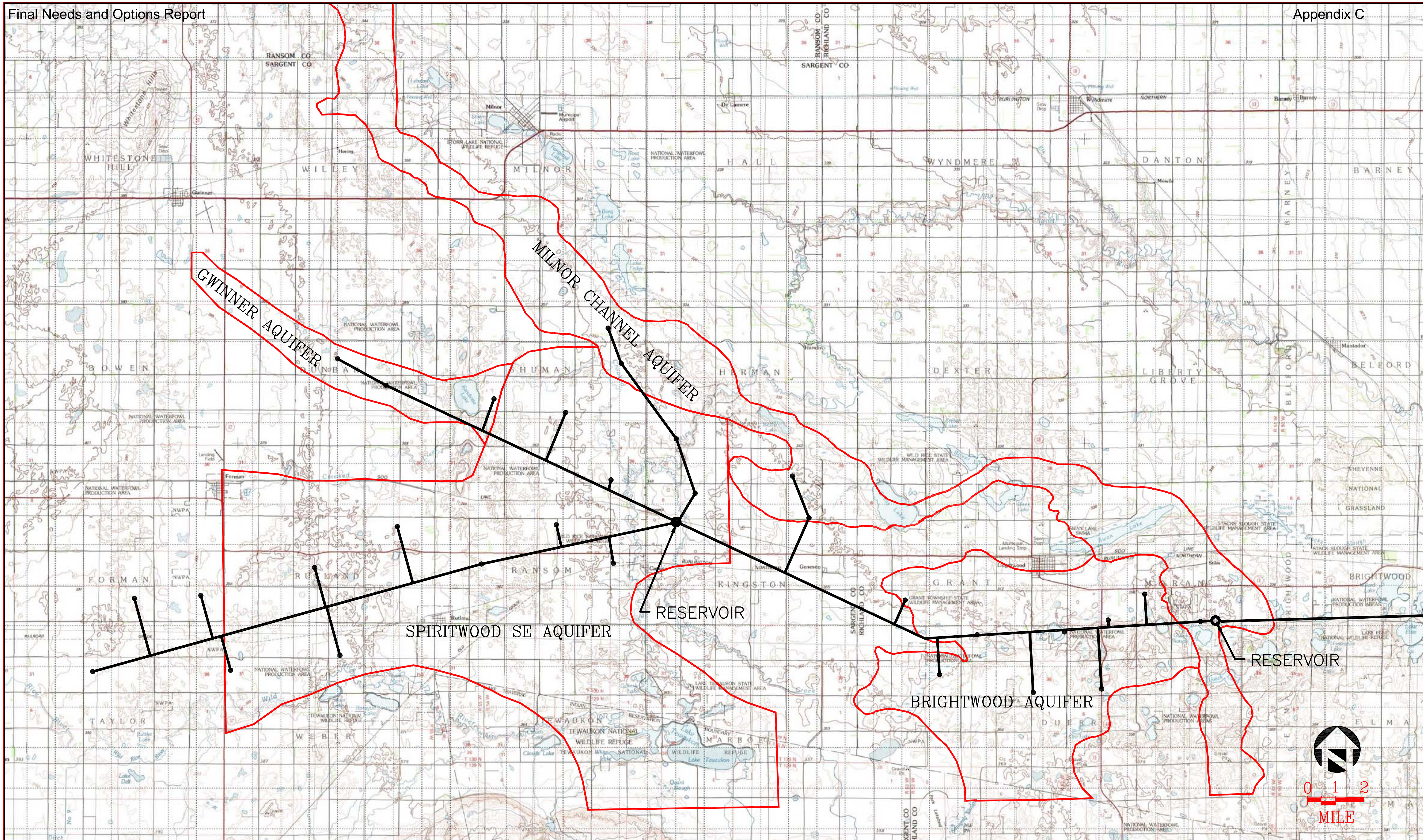


SOUTHEASTERN NORTH DAKOTA AQUIFERS
PROPOSED WELLFIELD (16.7 CFS CAPACITY)
Figure 3

ATTACHMENT 1
PRELIMINARY OPINION OF PROBABLE COST
SOUTHEAST NORTH DAKOTA WAHPETON WELLFIELD
COSTS PER PRODUCTION WELL

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$200	Lin. Ft.	250	$50,000	Estimate based on typ. 10" well costs
Column Pipe (4")	$39	Lin. Ft.	220	$8,580	Means 15107.620.1400
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Outflow Meter with Totalizer	$9,050	Each	1	$9,050	Means 15120.940.1180
Sampling Port	$500	Each	1	$500	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Pump (30 hp Submersible)	$12,000	Each	1	$12,000	Grundfos 7/1/04 price list, plus starter
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Pump House	$20,000	Each	1	$20,000	Assumed based on experience
Chain-Link Fence	$23	Lin. Ft.	800	$18,400	Means 02820.130.0800
Miscellaneous		Each	1	$16,393	10% of costs
TOTAL				**$180,323**	

TABLE 1

PRELIMINARY OPINION OF PROBABLE COST
WAHPETON 11.7 CFS WELLFIELD, RESERVOIRS, PUMP STATIONS, PRESSURE CONTROL STATIONS, AND PIPELINES

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Production Well	21	Each	$180,000	$3,780,000	See Attachment 1
Wellfield Piping:					
6-inch PVC Pipe	117,900	Feet	$10.93	$1,288,647	Quote for RRVWSP Cost Analysis
8-inch PVC Pipe	58,300	Feet	$13.41	$781,803	Quote for RRVWSP Cost Analysis
10-inch PVC Pipe	26,000	Feet	$16.39	$426,140	Quote for RRVWSP Cost Analysis
12-inch PVC Pipe	36,800	Feet	$19.90	$732,320	Quote for RRVWSP Cost Analysis
14-inch PVC Pipe	45,600	Feet	$20.46	$932,976	Quote for RRVWSP Cost Analysis
16-inch PVC Pipe	22,800	Feet	$24.11	$549,708	Quote for RRVWSP Cost Analysis
18-inch PVC Pipe	15,800	Feet	$28.29	$446,982	Quote for RRVWSP Cost Analysis
24-inch DI Pipe	20,300	Feet	$77.82	$1,579,746	Quote for RRVWSP Cost Analysis
Reservoir and Pump Station	720,000	Gallons	$1.75	$1,260,000	Assumes storage for 2 wells/24 hrs and high head/hp pump station; unit cost from experience
Pressure Control Stations	1	Each	$250,000	$250,000	Pressure regulation to maintain high/low pressures; unit cost based on experience.
Pump Station Electrical	1	Each	$20,000	$20,000	
Subtotal (Direct Costs)				**$12,048,322**	

Contractor OH&P (30%)	$3,614,497
Contractor Costs (15%)	$1,807,248
SUBTOTAL (Burdened Costs including mobilization)	**$17,470,067**
Unlisted Items (5% of Subtotal (Burdened))	$873,503
CONTRACT COST	**$18,343,570**
Contingency (25% of Contract Cost)	$4,585,893
FIELD COST	**$22,929,463**
Non-Contractor Costs (25% of Field Costs)	$5,732,366
CONSTRUCTION COST (w/o ROW)	**$28,661,829**

TABLE 2

PRELIMINARY OPINION OF PROBABLE COST
WAHPETON 16.7 CFS WELLFIELD, RESERVOIRS, PUMP STATIONS, PRESSURE CONTROL STATIONS, AND PIPELINES

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Production Well	30	Each	$180,000	$5,400,000	See Attachment 1
Wellfield Piping:					
6-inch PVC Pipe	160,900	Feet	$10.93	$1,758,637	Quote for RRVWSP Cost Analysis
8-inch PVC Pipe	58,300	Feet	$13.41	$781,803	Quote for RRVWSP Cost Analysis
10-inch PVC Pipe	26,000	Feet	$16.39	$426,140	Quote for RRVWSP Cost Analysis
12-inch PVC Pipe	36,800	Feet	$19.90	$732,320	Quote for RRVWSP Cost Analysis
14-inch PVC Pipe	45,600	Feet	$20.46	$932,976	Quote for RRVWSP Cost Analysis
16-inch PVC Pipe	22,800	Feet	$24.11	$549,708	Quote for RRVWSP Cost Analysis
18-inch PVC Pipe	15,800	Feet	$28.29	$446,982	Quote for RRVWSP Cost Analysis
24-inch DI Pipe	60,800	Feet	$77.82	$4,731,456	Quote for RRVWSP Cost Analysis
30-inch DI Pipe	47,500	Feet	$160.77	$7,636,575	Quote for RRVWSP Cost Analysis
Reservoir and Pump Station	1,080,000	Gallons	$1.75	$1,890,000	Assumes storage for 3 wells/24 hrs and high head/hp pump station; unit cost from experience
Reservoir and Pump Station	720,000	Gallons	$1.75	$1,260,000	Assumes storage for 2 wells/24 hrs and high head/hp pump station; unit cost from experience
Pressure Control Stations	2	Each	$250,000	$500,000	Pressure regulation to maintain high/low pressures; unit cost based on experience.
Pump Station Electrical	2	Each	$20,000.00	$40,000	
Subtotal (Direct Costs)				**$27,086,597**	
Contractor OH&P (30%)				$8,125,979	
Contractor Costs (15%)				$4,062,990	
SUBTOTAL (Burdened Costs including mobilization)				**$39,275,566**	
Unlisted Items (5% of Subtotal (Burdened))				$1,963,778	
CONTRACT COST				**$41,239,344**	
Contingency (25% of Contract Cost)				$10,309,836	
FIELD COST				**$51,549,180**	
Non-Contractor Costs (25% of Field Costs)				$12,887,295	
CONSTRUCTION COST (w/o ROW)				**$64,436,475**	

TECHNICAL MEMORANDUM

MWH

To:	Ed Cryer	**Date:**	May 6, 2005
From:	Pat Naylor	**Reference:**	1690583.011801
Subject:	WFN ASR Cost Opinion		

PURPOSE

This preliminary opinion of probable cost pertains to wells and well site equipment for an aquifer storage and recovery (ASR) program under consideration for the West Fargo North (WFN) aquifer in the Fargo/West Fargo area, North Dakota. The location of the WFN aquifer is shown in Figure 1. The ASR program is one option being evaluated to address future water resource needs in this area. This preliminary opinion of probable cost is very general and has been prepared to help determine whether ASR would be an economically viable option.

PROPOSED PROJECT

Wellfield Capacity

The proposed wellfield would have a capacity of 14.5 cfs under Scenario #1 and 14.8 cfs under Scenario #2. Because these capacities are so close together, this evaluation assumes a wellfield capacity of 15 cfs. Costs for a 15 cfs wellfield should be representative for either Scenario #1 or #2.

Production would occur from 45 wells, including 15 dual-use wells and 30 injection wells. The dual-use wells would be used to inject treated water during periods of low demand. Injection would occur at an average of 150 gpm. The design production rate for the dual-use wells would be 500 gpm. All production and injection would occur in the West Fargo North Aquifer. Some existing wells may be available for use, but these wells would eventually be replaced. For the purposes of this evaluation, it is assumed that all wells would be new.

Pipelines

Water pumped from the wells would be conveyed to a downstream reservoir in the wellfield. Pipelines 20 inches in diameter or less would be PVC. Pipelines larger than 20 inches in diameter would be ductile iron.

Reservoir

A reservoir would be located downstream of the pipeline collection system in the wellfield. It would serve the purposes of controlling surge, providing storage, to keep system head within a reasonable range, and regulate delivery pressure. The reservoir would have a pump station to convey flow from the wellfield to a central reservoir in Fargo. A pressure control station also would be constructed as part of the wellfield reservoir. The wellfield reservoir, pump station, and pressure control station are included in this evaluation. The central reservoir, any associated water treatment, and the pipeline to convey flow from the wellfield reservoir to the central reservoir are beyond the scope of this evaluation.

COST OPINION

The costs shown have been prepared using various general sources of information, including preliminary (nonbinding) cost estimates from local contractors, cost estimating aids such as RS Means 2004 Cost Estimating Data, on-line equipment catalogs, on-line equipment quotes, and assumptions based on past experience. Because only limited design information was available, the opinion of probable cost is based on assumptions that were made after reviewing information provided by the U.S. Bureau of Reclamation (unpublished groundwater modeling data and discussion), by Houston Engineers, and by LTP Drilling, as well as from a report prepared by the North Dakota State Water Commission *(Ripley, D.P., 2000, The Water Resource Characteristics of the West Fargo Aquifer System: North Dakota Ground-Water Studies Number 106 – Part II, 233 pp.)*.

The assumptions developed for this cost opinion for the WFN aquifer wellfield include the following:

- Average depth to top of aquifer is about 130 ft
- Average depth to bottom of aquifer is about 215 ft
- Average design production capacity would be 500 gpm per well (outflow)
- Average design recharge capacity would be about 150 gpm per well (inflow)
- Total wellfield design inflow and outflow would be 15 cfs (6,750 gpm)
- Static water level is between roughly 100 to 130 ft
- 45 wells at 15 sites, including 15 dual-use wells and 30 injection wells
- Well screen average length would be 40 feet (shorter screen may be possible, but a longer screen is preferred to minimize entrance velocities and to allow for the effects of aquifer anisotropy)
- Up to seven existing wells, which may be available for use during initial phases of the project, would be replaced by new wells; therefore cost opinion assumes new wells required at all locations
- One monitoring well would be required downgradient of each injection or dual-use well for the purpose of monitoring water quality impacts on the aquifer

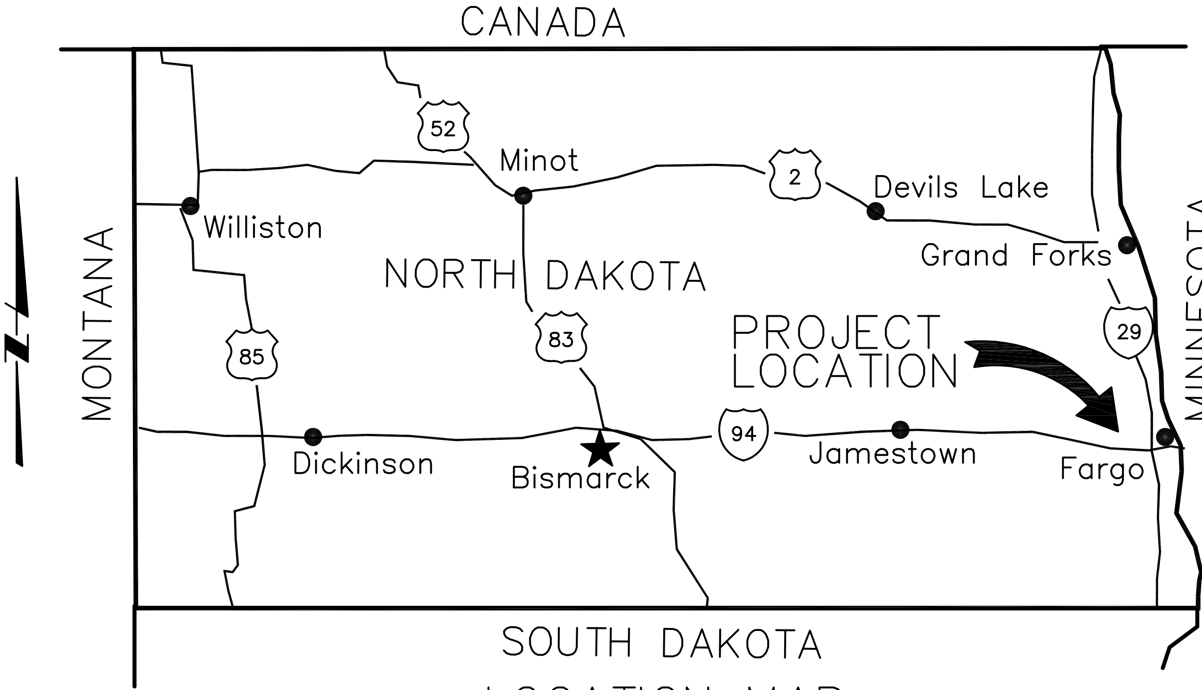
Using these assumptions, I estimated that an ASR wellfield in the WFN aquifer system would have the following design criteria:

- Wells would be installed at 15 locations, with one dual-use well and two injection wells at each location (three wells per location, 45 total)
- Wells would be spaced 500 ft apart at the 15 locations as directed by the U.S. Bureau of Reclamation
- Average well depth would be 225 ft, including 40 ft of screen and 10 ft of tailpipe below bottom of aquifer
- Screen would be stainless steel
- A vacuum seal would be maintained in the well above the water level to reduce casing rust
- Well production capacity (outflow) would be 500 gpm
- Average required head (in and out) would be 250 ft
- Each well nominal diameter would be 12 inches (conservative)
- ASR system would use a single column pipe for injection and discharge, with a 2-way valve to prevent backflow, air entrainment, and water hammer (15 dual wells)
- Injection wells would use same valving but would not require submersible pump (30 wells)
- Submersible pump in each dual well would be 50 horsepower and would require 460-V 3-phase power
- Each dual well would have separate inflow and outflow lines at the wellhead with totalizing flow meters (15 wells)
- Each injection well would have only inflow lines
- Each dual-use well would be housed in an HVAC-regulated pump and control house
- Each injection well would be housed in a non-HVAC-regulated control house
- Each pump system would be managed with a SCADA-type central control system and individual PLC
- Each well lot would require approximately ¾ acre (200 ft x 200 ft) to allow for the wellhouse, security fence, minimum wellhead protection setback, and working space
- Injection pumping head would originate from a separate reservoir pump station
- Each monitoring well would be located downgradient of an injection or dual-use well
- Each monitoring well would be the same depth as the associated injection or dual-use well
- One collection reservoir would be located just downstream of the last collector well to facilitate variations in demand, to provide storage in the event of well or pump down time, and to maintain constant pressure.
- Pumping to the reservoir would be accomplished using pumps in the individual wells.
- Failed pump or similar equipment problems we have assumed would take no more than 24 hours to repair or replace
- Reservoir would be designed to contain enough storage capacity to accommodate the production capacity from about ten percent of the dual-use wells (i.e. two total wells in this case) to be out of service for 24 hours (at 500 gpm each for two wells, reservoir would hold about 1.5 million gallons)
- Reservoir would be a buried concrete tank.

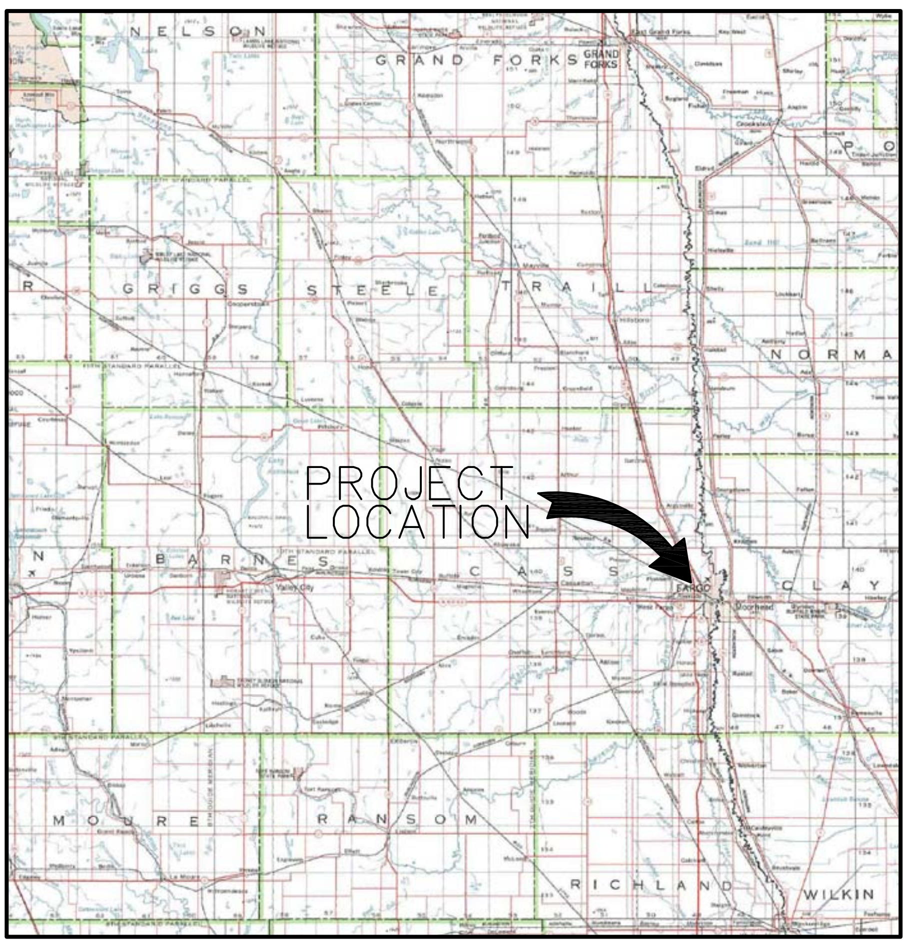
The wellfield configuration used for the opinion of probable cost is shown in Figure 2.

The opinion of probable cost does not include water quality testing, although it does include an automated sampler for some basic water quality parameters at the wellhead. The cost opinion also includes one monitoring well for each injection and dual-use well, for the purpose of monitoring impacts of recharge on aquifer water quality. It does not include costs for a centralized control system, but does include the local controls and telemetry from each wellhead capable of communicating with the SCADA controller. The cost opinion does include a wellfield reservoir located just downstream of the wellfield. The cost includes pipelines for collection of water from the wells to the wellfield reservoir but does not include the pipeline from the wellfield reservoir to a central reservoir near Fargo, and it does not include the cost of a central reservoir.

The average cost per dual use well is preliminarily estimated to be about $271,000. The average cost per injection well is estimated at about $226,000. The preliminary opinion of probable cost for this wellfield is approximately $17.1 million. These are unburdened costs. The summary of the opinion of probable costs are shown in Table 1, including an itemized opinion of burdened construction costs.



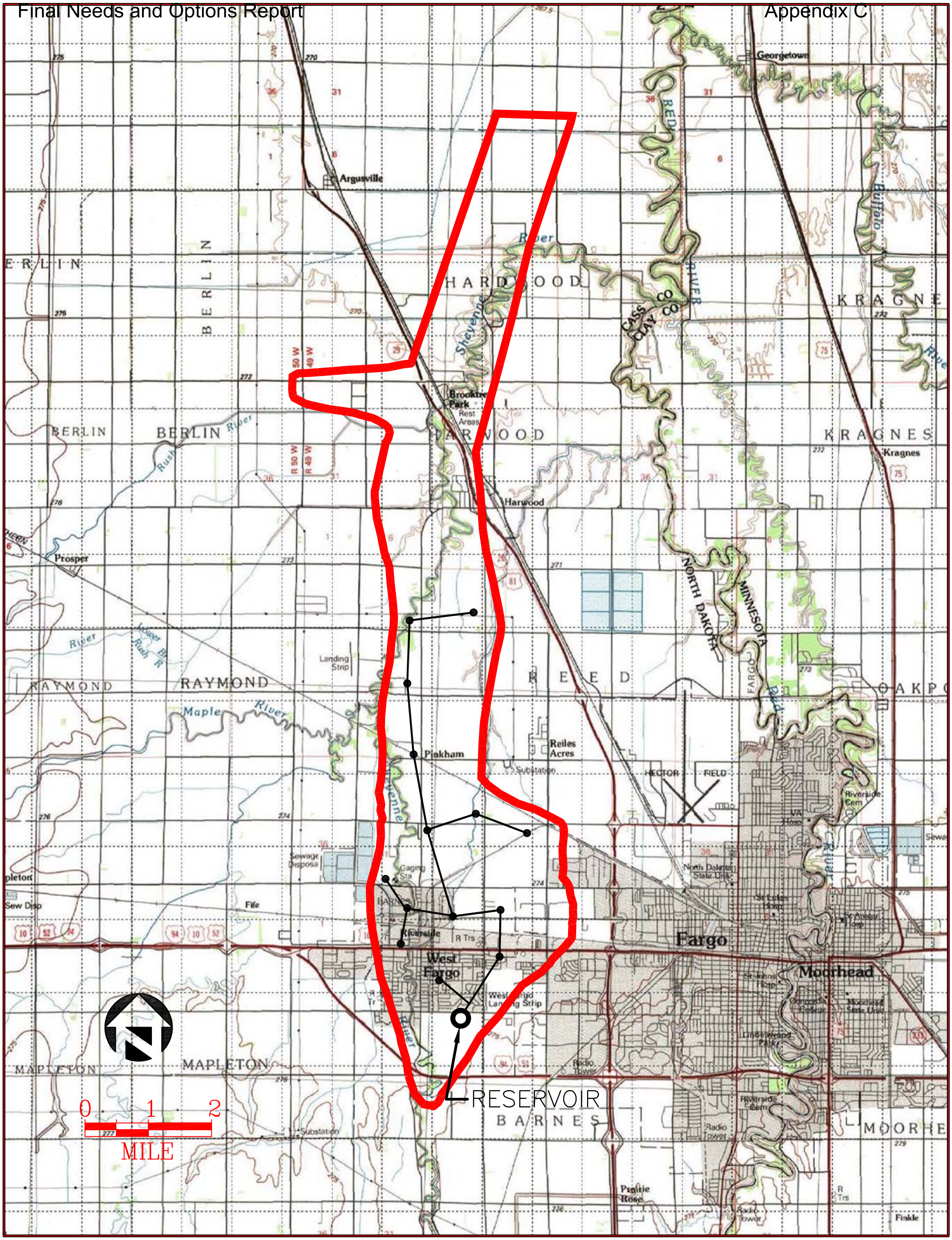
LOCATION MAP



VICINITY MAP

WEST FARGO NORTH AQUIFER
LOCATION MAP
Figure 1

MWH



WEST FARGO NORTH AQUIFER
PROPOSED WELL FIELD
Figure 2

MWH

ATTACHMENT 1
ASR PRELIMINARY OPINION OF PROBABLE COST
WEST FARGO NORTH WELLFIELD
COSTS PER DUAL USE WELL

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$48,165	Each	1	$48,165	Quote, modified, see attached
Column Pipe (6")	$69	Lin. Ft.	180	$12,420	Means 15107.620.1410
Valve (2-way)	$40,000	Each	1	$40,000	Verbal estimate from Baski Valves
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Inflow Meter with Totalizer	$13,000	Each	1	$13,000	Means 15120.940.1220
Outflow Meter with Totalizer	$13,000	Each	1	$13,000	Means 15120.940.1220
Automated Water Quality Monit. (pH, Turb, TDS, T)	$18,000	Each	1	$18,000	Assumed based on experience
Sampling Ports (Injection and Recovery)	$500	Each	2	$1,000	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Pump (50 hp Submersible)	$17,000	Each	1	$17,000	Grundfos 7/1/04 price list, plus starter
Pump House w/HVAC	$20,000	Each	1	$20,000	Assumed based on experience
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Chain-Link Fence	$23	Lin. Ft.	800	$18,400	Means 02820.130.0800
Miscellaneous		Each	1	$24,639	10% of costs
TOTAL				**$271,024**	

ATTACHMENT 2
ASR PRELIMINARY OPINION OF PROBABLE COST
WEST FARGO NORTH WELLFIELD
COSTS PER INJECTION WELL

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$45,650	Each	1	$45,650	Quote, see attached
Column Pipe (5")	$53	Lin. Ft.	180	$9,540	Means 15107.620.1410
Valve (2-way)	$40,000	Each	1	$40,000	Verbal estimate from Baski Valves
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Inflow Meter with Totalizer	$9,050	Each	1	$9,050	Means 15120.940.1180
Automated Water Quality Monit. (pH, Turb, TDS, T)	$18,000	Each	1	$18,000	Assumed based on experience
Sampling Ports (Injection and Recovery)	$500	Each	2	$1,000	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Pump House	$18,000	Each	1	$18,000	Assumed based on experience
Chain-Link Fence	$23	Lin. Ft.	800	$18,400	Means 02820.130.0800
Miscellaneous		Each	1	$20,504	10% of costs
TOTAL				**$225,544**	

TABLE 1

PRELIMINARY OPINION OF PROBABLE COST
WEST FARGO NORTH 15 CFS ASR WELLFIELD, RESERVOIR, PUMP STATION, PRESSURE CONTROL STATION, AND PIPELINES

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Dual Use Well	15	Each	$271,000	$4,065,000	See Attachment 1
Injection Well	30	Each	$226,000	$6,780,000	See Attachment 2
Monitoring Well	10,125	Feet	$15	$151,875	Unit cost estimate from LTP Drilling; 1 for each dual use or production well, same depth
Wellfield Piping:					
6-inch PVC Pipe	15,000	Feet	$10.93	$163,950	Quote for RRVWSP Cost Analysis
8-inch PVC Pipe	20,460	Feet	$13.41	$274,369	Quote for RRVWSP Cost Analysis
12-inch PVC Pipe	9,600	Feet	$19.90	$191,040	Quote for RRVWSP Cost Analysis
14-inch PVC Pipe	9,840	Feet	$20.46	$201,326	Quote for RRVWSP Cost Analysis
16-inch PVC Pipe	6,160	Feet	$24.11	$148,518	Quote for RRVWSP Cost Analysis
20-inch PVC Pipe	7,480	Feet	$32.85	$245,718	Quote for RRVWSP Cost Analysis
24-inch DI Pipe	3,960	Feet	$77.82	$308,167	Quote for RRVWSP Cost Analysis
30-inch DI Pipe	10,560	Feet	$160.77	$1,697,731	Quote for RRVWSP Cost Analysis
Reservoir and Pump Station	1,500,000	Gallons	$1.75	$2,625,000	Assumes storage for 2 wells/24 hrs and high head/hp pump station; unit cost from experience
Pressure Control Station	1	Each	$250,000	$250,000	Pressure regulation to maintain high/low pressures; unit cost based on experience
Pump Station Electrical	1	Each	$40,000	$40,000	
Subtotal (Direct Costs)				$17,142,694	

Contractor OH&P (30%)	**$5,142,808**
Contractor Costs (15%)	$2,571,404
SUBTOTAL (Burdened Costs including mobilization)	**$24,856,906**
Unlisted Items (5% of Subtotal (Burdened))	$1,242,845
CONTRACT COST	**$26,099,752**
Contingency (25% of Contract Cost)	$6,524,938
FIELD COST	**$32,624,690**
Non-Contractor Costs (25% of Field Costs)	$8,156,172
CONSTRUCTION COST (w/o ROW)	**$40,780,862**

TECHNICAL MEMORANDUM

MWH

To:	Ed Cryer	**Date:**	May 6, 2005
From:	Pat Naylor	**Reference:**	1690583.011801
Subject:	WFS ASR Cost Opinion		

PURPOSE

This evaluation and preliminary opinion of probable cost has bee prepared for wells and well site equipment for an aquifer storage and recovery (ASR) program under consideration for the West Fargo South (WFS) aquifer in the Fargo/West Fargo area, North Dakota. The location of the project is shown in Figure 1. The ASR program is one option being evaluated to address future water resource needs in this area. The preliminary opinion of probable cost is very general and has been prepared to help determine whether ASR would be an economically viable option. It addresses two scenarios, including a 40 cfs production capacity (Scenario #1) and a 47 cfs production capacity (Scenario #2).

PROPOSED PROJECT

Wellfield Capacity

The proposed wellfield would have a capacity of 40 cfs (about 18,000 gpm) under Scenario #1 and 47 cfs (about 21,000 gpm) under Scenario #2. Production would occur from 36 wells in Scenario #1, including 15 dual-use wells and 21 production wells. Scenario #2 would have 42 wells, including 18 dual-use wells and 24 production wells. The dual-use wells would be used to inject treated water during periods of low demand. Injection would occur at an average of 200 gpm. The design production rate for the dual-use wells would be 500 gpm. All production and injection would occur in the West Fargo South Aquifer.

Pipelines

Water pumped from the wells would be conveyed to a downstream reservoir in the wellfield. Pipelines 20 inches in diameter or less would be PVC. Pipelines larger than 20 inches in diameter would be ductile iron. Pipelines would collect water from the individual wells to a wellfield reservoir.

Reservoir

A reservoir would be located downstream of the pipeline collection system in the wellfield. It would serve the purposes of controlling surge, providing storage, to keep system head within a reasonable range, and regulate delivery pressure. The reservoir would hold the 24-hour pumping capacity of about ten percent of the wells in the wellfield.

The reservoir would have a pump station to convey flow from the wellfield to a central reservoir in Fargo. A pressure control station also would be constructed as part of the wellfield reservoir. The wellfield reservoir, pump station, and pressure control station are included in this evaluation. The central reservoir, any associated water treatment, and the pipeline to convey flow from the wellfield reservoir to the central reservoir are beyond the scope of this evaluation.

COST OPINION

The costs shown have been prepared using various general sources of information, including preliminary (nonbinding) cost estimates from local contractors, cost estimating aids such as RS Means 2004 Cost Estimating Data, on-line equipment catalogs, on-line equipment quotes, and assumptions based on past experience. Because only preliminary design information was available, the opinion of probable cost is based in part on direction from the U.S. Bureau of Reclamation (USBR) and on assumptions that were made after reviewing information provided by the USBR (unpublished groundwater modeling data and discussion), by Houston Engineers, and by LTP Drilling, as well as from a report prepared by the North Dakota State Water Commission *(Ripley, D.P., 2000, The Water Resource Characteristics of the West Fargo Aquifer System: North Dakota Ground-Water Studies Number 106 – Part II, 233 pp.).*

The assumptions developed for this cost opinion for the WFS aquifer wellfield include the following:

- Average depth to top of aquifer is approximately 150 ft
- Average well depth is 285 ft
- Average design production capacity would be 500 gpm per well (outflow)
- Average design recharge (injection) capacity would be approximately 200 gpm per well (inflow)
- Total wellfield design inflow and outflow would be 40 cfs (18,000 gpm) for the first scenario and 47 cfs (21,000 gpm) for the second scenario
- Static water level is between roughly 100 to 130 ft
- 36 wells, including 15 dual-use wells and 21 production wells, for a 40 cfs wellfield
- 42 wells, including 18 dual-use wells and 24 production wells, for a 47 cfs wellfield
- Well screen average length would be 40 feet (shorter screen may be possible, but a longer screen is preferred to minimize entrance velocities and to allow for the effects of aquifer anisotropy)
- One monitoring well would be required downgradient of each injection or dual-use well for the purpose of monitoring water quality impacts on the aquifer

Using these assumptions, I estimated that an ASR wellfield in the WFS aquifer system would have the following design criteria:

- Wells would be placed at locations previously determined by the U.S. Bureau of Reclamation for the 47 cfs wellfield (see Figure 3)
- Wells would be placed at locations previously by USBR for the 40 cfs wellfield, but three dual-use wells and three production wells would be omitted at selected locations spread throughout the wellfield (see Figure 2)
- Average well depth would be 285 ft, including 40 ft of screen and 5 ft of tailpipe below bottom of aquifer
- Screen would be stainless steel
- A vacuum seal would be maintained in the well above the water level to reduce casing rust
- Dual-use well and production well capacity (outflow) would be 500 gpm
- Dual-use well injection capacity (inflow) would be 200 gpm
- Average required head (in and out) would be 300 ft
- Each well nominal diameter would be 12 inches
- ASR system (dual use wells) would use a single column pipe for injection and discharge, with a 2-way valve to prevent backflow, air entrainment, and water hammer
- Submersible pump in each dual-use and production well would be 60 horsepower and would require 460-V 3-phase power
- Each dual-use well would have separate inflow and outflow lines at the wellhead with totalizing flow meters
- Each production well would have only outflow lines
- Each well would be housed in an HVAC-regulated pump house
- Each pump system would be managed with a SCADA-type central control system and individual PLC
- Each well lot would be approximately ¾ acre (200 ft x 200 ft) to allow for the wellhouse, security fence, minimum wellhead protection setback, and working space
- Each monitoring well would be located downgradient of an injection or dual-use well
- Each monitoring well would be the same depth as the associated injection or dual-use well
- Injection pumping head would originate from a separate reservoir pump station (not included in cost opinion). One collection reservoir would be located just downstream of the last collector well to facilitate variations in demand, to provide storage in the event of well or pump down time, and to maintain constant pressure.
- Pumping to the reservoir would be accomplished using pumps in the individual wells.
- Failed pump or similar equipment problem would take no more than 24 hours to repair or replace
- Reservoir would be designed to contain enough storage capacity to accommodate the production capacity from about ten percent of the wells (i.e. four total wells in this case) to be out of service for 24 hours (at 500 gpm each for four wells, reservoir would hold about 2.88 million gallons)
- Reservoir would be a buried concrete tank.

Figure 2 shows the wellfield configuration used for the 40 cfs scenario opinion of probable cost. Figure 3 shows the configuration used for the 47 cfs cost opinion.

The opinion of probable cost does not include water quality testing, although it does include an automated sampler for some basic water quality parameters at the wellhead, and it does include the cost of a monitoring well downgradient of each injection or dual-use well. It does not include costs for a centralized control system, but does include the local controls and telemetry from each wellhead capable of communicating with the SCADA controller. The cost opinion does include a wellfield reservoir located just downstream of the wellfield. The cost includes pipelines for collection of water from the wells to the wellfield reservoir, but it does not include the pipeline from the wellfield reservoir to a central reservoir near Fargo, and it does not include the cost of a central reservoir.

The average cost per dual-use well is preliminarily estimated to be about $281,000. The average cost per production well is estimated at about $198,000. The preliminary opinion of probable cost for this wellfield is approximately $18.6 million for a 40 cfs capacity wellfield and approximately $20.2 million for a 47 cfs capacity wellfield. These are unburdened costs. The summary of costs per well are shown in Table 1 for a 40 cfs wellfield and Table 2 for a 47 cfs wellfield, including an itemized opinion of burdened construction costs.
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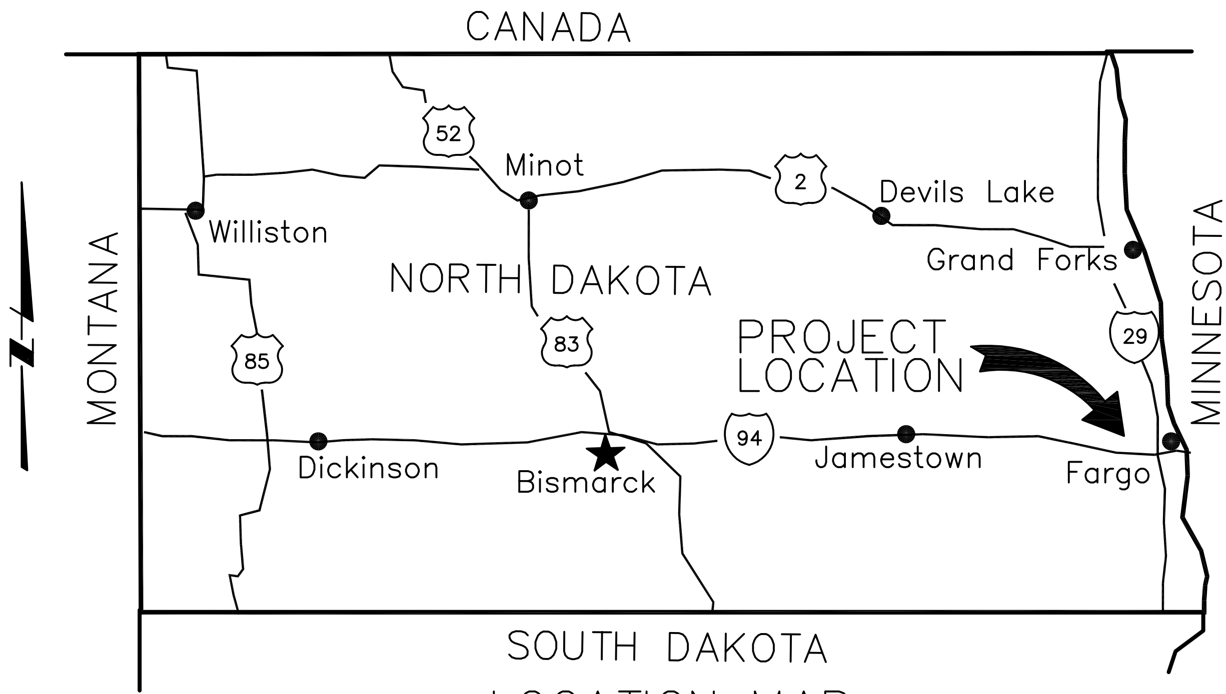
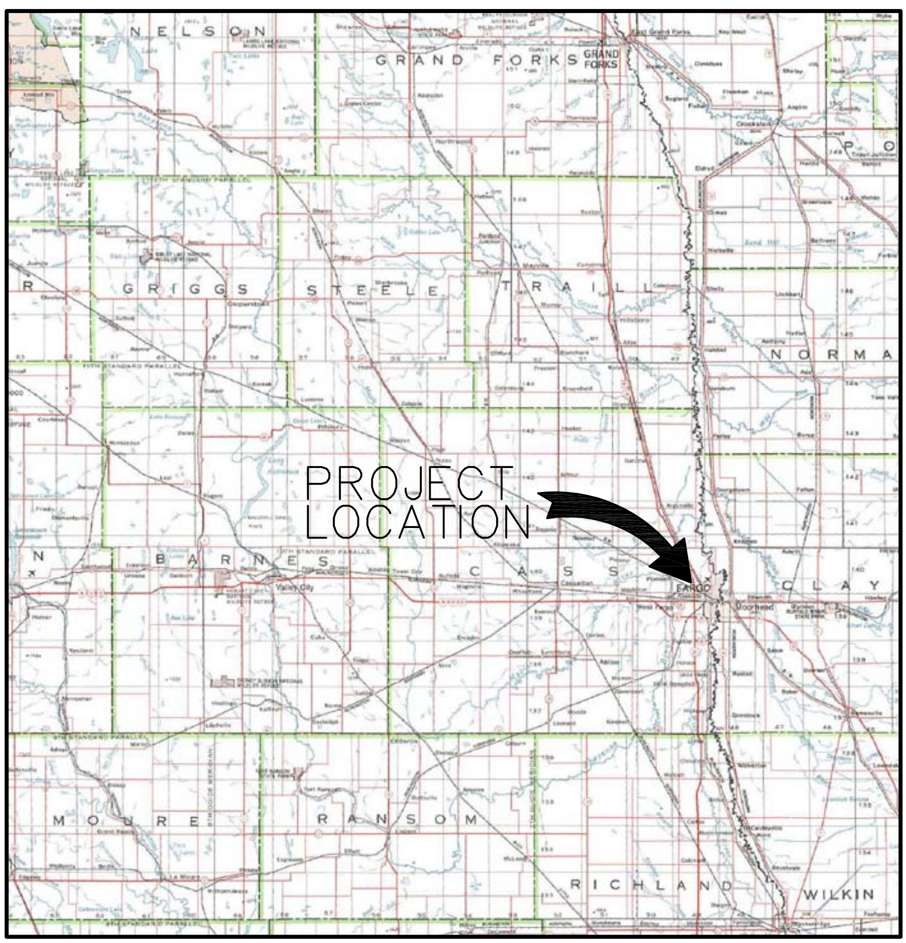


LOCATION MAP



VICINITY MAP

WEST FARGO SOUTH AQUIFER
LOCATION MAP
Figure 1

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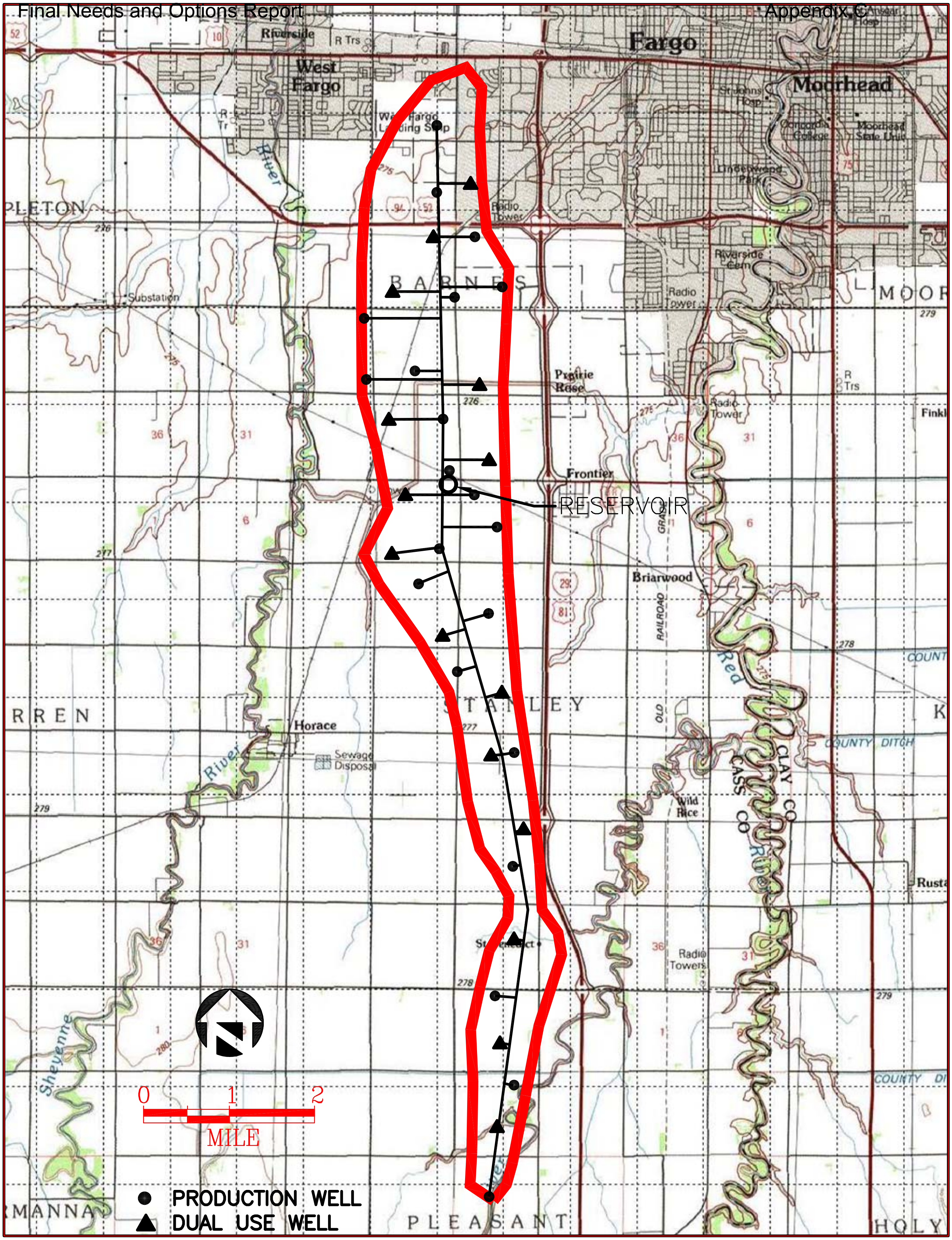

WEST FARGO SOUTH AQUIFER
PROPOSED WELL FIELD (40 CFS)
Figure 2

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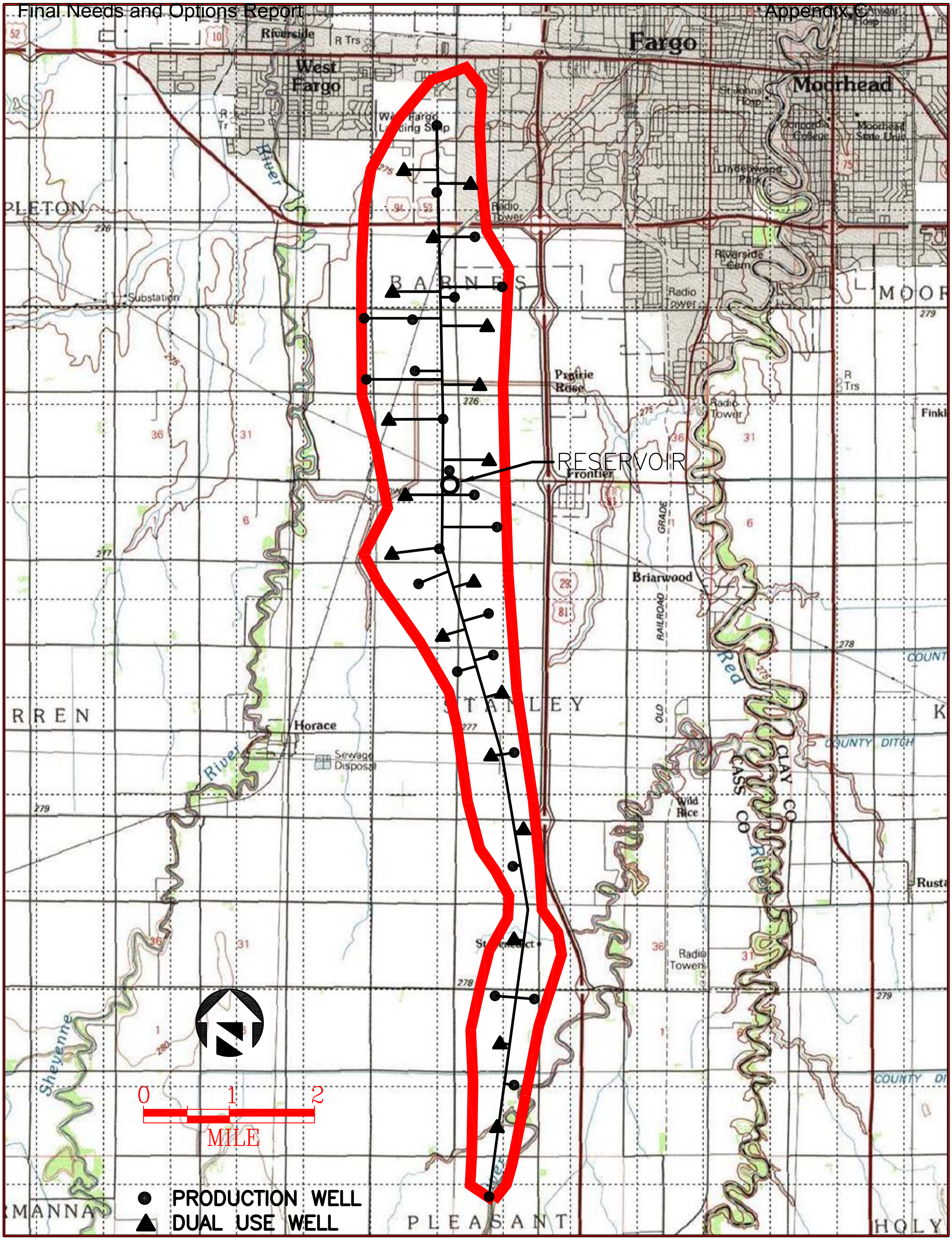

WEST FARGO SOUTH AQUIFER
PROPOSED WELL FIELD (47 CFS)
Figure 3

ATTACHMENT 1
ASR PRELIMINARY OPINION OF PROBABLE COST
WEST FARGO SOUTH WELLFIELD
COSTS PER DUAL USE WELL

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$54,710	Each	1	$54,710	Estimate from driller
Column Pipe (6")	$69	Lin. Ft.	220	$15,180	Means 15107.620.1410
Valve (2-way)	$40,000	Each	1	$40,000	Verbal estimate from Baski Valves
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Inflow Meter with Totalizer	$13,000	Each	1	$13,000	Means 15120.940.1220
Outflow Meter with Totalizer	$13,000	Each	1	$13,000	Means 15120.940.1220
Automated Water Quality Monit. (pH, Turb, TDS, T)	$18,000	Each	1	$18,000	Assumed based on experience
Sampling Ports (Injection and Recovery)	$500	Each	2	$1,000	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Pump (60 hp Submersible)	$17,000	Each	1	$17,000	Assumed based on experience
Pump House w/HVAC	$20,000	Each	1	$20,000	Assumed based on experience
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Chain-Link Fence	$23	Lin. Ft.	800	$18,400	Means 02820.130.0800
Miscellaneous		Each	1	$25,569	10% of costs
TOTAL				**$281,259**	

ATTACHMENT 2
ASR PRELIMINARY OPINION OF PROBABLE COST
WEST FARGO SOUTH WELLFIELD
COSTS PER PRODUCTION WELL

ITEM	UNIT COST	UNIT	QTY.	TOTAL COST	SOURCE
Well	$54,710	Each	1	$54,710	Quote, see attached
Column Pipe (6")	$69	Lin. Ft.	220	$15,180	Means 15107.620.1410
Miscellaneous Valves	$1,000	Each	3	$3,000	Assumed based on experience
Overflow/Bypass Valve and Piping	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Relief Valve (4")	$2,500	Each	1	$2,500	Assumed based on experience
Pressure Transducer	$300	Each	1	$300	Catalog list price, see attached
Emergency Pressure Shutoff Switch	$100	Each	1	$100	Catalog list price, see attached
Outflow Meter with Totalizer	$9,050	Each	1	$9,050	Means 15120.940.1180
Sampling Port	$500	Each	1	$500	Assumed based on experience
Automated Control (Wellhead)	$20,000	Each	1	$20,000	Assumed based on experience
Pressure/Overflow Relief (6' ID x 10' Manhole)	$4,000	Each	1	$4,000	Means 02630.400.1210
Pump (60 hp Submersible)	$17,000	Each	1	$17,000	Assumed based on experience
Electrical	$6,000	Each	1	$6,000	Assumed based on experience
Double Check Backflow Preventer	$7,000	Each	1	$7,000	Means 15140.100.1240
Pump House	$20,000	Each	1	$20,000	Assumed based on experience
Chain-Link Fence	$23	Lin. Ft.	800	$18,400	Means 02820.130.0800
Miscellaneous		Each	1	$18,024	10% of costs
TOTAL				**$198,264**	

TABLE 1

PRELIMINARY OPINION OF PROBABLE COST
WEST FARGO SOUTH 40 CFS ASR WELLFIELD, RESERVOIRS, PUMP STATIONS, PRESSURE CONTROL STATIONS, AND PIPELINES

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Dual Use Well	15	Each	$281,000	$4,215,000	See attached
Production Well	21	Each	$198,000	$4,158,000	See attached
Monitoring Well	4,275	Feet	$15	$64,125	Unit cost estimate from LTP Drilling; 1 for each dual use or production well, same depth
Wellfield Piping:					
8-inch PVC Pipe	64,170	Feet	$13.41	$860,520	Quote for RRVWSP Cost Analysis
12-inch PVC Pipe	3,170	Feet	$19.90	$63,083	Quote for RRVWSP Cost Analysis
14-inch PVC Pipe	5,000	Feet	$20.46	$102,300	Quote for RRVWSP Cost Analysis
16-inch PVC Pipe	3,170	Feet	$24.11	$76,429	Quote for RRVWSP Cost Analysis
18-inch PVC Pipe	9,680	Feet	$28.29	$273,847	Quote for RRVWSP Cost Analysis
20-inch PVC Pipe	12,000	Feet	$32.85	$394,200	Quote for RRVWSP Cost Analysis
24-inch DI Pipe	11,100	Feet	$77.82	$863,802	Quote for RRVWSP Cost Analysis
30-inch DI Pipe	13,340	Feet	$160.77	$2,144,672	Quote for RRVWSP Cost Analysis
Reservoir and Pump Station	2,888,000	Gallons	$1.75	$5,054,000	Assumes storage for 4 wells/24 hrs and high head/hp pump station; unit cost from experience
Pressure Control Station	1	Each	$250,000	$250,000	Pressure regulation to maintain high/low pressures; unit cost based on experience
Pump Station Electrical	1	Each	$40,000	$40,000	Assumed based on experience
Subtotal (Direct Costs)				$18,559,977	

Contractor OH&P (30%)	**$5,567,993**
Contractor Costs (15%)	$2,783,997
SUBTOTAL (Burdened Costs including mobilization)	**$26,911,967**
Unlisted Items (5% of Subtotal (Burdened))	$1,345,598
CONTRACT COST	**$28,257,566**
Contingency (25% of Contract Cost)	$7,064,391
FIELD COST	**$35,321,957**
Non-Contractor Costs (25% of Field Costs)	$8,830,489
CONSTRUCTION COST (w/o ROW)	**$44,152,446**

TABLE 2

PRELIMINARY OPINION OF PROBABLE COST
WEST FARGO SOUTH 47 CFS ASR WELLFIELD, RESERVOIRS, PUMP STATIONS, PRESSURE CONTROL STATIONS, AND PIPELINES

Feature	Quantity	Unit	Unit Cost	Feature Cost	Remarks
Dual Use Well	18	Each	$281,000	$5,058,000	See attached
Production Well	24	Each	$198,000	$4,752,000	See attached
Monitoring Well	5,130	Feet	$15	$76,950	Unit cost estimate from LTP Drilling; 1 for each dual use or production well, same depth
Wellfield Piping:					
8-inch PVC Pipe	69,500	Feet	$13.41	$931,995	Quote for RRVWSP Cost Analysis
12-inch PVC Pipe	5,280	Feet	$19.90	$105,072	Quote for RRVWSP Cost Analysis
14-inch PVC Pipe	4,770	Feet	$20.46	$97,594	Quote for RRVWSP Cost Analysis
16-inch PVC Pipe	3,060	Feet	$24.11	$73,777	Quote for RRVWSP Cost Analysis
18-inch PVC Pipe	10,560	Feet	$28.29	$298,742	Quote for RRVWSP Cost Analysis
20-inch PVC Pipe	12,000	Feet	$32.85	$394,200	Quote for RRVWSP Cost Analysis
24-inch DI Pipe	13,630	Feet	$77.82	$1,060,687	Quote for RRVWSP Cost Analysis
30-inch DI Pipe	12,260	Feet	$160.77	$1,971,040	Quote for RRVWSP Cost Analysis
Reservoir and Pump Station	2,880,000	Gallons	$1.75	$5,040,000	Assumes storage for 4 wells/24 hrs and high head/hp pump station; unit cost from experience
Pressure Control Station	1	Each	$250,000	$250,000	Pressure regulation to maintain high/low pressures; unit cost based on experience.
Pump Station Electrical	1	Each	$40,000	$40,000	Assumed based on experience
Subtotal (Direct Costs)				**$20,150,057**	

Contractor OH&P (30%)	$6,045,017
Contractor Costs (15%)	$3,022,509
SUBTOTAL (Burdened Costs including mobilization)	**$29,217,583**
Unlisted Items (5% of Subtotal (Burdened))	$1,460,879
CONTRACT COST	**$30,678,462**
Contingency (25% of Contract Cost)	$7,669,615
FIELD COST	**$38,348,077**
Non-Contractor Costs (25% of Field Costs)	$9,587,019
CONSTRUCTION COST (w/o ROW)	**$47,935,097**

Appendix C – Attachment 6

Right-of-way Cost Estimates

Report on Red River Valley Water Supply Project
Estimated Right of Way Costs
Bureau of Reclamation May 2005

Introduction
Cost estimates for each of the proposed options (alternatives) for the Red River Valley Water Supply Project must include the costs of obtaining land or land rights on which facilities will be constructed. These rights of way can be procured either as an easement or fee acquisition. Two types of easements, permanent and temporary, are needed for the construction of pipelines and are described in this document. Some permanent project facilities require out-right ownership of land or fee acquisition, which is also discussed.

The geographic area of the alternatives includes counties in central and eastern North Dakota and western Minnesota. After a review of option routes, facility locations, individual county land values and a search for published land valuation data, it was decided to use information published by the USDA (U.S. Department of Agriculture), through the National Agricultural Statistics Service, to prepare this estimate. This information was gathered, analyzed, and published for each state in cooperation with the local state agriculture department. Therefore, information for both North Dakota and Minnesota was readily available and met the same standards for collection and interpretation.

Figures 1 and 2 show the estimated average per-acre values for cropland in North Dakota and Minnesota. Values were taken from the 2004 reports published cooperatively by the USDA and the Agricultural Statistics Service of the appropriate state. (USDA et. al. 2004a and 2004b).

Cost Estimate Assumptions

Easements
Permanent and temporary easements are used in estimating rights of way costs in the Needs and Options Report. Permanent easements are generally obtained for pipeline installation and while the landowner retains ownership, future development of this land by the landowner is limited. The land could continue to be used for cropland or grazing, but no construction of permanent features or tree planting would be allowed. This allows the pipeline owner full access to the land in the event of a pipeline break for example. A temporary easement is used to procure more land for original construction of the pipeline or other facility. Once construction is complete, the land can be used by the landowner without any limitations.

To determine the appropriate costs for permanent and temporary easements, adjustments to land values were necessary based on the professional experience, knowledge and judgment of the Bureau of Reclamation's Realty Specialist. Right of way costs for the pipeline were assumed to be 80% of the land value for permanent easements and 50% of the land value for temporary construction easements.

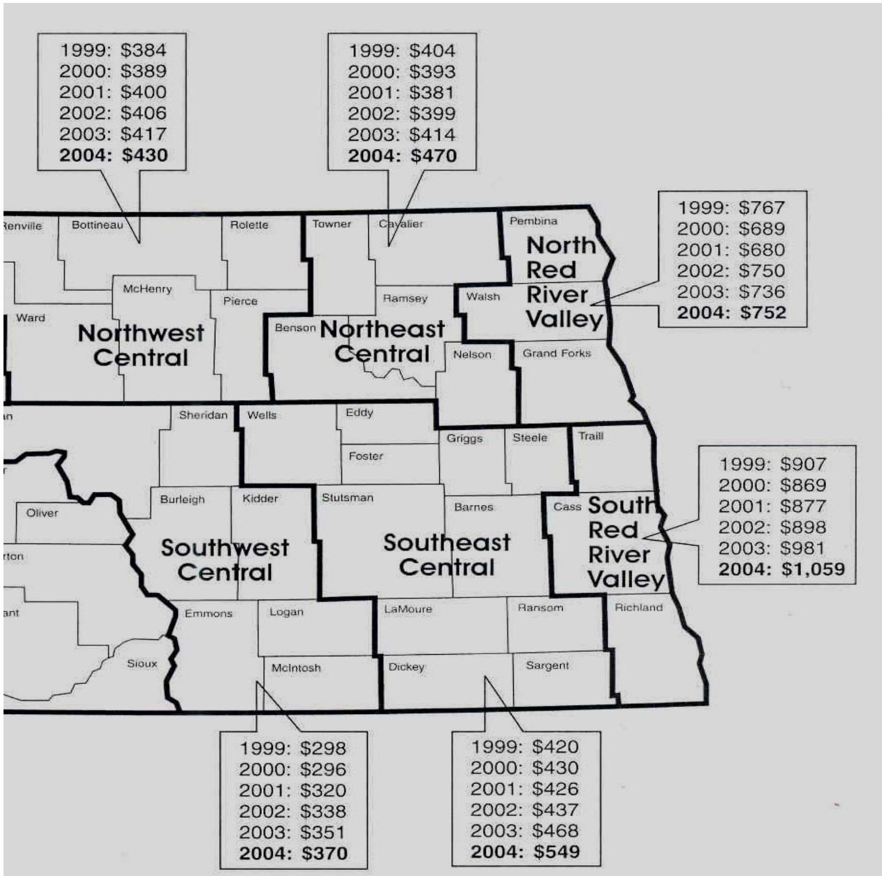

Figure 1. The eastern two-thirds of the State of North Dakota along with cropland values for each Agricultural District.

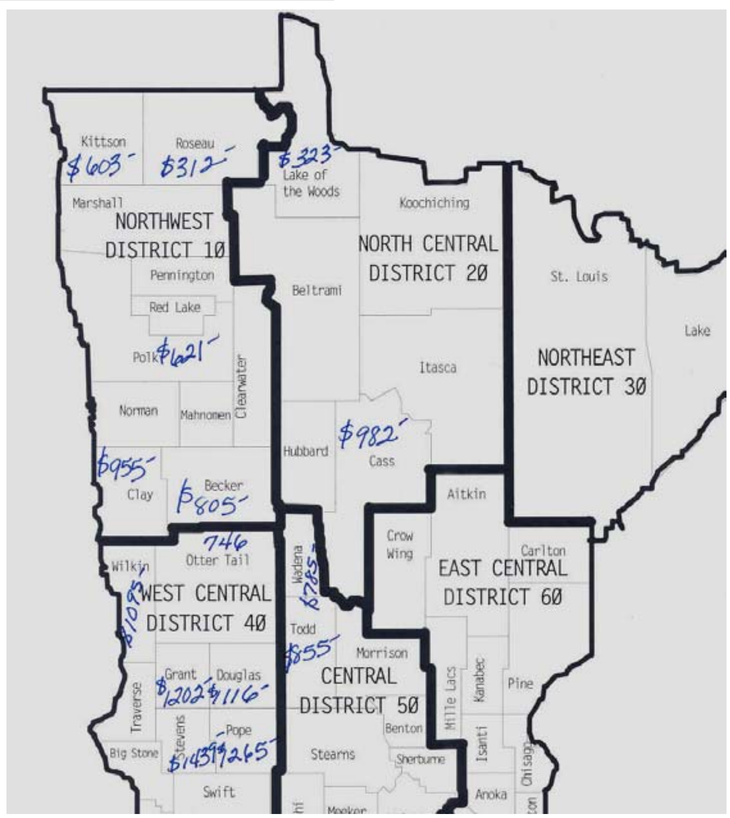

Figure 2. The northwestern portion of the State of Minnesota with the cropland values for each agricultural district. Cropland values inserted on the exhibit are from the 2004 Minnesota Agricultural Statistics publication (USDA et. al. 2004b).

Fee Acquisition Some facilities are permanent and require fee acquisitions to assure unlimited rights to use for project purposes. The acquisition of permanent facilities was based on the following assumptions:

- Wells (Aquifer Storage and Recovery or extraction) – five acres each
- PRV (pressure reducing valve) Stations – two acres each
- Reservoirs or pump stations – five acres each
- Water treatment plants and intakes – varies based on plant capacity
  - 0 – 50 cfs – 20 acres
  - 50-100 cfs – 25 acres
  - 100 – 200 cfs – 35 acres
  - 200 – 300 cfs – 50 acres
  - > 300 cfs - 60 acres
- Intake and pump station - 10 acres each

Conversion of Irrigated Land to Dryland

The Elk Valley feature included in some of the alternatives proposes the conversion of irrigation water rights to domestic water rights. The analysis below concluded that irrigated land would be purchased for $3,000 per acre and has a salvage value at $500 per acre, for a net conversion cost of $2,500 per irrigated acre. Value for irrigated lands in North Dakota was not available so data published by the National Agricultural Statistics Service which shows the difference between dry cropland and irrigated cropland for surrounding states was used to estimate conversion costs.

A conversion factor was estimated by dividing irrigated cropland value by the dryland cropland value. These values were obtained from the *Land Values and Cash Rents 2004 Summary* (USDA 2004). The conversion factors for states surrounding North Dakota were Kansas at +1.65, Nebraska at +1.78, South Dakota at +1.53, and Montana at + 4.03. Keeping to the conservative side of the range, based on these factors, a value conversion factor of +2.0 was used for Grand Forks County. Therefore, if dryland cropland in Grand Forks County has a value of $752 per acre, the irrigated value would be doubled and rounded to $1,500 per acre. However, in purchasing irrigated land from a farm, Federal Regulations require the Federal agency to keep the farmer financially "whole". This requires that all irrigation facilities and excess equipment and property also be acquired. In an effort to reflect these purchases, without being able to specifically define them, the estimated value was again doubled resulting in an estimated purchase price of $3,000 per acre. The analysis also assumes the acquired land would be sold by a governmental agency at auction. Typically, larger parcels of land even if subdivided into several parcels will bring less that the market value. Therefore, the $752 per acre current value for Grand Forks County dryland cropland was lowered by one-third to $500 per acre.

Estimation of Administrative and Miscellaneous Costs

Administrative costs (including such costs as appraisals, staff salaries and benefits, condemnation actions, title insurance, recording fees, subordinations and satisfactions of prior rights, etc.) were estimated at an equal value to the land value. For example, if 20 acres of easement are required through a parcel of land at a purchase cost of $10,000, the cost of administering that purchase is estimated at an equal cost of $10,000.

Administrative costs on the conversion of irrigated lands in the Elk Valley area to dryland are not estimated using the assumptions in the prior paragraph. Instead the administrative costs were estimated based on an assumed cost of $20,000 per 160 acre tract of converted irrigated land.

Miscellaneous costs include, but in no way are limited to, the payment for above ground appurtenances for the pipeline constructed in the permanent easement area. Currently several projects in both North Dakota and South Dakota pay $500.00 per structure located in cropland while payments for structures located in pastureland vary from zero to $250.00. A factor of 0.25 times the land cost for permanent easements was estimated for miscellaneous costs. While the number of structures required for an alternative is determined in large part on the surrounding terrain with the more hilly pasture and croplands requiring more structures, it is also expected that the flatter lands will be more expensive to purchase.

Conclusion

Assumptions established in this document were used to estimate the right of way costs for the seven options (alternatives) evaluated in the Needs and Options Report. An Excel spreadsheet was developed to estimate these costs using cropland cost data identified in figures 1 and 2. Permanent and temporary construction easement costs were estimated using the 80% and 50%, respectively, of cropland values as documented in this report. The fee acquisition acreage requirements for permanent project features were estimated based on the guidance provided by this document. Table 1 summarizes the estimated right of way cost for the Scenario One and Two water demands of each alternative. Also listed in the table is the right of way cost estimate for the Lake of the Woods peak day capacity in the pipeline option. This alternative was not discussed in the Needs and Options Report but was estimated for informational purposes.

Table 1 – Estimated Right of Way Costs for Each Option

Alternative	Scenario One Total ROW Cost	Scenario Two Total ROW Cost
North Dakota In-Basin	$23,923,166	$23,964,509
Red River Basin	$25,489,536	$26,639,416
Lake of the Woods	$27,338,945	$27,861,361
GDU Import to Sheyenne River	$4,177,353	$4,325,805
GDU Import Pipeline	$9,471,684	$9,755,397
Missouri River to Red River Valley Import	$28,164,854	$28,781,965
GDU Water Supply Replacement Pipeline	$15,919,492	$16,127,637
Lake of the Woods (Peak Day in Pipe)	$9,162,489	$9,566,045

Literature Cited

U.S. Department of Agriculture. 2004. *Land Values and Cash Rents 2004 Summary.* National Agricultural Statistics Service. Document in electronic format is available at: www.usda.gov/nass.

U.S. Department of Agriculture, North Dakota Department of Agriculture, and North Dakota State University, 2004a. *North Dakota Agricultural Statistics.* Ag Statistics No. 73. North Dakota Agricultural Statistics Service, North Dakota State University. Fargo, North Dakota.

U.S. Department of Agriculture and Minnesota Department of Agriculture. 2004b. *Minnesota Agricultural Statistics*. Minnesota Department of Agriculture Statistics Service. St. Paul, Minnesota.

RRVWSP Alternative Right-of-way Cost Estimates

Alternative/Feature	Scenario One ROW Cost	Scenario Two ROW Cost		Scenario One ROW Administrative Cost	Scenario Two ROW Administrative Cost		Scenario One Total ROW Cost	Scenario Two Total ROW Cost
North Dakota In-Basin	**$19,298,549**	**$19,295,719**		**$4,624,617**	**$4,668,790**		**$23,923,166**	**$23,964,509**
North Dakota In-Basin Pipeline	$1,426,702	$1,348,069		$1,426,702	$1,348,069		$2,853,403	$2,696,137
SE ND Groundwater	$1,062,413	$1,094,621		$1,062,413	$1,094,621		$2,124,827	$2,189,243
Elk Valley	$16,036,105	$16,044,492		$1,362,172	$1,417,564		$17,398,277	$17,462,056
ASR West Fargo North Aquifer	$256,343	$256,343		$256,343	$256,343		$512,687	$512,687
ASR West Fargo South Aquifer	$504,011	$539,218		$504,011	$539,218		$1,008,022	$1,078,437
Storage Reservoirs	$12,975	$12,975		$12,975	$12,975		$25,950	$25,950
Red River Basin	**$20,081,734**	**$20,633,172**		**$5,407,802**	**$6,006,244**		**$25,489,536**	**$26,639,416**
Minnesota Pipeline and Well Fields	$2,209,887	$2,685,522		$2,209,887	$2,685,522		$4,419,773	$5,371,044
SE ND Groundwater	$1,062,413	$1,094,621		$1,062,413	$1,094,621		$2,124,827	$2,189,243
Elk Valley	$16,036,105	$16,044,492		$1,362,172	$1,417,564		$17,398,277	$17,462,056
ASR West Fargo North Aquifer	$256,343	$256,343		$256,343	$256,343		$512,687	$512,687
ASR West Fargo South Aquifer	$504,011	$539,218		$504,011	$539,218		$1,008,022	$1,078,437
Storage Reservoirs	$12,975	$12,975		$12,975	$12,975		$25,950	$25,950
Lake of the Woods	**$21,006,439**	**$21,244,145**		**$6,332,506**	**$6,617,216**		**$27,338,945**	**$27,861,361**
Lake of the Woods Pipeline	$3,521,983	$3,705,418		$3,521,983	$3,705,418		$7,043,966	$7,410,835
Elk Valley	$16,036,105	$16,044,492		$1,362,172	$1,417,564		$17,398,277	$17,462,056
ASR West Fargo North Aquifer	$256,343	$256,343		$256,343	$256,343		$512,687	$512,687
ASR West Fargo South Aquifer	$504,011	$539,218		$504,011	$539,218		$1,008,022	$1,078,437
Pipeline to SE ND	$675,021	$685,698		$675,021	$685,698		$1,350,043	$1,371,397
Storage Reservoirs	$12,975	$12,975		$12,975	$12,975		$25,950	$25,950
GDU Import to Sheyenne River	**$2,088,677**	**$2,162,903**		**$2,088,677**	**$2,162,903**		**$4,177,353**	**$4,325,805**
GDU Import to Sheyenne River Pipeline	$1,413,655	$1,477,204		$1,413,655	$1,477,204		$2,827,311	$2,954,408
Pipeline to SE ND	$675,021	$685,698		$675,021	$685,698		$1,350,043	$1,371,397
GDU Import Pipeline	**$4,735,842**	**$4,877,698**		**$4,735,842**	**$4,877,698**		**$9,471,684**	**$9,755,397**
GDU Import Pipeline	$4,060,821	$4,192,000		$4,060,821	$4,192,000		$8,121,641	$8,384,000
Pipeline to SE ND	$675,021	$685,698		$675,021	$685,698		$1,350,043	$1,371,397
Missouri River to Red River Valley Import	**$21,419,393**	**$21,704,447**		**$6,745,460**	**$7,077,518**		**$28,164,854**	**$28,781,965**
Missouri River to RRV Import Pipeline	$3,547,545	$3,756,796		$3,547,545	$3,756,796		$7,095,091	$7,513,592
SE ND Groundwater	$1,062,413	$1,094,621		$1,062,413	$1,094,621		$2,124,827	$2,189,243
Elk Valley	$16,036,105	$16,044,492		$1,362,172	$1,417,564		$17,398,277	$17,462,056
ASR West Fargo North Aquifer	$256,343	$256,343		$256,343	$256,343		$512,687	$512,687
ASR West Fargo South Aquifer	$504,011	$539,218		$504,011	$539,218		$1,008,022	$1,078,437
Storage Reservoirs	$12,975	$12,975		$12,975	$12,975		$25,950	$25,950
GDU Water Supply Replacement Pipeline	**$7,959,746**	**$8,063,818**		**$7,959,746**	**$8,063,818**		**$15,919,492**	**$16,127,637**
Lake of the Woods (Peak Day in Pipe)	**$4,581,245**	**$4,783,022**		**$4,581,245**	**$4,783,022**		**$9,162,489**	**$9,566,045**
Lake of the Woods Pipeline (peak day)	$3,893,248	$4,084,349		$3,893,248	$4,084,349		$7,786,497	$8,168,698
Pipeline to SE ND	$675,021	$685,698		$675,021	$685,698		$1,350,043	$1,371,397
Storage Reservoirs	$12,975	$12,975		$12,975	$12,975		$25,950	$25,950

Alternative/Feature	Scenario One Total ROW Cost	Scenario Two Total ROW Cost
North Dakota In-Basin	$23,923,166	$23,964,509
Red River Basin	$25,489,536	$26,639,416
Lake of the Woods	$27,338,945	$27,861,361
GDU Import to Sheyenne River	$4,177,353	$4,325,805
GDU Import Pipeline	$9,471,684	$9,755,397
Missouri River to Red River Valley Import	$28,164,854	$28,781,965
GDU Water Supply Replacement Pipeline	$15,919,492	$16,127,637
Lake of the Woods (Peak Day in Pipe)	$9,162,489	$9,566,045

North Dakota In-Basin ROW Cost Estimate

Scenario One ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Grand Forks	50	103,274	303	225	$239,618	$84,687	529	$324,305
Griggs	50	12,672	37	28	$21,465	$7,586	65	$29,051
Steele	50	126,358	371	276	$214,036	$75,645	647	$289,681
Traill	50	174,039	511	380	$568,662	$200,978	891	$769,640
Pipeline Totals		416,343	1,223	908	$1,043,781	$368,896	2,131	$1,412,677

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Grand Forks	54	103,274	309	165	$244,298	$61,955	474	$306,253
Griggs	54	12,672	38	20	$21,884	$5,550	58	$27,434
Steele	54	126,358	379	202	$218,216	$55,340	580	$273,557
Traill	54	174,039	521	278	$579,768	$147,031	799	$726,800
Pipeline Totals		416,343	1,247	664	$1,064,167	$269,876	1,912	$1,334,044

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Grand Forks	Intake and Pump Station	1	10	10				$7,520
Grand Forks	Pump Station	1	5	5				$3,760
Steele	Pump Station	1	5	5				$2,745
Griggs	Reservoir Discharge Structure	1	10	10				$5,490
		4	30	20				$14,025

Scenario One Total ROW Costs:	$1,426,702
ROW Procurement Costs:	$1,426,702
Scenario One Total ROW and Acquisition Costs:	**$2,853,403**
Scenario Two Total ROW Costs:	$1,348,069
ROW Procurement Costs:	$1,348,069
Scenario One Total ROW and Acquisition Costs:	**$2,696,137**

Red River Basin ROW Cost Estimate

Red River Basin Pipeline - Scenario One

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Clay	45	184,800	530	233	$531,761	$111,417	764	$643,178
Pipe Totals		184,800	530	233	$531,761	$111,417	764	$643,178

Note: Assume pipe length is 35 miles

Minnesota Groundwater Feature - Scenario One

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Composite	6	295,600	499	112	$319,215	$44,788	611	$364,003
Value	8	86,100	145	33	$92,979	$13,045	178	$106,024
Used	10	30,200	51	11	$32,613	$4,576	62	$37,188
	12	32,900	56	12	$35,770	$4,834	68	$40,604
	14	79,000	134	29	$85,892	$11,607	163	$97,499
	16	25,100	43	9	$27,290	$3,688	52	$30,977
	18	6,300	11	2	$6,850	$926	13	$7,775
	20	48,800	83	18	$53,057	$7,170	101	$60,227
	24	0	0	0	$0	$0	0	$0
	30	88,300	202	62	$129,085	$24,730	264	$153,816
	36	136,900	339	132	$217,230	$52,799	471	$270,029
	42	28,500	76	28	$48,782	$11,384	105	$60,167
Pipe Totals		857,700	1,639	449	$1,048,762	$179,547	2,088	$1,228,309

Note: The deliniation of which county the pipeline was in was difficult for this feature so a composite value of $800 for land value was used
Therefore, the permanent easement was estimated at $640/ acre and the temportany easement was estimated at $400/acre

Scenario One - ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
	Well	81	5	405				$324,000
	Reservoir and Pump Station	2	5	10				$8,000
	PRV	2	2	4				$3,200
	Substation	2	2	4				$3,200
Pipe Totals		87		423	0	0	0	$338,400

Note: The deliniation of which county the pipeline was in was difficult for this feature so a composite value of $800 for land value was used

Scenario One Total ROW Costs:	$2,209,887
ROW Procurement Costs:	$2,209,887
Scenario One Total ROW and Acquisition Costs:	**$4,419,773**

Red River Basin Pipeline - Scenario Two

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Clay	60	184,800	571	278	$572,175	$132,687	848	$704,862
Pipe Totals		184,800	571	278	$572,175	$132,687	848	$704,862

Note: Assume pipe length is 35 miles

Minnesota Groundwater Feature - Scenario Two

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Composite	6	451,800	762	171	$487,894	$68,455	933	$556,349
Value	8	132,600	224	50	$143,193	$20,091	274	$163,284
Used	10	49,600	84	19	$53,563	$7,515	102	$61,078
	12	29,400	50	11	$31,965	$4,320	61	$36,284
	14	120,800	205	44	$131,338	$17,748	250	$149,087
	16	22,200	38	8	$24,137	$3,262	46	$27,398
	18	20,100	34	7	$21,853	$2,953	42	$24,807
	20	26,400	45	10	$28,703	$3,879	55	$32,582
	24	21,100	44	14	$28,211	$5,619	58	$33,830
	30	77,900	178	55	$113,881	$21,818	232	$135,699
	36	17,100	42	16	$27,134	$6,595	59	$33,729
	42	87,600	234	87	$149,942	$34,992	322	$184,933
	48	153,800	441	194	$282,461	$77,677	636	$360,138
Pipe Totals		1,210,400	1,940	493	$1,241,814	$197,246	2,433	$1,439,059

Note: The delineation of which county the pipeline was in was difficult for this feature so a composite value of $800 for land value was use
Therefore, the permanent easement was estimated at $640/ acre and the temporary easement was estimated at $400/acre

Scenario Two - ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
	Well	130	5	650				$520,000
	Reservoir and Pump Station	3	5	15				$12,000
	PRV	3	2	6				$4,800
	Substation	3	2	6				$4,800
Pipe Totals		139		677	0	0	0	$541,600

Note: The delineation of which county the pipeline was in was difficult for this feature so a composite value of $800 for land value was use

Scenario Two Total ROW Costs:	$2,685,522
ROW Procurement Costs:	$2,685,522
Scenario One Total ROW and Acquisition Costs:	**$5,371,044**

Lake of the Woods ROW Cost Estimate

Scenario One ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Cass	46	255,402	733	322	$814,951	$170,752	1,055	$985,703
Traill	48	149,861	430	189	$478,185	$100,191	619	$578,376
Traill	46	8,011	23	10	$25,562	$5,356	33	$30,918
Grand Forks	52	127,855	383	204	$302,446	$76,701	587	$379,147
Grand Forks	48	56,945	163	72	$129,028	$27,034	235	$156,063
Walsh	52	127,776	383	204	$302,259	$76,654	587	$378,913
Kittson	52	209,616	628	334	$397,607	$100,834	962	$498,441
Roseau	44	75,837	218	96	$71,293	$14,938	313	$86,231
Roseau	52	293,179	878	468	$287,739	$72,972	1,346	$360,711
Lake of the Woods	44	37,736	108	48	$36,726	$7,695	156	$44,421
Pipeline Totals		1,342,218	3,947	1,947	$2,845,796	$653,127	5,895	$3,498,923

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Cass	54	255,402	765	407	$850,809	$215,768	1,173	$1,066,577
Traill	54	149,861	449	239	$499,225	$126,605	688	$625,830
Traill	54	8,011	24	13	$26,687	$6,768	37	$33,455
Grand Forks	58	127,855	395	192	$311,716	$72,287	587	$384,003
Grand Forks	54	56,945	171	91	$134,706	$34,162	261	$168,867
Walsh	58	127,776	395	192	$311,524	$72,242	587	$383,766
Kittson	58	209,616	647	315	$409,794	$95,031	962	$504,825
Roseau	50	75,837	223	165	$73,004	$25,801	388	$98,805
Roseau	58	293,179	905	441	$296,559	$68,772	1,346	$365,331
Lake of the Woods	50	37,736	111	82	$37,607	$13,291	193	$50,898
Pipeline Totals		1,342,218	4,084	2,138	$2,951,630	$730,727	6,223	$3,682,358

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Lake of the Woods	Intake and Pump Station	1	20	20				$6,460
Roseau	Pump Station	1	5	5				$1,560
Walsh	Pump Station	1	5	5				$3,760
Grand Forks	Pump Station	1	5	5				$3,760
Grand Forks	Pump Station	1	10	10				$7,520
		5	45	30				$23,060

Scenario One Total ROW Costs:	$3,521,983
ROW Procurement Costs:	$3,521,983
Scenario One Total ROW and Acquisition Costs:	**$7,043,966**
Scenario Two Total ROW Costs:	$3,705,418
ROW Procurement Costs:	$3,705,418
Scenario Two Total ROW and Acquisition Costs:	**$7,410,835**

GDU to Sheyenne Import ROW Cost Estimate

Scenario One ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Sheridan	50	62,818	185	137	$71,713	$25,345	322	$97,058
Sheridan	56	51,758	157	81	$61,010	$14,911	238	$75,921
Wells	56	200,112	607	312	$350,001	$85,540	919	$435,541
Foster	56	189,552	575	295	$331,531	$81,026	870	$412,557
Griggs	56	174,768	530	272	$305,673	$74,707	802	$380,380
Pipeline Totals		679,008	2,054	1,097	$1,119,928	$281,529	3,151	$1,401,457

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Sheridan	60	62,818	194	94	$75,355	$17,475	288	$92,829
Sheridan	66	51,758	165	85	$63,934	$15,717	250	$79,651
Wells	66	200,112	636	328	$366,772	$90,164	965	$456,937
Foster	66	189,552	603	311	$347,418	$85,406	914	$432,824
Griggs	66	174,768	556	287	$320,321	$78,745	843	$399,066
Pipeline Totals		679,008	2,153	1,106	$1,173,799	$287,507	3,259	$1,461,306

Scenario One - ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Sheridan	WTP and Pump Station	1	25	25				$9,250
Sheridan	Reservoir	1	5	5				$1,850
Wells	PRV	1	2	2				$1,098
		3	32	32				$12,198

Scenario Two - ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Sheridan	WTP and Pump Station	1	35	35				$12,950
Sheridan	Reservoir	1	5	5				$1,850
Wells	PRV	1	2	2				$1,098
		3	42	42				$15,898

Scenario One Total ROW Costs:	$1,413,655
ROW Procurement Costs:	$1,413,655
Scenario One Total ROW and Acquisition Costs:	**$2,827,311**

Scenario Two Total ROW Costs:	$1,477,204
ROW Procurement Costs:	$1,477,204
Scenario Two Total ROW and Acquisition Costs:	**$2,954,408**

GDU Import ROW Cost Estimate

Scenario One ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Sheridan	72	62,818	205	97	$79,837	$18,008	303	$97,845
Sheridan	72	51,758	169	80	$65,780	$14,838	250	$80,618
Wells	72	119,561	391	185	$225,465	$50,857	576	$276,321
Wells	80	80,551	271	136	$156,165	$37,309	407	$193,473
Foster	80	189,552	637	320	$367,485	$87,795	957	$455,280
Griggs	80	129,888	437	219	$251,814	$60,160	656	$311,975
Steele	80	19,015	64	32	$36,864	$8,807	96	$45,672
Steele	72	107,705	352	167	$203,107	$45,814	519	$248,920
Traill	72	87,773	287	136	$319,281	$72,018	423	$391,299
Traill	48	78,641	226	99	$250,932	$52,576	325	$303,508
Traill	60	80,690	249	121	$277,038	$64,245	370	$341,283
Grand Forks	48	79,579	228	100	$180,313	$37,780	329	$218,093
Grand Forks	36	13,486	33	13	$26,401	$4,889	46	$31,290
Polk	18	43,712	83	28	$109,963	$17,454	110	$127,417
Cass	60	25,846	80	39	$88,739	$20,578	119	$109,317
Cass	60	189,465	585	285	$650,502	$150,851	870	$801,353
Pipeline Totals		1,360,040	4,299	2,058	$3,289,686	$743,980	6,357	$4,033,667

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Sheridan	80	62,818	217	100	$84,319	$18,542	317	$102,861
Sheridan	80	51,758	179	83	$69,473	$15,277	261	$84,750
Wells	80	119,561	413	191	$238,122	$52,364	604	$290,486
Wells	88	80,551	286	121	$164,692	$33,248	407	$197,940
Foster	88	189,552	672	285	$387,553	$78,239	957	$465,792
Griggs	88	129,888	461	195	$265,565	$53,612	656	$319,178
Steele	88	19,015	67	29	$38,878	$7,849	96	$46,726
Steele	80	107,705	372	172	$214,509	$47,171	544	$261,680
Traill	80	87,773	303	140	$337,206	$74,152	443	$411,358
Traill	48	78,641	226	99	$250,932	$52,576	325	$303,508
Traill	66	80,690	257	132	$285,277	$70,130	389	$355,407
Grand Forks	48	79,579	228	100	$180,313	$37,780	329	$218,093
Grand Forks	38	13,486	33	13	$26,401	$4,889	46	$31,290
Polk	20	43,712	83	28	$109,963	$17,454	110	$127,417
Cass	66	25,846	82	42	$91,378	$22,464	125	$113,841
Cass	66	189,465	602	311	$669,848	$164,669	913	$834,517
Pipeline Totals		1,360,040	4,482	2,042	$3,414,429	$750,417	6,524	$4,164,846

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Sheridan	WTP and Pump Station	1	35	35				$12,950
Sheridan	Reservoir	1	5	5				$1,850
Wells	PRV	1	2	2				$1,098
Steele	Reservoir	1	5	5				$2,745
Steele	PRV	1	2	2				$1,098
Traill	PRV	1	2	2				$2,118
Cass	Pump Station	1	5	5				$5,295
		7	56	56				$27,154

Scenario One Total ROW Costs:	$4,060,821
ROW Procurement Costs:	$4,060,821
Scenario One Total ROW and Acquisition Costs:	**$8,121,641**
Scenario Two Total ROW Costs:	$4,192,000
ROW Procurement Costs:	$4,192,000
Scenario Two Total ROW and Acquisition Costs:	**$8,384,000**

Missouri to Red River Valley Import ROW Cost Estimate

Scenario One ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Burleigh	40	128,603	344	128	$133,623	$23,759	472	$157,381
Burleigh	48	74,677	214	94	$83,253	$17,443	309	$100,697
Kidder	48	168,432	483	213	$187,775	$39,343	696	$227,118
Stutsman	48	83,372	239	105	$137,913	$28,896	345	$166,809
Stutsman	38	58,345	156	58	$89,950	$15,994	214	$105,944
Stutsman	46	121,227	348	153	$200,532	$42,016	501	$242,548
Barnes	46	134,302	385	170	$222,160	$46,548	555	$268,708
Barnes	38	41,756	112	42	$64,375	$11,446	153	$75,821
Barnes	30	77,534	177	54	$102,091	$14,902	231	$116,993
Barnes	46	10,000	29	13	$16,542	$3,466	41	$20,008
Cass	46	140,923	404	178	$449,665	$94,216	582	$543,881
Cass	30	84,606	193	59	$214,893	$31,367	252	$246,260
Cass	32	152,877	349	107	$388,296	$56,679	456	$444,974
Cass	32	60,000	137	42	$152,395	$22,245	179	$174,640
Traill	32	158,400	362	111	$402,324	$58,726	473	$461,050
Grand Forks	32	81,660	187	57	$147,283	$21,499	244	$168,781
Pipeline Totals		1,576,714	4,120	1,584	$2,993,070	$528,545	5,704	$3,521,614

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Burleigh	46	128,603	369	162	$143,372	$30,040	531	$173,412
Burleigh	54	74,677	224	119	$86,916	$22,042	343	$108,958
Kidder	54	168,432	505	269	$196,037	$49,716	773	$245,753
Stutsman	54	83,372	250	133	$143,981	$36,514	383	$180,495
Stutsman	44	58,345	156	58	$89,950	$15,994	214	$105,944
Stutsman	52	121,227	363	193	$209,355	$53,093	557	$262,448
Barnes	52	134,302	402	214	$231,935	$58,820	617	$290,755
Barnes	44	41,756	112	42	$64,375	$11,446	153	$75,821
Barnes	38	77,534	192	75	$110,813	$20,521	267	$131,334
Barnes	52	10,000	30	16	$17,270	$4,380	46	$21,649
Cass	52	140,923	422	225	$469,450	$119,054	647	$588,505
Cass	38	84,606	226	84	$251,608	$44,737	311	$296,345
Cass	32	152,877	349	107	$388,296	$56,679	456	$444,974
Cass	32	60,000	137	42	$152,395	$22,245	179	$174,640
Traill	32	158,400	362	111	$402,324	$58,726	473	$461,050
Grand Forks	32	81,660	187	57	$147,283	$21,499	244	$168,781
Pipeline Totals		1,576,714	4,286	1,908	$3,105,360	$625,505	6,194	$3,730,865

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Burleigh	Intake, WTP and Pump Station	1	25	25				$9,250
Burleigh	Pump Station and Reservoir	1	10	10				$3,700
Stutsman	Reservoir	1	5	5				$2,745
Stutsman	PRV	1	2	2				$1,098
Barnes	Reservoir	1	5	5				$2,745
Barnes	PRV	1	2	2				$1,098
Cass	Pump Station	1	5	5				$5,295
		7	54	54				$25,931

Scenario One Total ROW Costs:	$3,547,545
ROW Procurement Costs:	$3,547,545
Scenario One Total ROW and Acquisition Costs:	**$7,095,091**
Scenario Two Total ROW Costs:	$3,756,796
ROW Procurement Costs:	$3,756,796
Scenario Two Total ROW and Acquisition Costs:	**$7,513,592**

GDU Replacement Alternative ROW Cost Estimate

Scenario One ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Sheridan	88	62,818	223	94	$86,560	$17,475	317	$104,034
Sheridan	90	51,758	184	78	$71,320	$14,398	261	$85,718
Wells	90	118,774	421	179	$242,842	$49,025	600	$291,867
Wells	108	81,338	311	156	$179,218	$42,799	467	$222,017
Foster	108	189,552	725	363	$417,654	$99,740	1,088	$517,394
Griggs	108	130,023	497	249	$286,489	$68,417	746	$354,906
Griggs	10	70,006	118	27	$68,092	$7,279	145	$75,371
Griggs	26	75,000	163	53	$93,792	$14,415	215	$108,207
Steele	94	20,000	73	33	$41,950	$9,011	106	$50,961
Steele	94	15,217	55	25	$31,918	$6,856	80	$38,774
Steele	76	95,819	322	162	$185,765	$44,381	484	$230,145
Steele	18	94,689	179	60	$103,378	$16,409	239	$119,787
Steele	62	100,525	320	165	$184,246	$45,293	485	$229,539
Traill	18	10,000	19	6	$21,060	$3,343	25	$24,402
Grand Forks	62	67,963	216	112	$170,625	$41,945	328	$212,569
Grand Forks	50	56,966	167	124	$132,174	$46,713	292	$178,887
Grand Forks	54	123,639	375	193	$296,208	$72,393	568	$368,601
Grand Forks	34	134,272	333	129	$262,862	$48,678	462	$311,541
Grand Forks	26	46,195	100	32	$79,131	$12,162	133	$91,293
Grand Forks	18	23,721	45	15	$35,474	$5,631	60	$41,104
Polk	24	44,639	93	30	$60,806	$9,228	123	$70,034
Walsh	26	115,792	251	81	$198,349	$30,484	332	$228,833
Walsh	18	50,000	95	32	$74,773	$11,869	126	$86,641
Cass	76	128,211	431	216	$479,469	$114,549	648	$594,018
Cass	34	134,564	334	130	$370,980	$68,700	463	$439,680
Cass	72	217,598	692	357	$769,311	$189,121	1,049	$958,432
Cass	38	50,000	134	50	$148,694	$26,439	184	$175,132
Cass	14	34,763	59	13	$65,667	$6,761	72	$72,428
Clay	38	44,708	120	45	$119,899	$21,319	164	$141,218
Ransom	34	90,785	225	88	$129,751	$24,028	313	$153,779
Ransom	14	81,988	139	30	$80,289	$8,267	169	$88,556
Ransom	12	51,456	87	19	$50,390	$5,188	106	$55,578
Sargent	12	23,232	39	9	$22,751	$2,342	48	$25,093
Richland	34	262,944	652	254	$724,911	$134,243	905	$859,153
Barnes	24	89,176	186	59	$107,390	$16,297	246	$123,687
Barnes	18	147,311	279	93	$160,828	$25,528	372	$186,357
Pipeline Totals		3,135,442	8,663	3,758	$6,555,012	$1,360,724	12,421	$7,915,736

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Sheridan	94	62,818	229	103	$88,801	$19,075	332	$107,876
Sheridan	98	51,758	188	85	$73,166	$15,717	273	$88,883
Wells	98	118,774	432	195	$249,129	$53,516	627	$302,645
Wells	114	81,338	318	148	$183,523	$40,749	467	$224,272
Foster	114	189,552	742	346	$427,687	$94,962	1,088	$522,649
Griggs	114	130,023	509	237	$293,372	$65,139	746	$358,511
Griggs	8	70,006	118	27	$68,092	$7,279	145	$75,371
Griggs	26	75,000	163	53	$93,792	$14,415	215	$108,207
Steele	112	20,000	78	37	$45,126	$10,020	115	$55,146
Steele	102	15,217	57	27	$32,723	$7,432	84	$40,155
Steele	82	95,819	331	153	$190,837	$41,965	484	$232,802
Steele	18	94,689	179	60	$103,378	$16,409	239	$119,787
Steele	64	100,525	320	165	$184,246	$45,293	485	$229,539
Traill	18	10,000	19	6	$21,060	$3,343	25	$24,402
Grand Forks	64	67,963	216	112	$170,625	$41,945	328	$212,569
Grand Forks	54	56,966	171	91	$134,755	$34,174	262	$168,930
Grand Forks	58	123,639	375	193	$296,208	$72,393	568	$368,601
Grand Forks	36	134,272	333	129	$262,862	$48,678	462	$311,541
Grand Forks	28	46,195	102	33	$80,387	$12,361	135	$92,748
Grand Forks	20	23,721	45	15	$35,474	$5,631	60	$41,104
Polk	26	44,639	97	31	$63,145	$9,705	128	$72,850
Walsh	28	115,792	255	82	$201,497	$30,984	338	$232,481
Walsh	20	50,000	95	32	$74,773	$11,869	126	$86,641
Cass	82	128,211	443	205	$492,560	$108,315	648	$600,875
Cass	36	134,564	334	130	$370,980	$68,700	463	$439,680
Cass	78	217,598	732	367	$813,748	$194,411	1,099	$1,008,159
Cass	40	50,000	134	50	$148,694	$26,439	184	$175,132
Cass	16	34,763	66	22	$73,210	$11,621	88	$84,830
Clay	40	44,708	120	45	$119,899	$21,319	164	$141,218
Ransom	36	90,785	225	88	$129,751	$24,028	313	$153,779
Ransom	14	81,988	139	30	$80,289	$8,267	169	$88,556
Ransom	12	51,456	87	19	$50,390	$5,188	106	$55,578
Sargent	12	23,232	39	9	$22,751	$2,342	48	$25,093
Richland	34	262,944	652	254	$724,911	$134,243	905	$859,153
Barnes	24	89,176	186	59	$107,390	$16,297	246	$123,687
Barnes	18	147,311	279	93	$160,828	$25,528	372	$186,357
Pipeline Totals		3,135,442	8,807	3,728	$6,670,058	$1,349,751	12,535	$8,019,808

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Sheridan	WTP and Pump Station	1	20	20				$7,400
Sheridan	Reservoir	1	5	5				$1,850
Wells	PRV	1	2	2				$1,098
Steele	Reservoir	1	5	5				$2,745
Steele	PRV	1	2	2				$1,098
Cass	Reservoir	1	5	5				$5,295
Grand Forks	PRV	1	2	2				$1,504
Grand Forks	Reservoir	1	5	5				$3,760
Cass	Pump Station	1	5	5				$5,295
Ransom	Pump Station	1	5	5				$2,745
Grand Forks	PRV	1	2	2				$1,504
Grand Forks	Reservoir	1	5	5				$3,760
Grand Forks	Pump Station	1	5	5				$3,760
Steele	PRV	1	2	2				$1,098
Barnes	PRV	1	2	2				$1,098
		15	72	72				$44,010

Scenario One Total ROW Costs:	$7,959,746
ROW Procurement Costs:	$7,959,746
Scenario One Total ROW and Acquisition Costs:	**$15,919,492**
Scenario Two Total ROW Costs:	$8,063,818
ROW Procurement Costs:	$8,063,818
Scenario Two Total ROW and Acquisition Costs:	**$16,127,637**

Lake of the Woods (peak day) ROW Cost Estimate

Scenario One ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Cass	62	255,402	789	384	$876,888	$203,350	1,173	$1,080,237
Traill	62	149,861	463	225	$514,527	$119,319	688	$633,846
Traill	62	8,011	25	12	$27,505	$6,378	37	$33,883
Grand Forks	70	127,855	418	198	$330,257	$74,494	616	$404,751
Grand Forks	62	56,945	176	86	$138,834	$32,196	261	$171,030
Grand Forks	14	54,094	92	20	$72,560	$7,471	112	$80,031
Walsh	70	127,776	418	198	$330,053	$74,448	616	$404,501
Kittson	70	209,616	686	325	$434,168	$97,933	1,011	$532,101
Roseau	72	75,837	248	118	$81,274	$18,332	366	$99,607
Roseau	62	293,179	905	441	$296,559	$68,772	1,346	$365,331
Lake of the Woods	62	37,736	117	57	$39,517	$9,164	173	$48,681
Pipeline Totals		1,396,312	4,336	2,063	$3,142,142	$711,856	6,399	$3,853,998

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Cass	70	255,402	836	396	$929,045	$209,559	1,231	$1,138,603
Traill	70	149,861	490	232	$545,131	$122,962	722	$668,093
Traill	70	8,011	26	12	$29,141	$6,573	39	$35,714
Grand Forks	76	127,855	430	216	$339,527	$81,116	646	$420,643
Grand Forks	70	56,945	186	88	$147,092	$33,179	275	$180,271
Grand Forks	16	54,094	102	34	$80,895	$12,840	137	$93,736
Walsh	76	127,776	430	216	$339,317	$81,066	645	$420,383
Kittson	76	209,616	705	354	$446,355	$106,638	1,059	$552,993
Roseau	78	75,837	255	128	$83,555	$19,962	383	$103,518
Roseau	68	293,179	932	481	$305,379	$75,072	1,413	$380,450
Lake of the Woods	68	37,736	120	62	$40,692	$10,003	182	$50,695
Pipeline Totals		1,396,312	4,513	2,219	$3,286,130	$758,969	6,732	$4,045,099

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Lake of the Woods	Intake and Pump Station	1	20	20				$12,060
Roseau	Pump Station	1	5	5				$1,560
Walsh	Pump Station	1	5	5				$3,760
Grand Forks	Pump Station	3	5	15				$11,280
Traill	Pump Station	1	5	5				$5,295
Cass	Pump Station	1	5	5				$5,295
		8	45	50				$39,250

Scenario One Total ROW Costs:	$3,893,248
ROW Procurement Costs:	$3,893,248
Scenario One Total ROW and Acquisition Costs:	**$7,786,497**
Scenario Two Total ROW Costs:	$4,084,349
ROW Procurement Costs:	$4,084,349
Scenario Two Total ROW and Acquisition Costs:	**$8,168,698**

Elk Valley ROW Cost Estimate

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Grand Forks	6	69,520	211	108	$166,552	$40,705	319	$207,258
Grand Forks	8	13,640	23	5	$18,173	$1,943	28	$20,115
Grand Forks	10	10,560	18	4	$14,069	$1,504	22	$15,573
Grand Forks	14	17,600	30	6	$23,608	$2,431	36	$26,039
Grand Forks	18	5,280	10	3	$7,896	$1,253	13	$9,149
Grand Forks	20	31,680	60	20	$47,376	$7,520	80	$54,896
Grand Forks	24	42,240	88	28	$69,676	$10,574	116	$80,250
Grand Forks	30	3,500	8	2	$6,313	$921	10	$7,234
Totals		194,020	448	178	$353,664	$66,851	626	$420,515

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Grand Forks	Well	54	5	270				$148,230
Grand Forks	Reservoir and Pump Station	1	5	5				$2,745
Pipe Totals		55	10	275				$150,975

Conversion of Irrigated Land to Dry-land Farming in Elk Valley Aquifer Area

The following design data were taken from the Elk Valley Conversion paper (Schlag 2005) and Conversion Costs (Olson 2005)						
For Scenario Two - 5,711 ac-ft of irrigated land is required for conversion to meet Grand Forks and GFTWD annual and peak day shortages						
About 160 acres of land needs to be purchased for every 135 acre of irrigated land						
The conversion of irrigated to non-irrigated land is estimated at a cost $2,500 (Olson 2005)						
Scenario Two Elk Valley Irrigated Land Conversion Cost =	6,769 acres	x	$2,500	=		$16,921,481
Scenario One conversion acreage requirement is less by the difference in peak day demand (32.7 cfs vs. 29.9 cfs or 91.44%)						
Scenario One Elk Valley Irrigated Land Conversion Cost =	6,189 acres	x	$2,500	=		$15,473,003

Scenario Two Total ROW Costs:	**$16,044,492**
ROW Procurement Costs (pipelines and facility sites):	$571,490
ROW Procurement Costs (conversion of irrigated to dryland farming):	
Assume each quarter of land will cost $20,000 to administer the acquisition (6,769/160 x $20,000)	$846,074
Scenario One Total ROW and Acquisition Costs:	**$17,462,056**
Scenario One Total ROW Costs:	
Only 51 rather 54 (Scenario Two) wells are required for Scenario One.	
Therefore Scenario Two well field cost will be adjusted by a factor or 51/54.	**$16,036,105**
ROW Procurement Costs (pipelines and facility sites):	$563,102
ROW Procurement Costs (conversion of irrigated to dryland farming):	
Assume each quarter of land will cost $10,000 to administer the acquisition (6,769/160 x $20,000 x 51/54)	$799,070
Scenario One Total ROW and Acquisition Costs:	**$17,398,277**

SE ND Groundwater ROW Cost Estimate

Southeastern ND Groundwater Feature - Scenario Two

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Richland	24	185,877	388	124	$431,782	$65,524	512	$497,306
Sargent	6	142,300	240	54	$138,410	$14,796	294	$153,206
Sargent	8	56,300	95	21	$54,761	$5,854	116	$60,615
Sargent	10	24,000	40	9	$23,344	$2,495	50	$25,839
Sargent	12	46,800	80	17	$45,830	$4,719	97	$50,549
Sargent	14	29,600	50	11	$28,987	$2,984	61	$31,971
Sargent	16	37,900	72	24	$41,378	$6,568	96	$47,946
Sargent	20	23,100	44	15	$25,220	$4,003	58	$29,223
Sargent	24	79,400	166	53	$95,617	$14,510	219	$110,127
Pipe Totals		625,277	1,175	327	$885,327	$121,454	1,503	$1,006,781

Note: The 24" 185,877 foot of pipeline under Scenario Two has the same ROW cost as the 22" pipeline in Scenario One.

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Sargent	Well	30	5	150				$82,350
Sargent	Reservoir and Pump Station	2	5	10				$5,490
Pipe Totals		32	10	160				$87,840

Scenario Two Total ROW Costs:	$1,094,621
ROW Procurement Costs:	$1,094,621
Scenario Two Total ROW and Acquisition Costs:	**$2,189,243**

Scenario One Total ROW Costs:
Only 19 rather 30 (Scenario Two) wells are required for Scenario One.

Therefore Scenario Two well field cost will be adjusted by a factor or 19/30.	$1,062,413
ROW Procurement Costs:	$1,062,413
Scenario One Total ROW and Acquisition Costs:	**$2,124,827**

West Fargo South ASR ROW Cost Estimate

Scenario One ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Cass	8	62,250	105	24	$116,795	$12,485	129	$129,280
Cass	12	2,640	4	1	$4,953	$530	5	$5,483
Cass	14	2,220	4	1	$4,165	$445	5	$4,610
Cass	16	3,060	6	2	$6,444	$1,023	8	$7,467
Cass	18	8,340	16	5	$17,564	$2,788	21	$20,352
Cass	20	6,950	13	4	$14,636	$2,323	18	$16,960
Cass	24	8,060	17	5	$18,723	$2,841	22	$21,564
Cass	30	13,340	30	9	$33,883	$4,946	40	$38,828
Cass	36	19,450	48	19	$53,622	$9,930	67	$63,552
Totals		126,310	244	70	$270,785	$37,311	314	$308,096

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Cass	Well	36	5	180				$190,620
Cass	Reservoir and Pump Station	1	5	5				$5,295
Pipe Totals		37	10	185				$195,915

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Cass	8	60,300	102	22	$113,906	$11,728	125	$125,634
Cass	12	2,640	4	1	$4,987	$513	5	$5,500
Cass	14	2,220	4	1	$4,194	$432	5	$4,625
Cass	16	3,060	6	2	$6,444	$1,023	8	$7,467
Cass	18	3,600	7	2	$7,581	$1,203	9	$8,785
Cass	20	12,200	23	8	$25,693	$4,078	31	$29,771
Cass	24	5,840	12	4	$13,566	$2,059	16	$15,625
Cass	30	11,100	25	8	$28,193	$4,115	33	$32,308
Cass	36	16,100	40	16	$44,386	$8,220	55	$52,606
Cass	42	8,340	22	8	$24,802	$4,410	31	$29,212
Totals		125,400	246	71	$273,752	$37,781	318	$311,533

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Cass	Well	42	5	210				$222,390
Cass	Reservoir and Pump Station	1	5	5				$5,295
Pipe Totals		43	10	215				$227,685

Scenario One Total ROW Costs:	$504,011
ROW Procurement Costs:	$504,011
Scenario One Total ROW and Acquisition Costs:	**$1,008,022**
Scenario Two Total ROW Costs:	$539,218
ROW Procurement Costs:	$539,218
Scenario Two Total ROW and Acquisition Costs:	**$1,078,437**

West Fargo North ASR ROW Cost Estimate

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Cass	6	15,000	25	6	$28,143	$3,009	31	$31,152
Cass	8	20,460	35	8	$38,388	$4,104	42	$42,491
Cass	12	10,560	18	4	$19,813	$2,118	22	$21,931
Cass	14	13,640	23	5	$25,592	$2,736	28	$28,327
Cass	16	6,160	12	4	$12,973	$2,059	16	$15,032
Cass	20	7,480	14	5	$15,753	$2,500	19	$18,253
Cass	24	3,960	8	3	$9,199	$1,396	11	$10,595
Cass	30	1,320	3	1	$3,353	$489	4	$3,842
Totals		78,580	138	35	$153,212	$18,411	173	$171,623

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Cass	Well	15	5	75				$79,425
Cass	Reservoir and Pump Station	1	5	5				$5,295
Pipe Totals		16	10	80				$84,720

Scenario One and Two Total ROW Costs:	$256,343
ROW Procurement Costs:	$256,343
Scenario One and Two Total ROW and Acquisition Costs:	**$512,687**

Pipeline to SE ND ROW Cost Estimate

Scenario One ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Cass	26	30,246	66	21	$72,962	$11,214	87	$84,176
Richland	26	210,400	456	147	$507,545	$78,005	604	$585,551
Pipeline Totals		240,646	522	168	$580,508	$89,219	691	$669,726

Scenario Two ROW Cost Estimate

County	Pipe Dia. (inches)	Pipe Length (feet)	Permanent Easement Acreage	Temporary Easement Acreage	Permanent Easement Cost	Temporary Easement Cost	Total County ROW (acres)	Total County ROW Cost
Cass	28	30,246	67	22	$74,120	$11,397	88	$85,518
Richland	28	210,400	464	150	$515,602	$79,284	613	$594,886
Pipeline Totals		240,646	530	171	$589,722	$90,681	702	$680,403

ROW Purchased for Permanent Alternative Facilities

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)				Purchase Cost
Cass	Pump Station	1	5	5				$5,295
Pipe Totals		1	5	5				$5,295

Scenario One Total ROW Costs:	$675,021
ROW Procurement Costs:	$675,021
Scenario One Total ROW and Acquisition Costs:	**$1,350,043**
Scenario Two Total ROW Costs:	$685,698
ROW Procurement Costs:	$685,698
Scenario Two Total ROW and Acquisition Costs:	**$1,371,397**

Storage Reservoirs ROW Cost Estimate

County	Type of Facility	Number of Facilities	Acres Per Facility	Acreage (ac-ft)	Purchase Cost
Cavalier	Storage Reservoir	1	5	5	$2,350
Pembina	Storage Reservoir	1	5	5	$3,760
Walsh	Storage Reservoir	1	5	5	$3,760
Polk	Storage Reservoir	1	5	5	$3,105
					$12,975

Scenario One and Two Total ROW Costs:	$12,975
ROW Procurement Costs:	$12,975
Scenario One and Two Total ROW and Acquisition Costs:	**$25,950**

Red River Valley Water Supply Project

Construction ROW Easement Width Requirements

Note: The following Right-of-Way (ROW) width estimates are based on the criteria developed for the Lewis & Clark Water Supply Project.

Pipe Size [1] (inches)	Trench Depth (feet)	Trench Top Width (feet)	Excavation Stockpile Width [2] (feet)	Pipe Assemble Width (feet)	Buffer Zone [3] (feet)	Construction ROW Width [4] (feet)	Permanent Easement Width [5] (feet)	Temporary Construction Easement [5] (feet)	Impact Zone vs. Easement Width Factor [6] (%)
10	8	21	33	20	20	90	74	17	11.3%
12	8	21	33	20	20	90	74	16	11.3%
18	9	23	35	25	25	110	83	28	13.8%
24	9	24	37	30	30	120	91	29	15.0%
26	9	25	38	32	32	125	95	31	15.6%
28	9	25	38	33	33	127	96	31	15.9%
30	10	26	39	35	35	130	100	31	16.3%
36	10	27	41	40	40	150	108	42	18.8%
42	11	29	43	45	45	160	117	44	20.0%
48	11	30	45	50	50	180	125	55	22.5%
50	11	31	46	51	60	190	128	95	23.8%
54	12	32	47	52	70	200	131	70	25.0%
56	12	32	48	52	70	200	132	68	25.0%
60	12	33	49	53	70	200	135	66	25.0%
66	13	35	51	53	70	210	139	72	26.3%
72	13	36	53	54	70	210	143	68	26.3%
78	14	38	55	54	70	220	147	74	27.5%
84	14	39	57	55	70	220	151	70	27.5%
90	15	41	59	55	70	220	155	66	27.5%
96	15	42	61	56	70	230	159	72	28.8%
102	16	44	63	56	80	240	163	78	30.0%
108	16	45	65	57	80	250	167	84	31.3%
114	17	47	67	57	80	250	171	80	31.3%
120	17	48	69	58	80	250	175	76	31.3%
126	18	50	71	58	80	260	179	82	32.5%
132	18	51	73	59	80	260	183	78	32.5%
138	19	53	75	59	80	270	187	84	33.8%

[1] A double-barrel pipeline configuration (two equal size pipes) may be more cost effective to install than one large diameter pipe at larger pipe sizes. However, the required construction ROW width would be approximately the same for pipe sizes over 120 inches.

[2] The stockpile width is based on a triangular shape with 1 1/2 :1 side slopes.

[3] Buffer zone is an additional width to account for unanticipated ROW needs including logistical space between stockpiles/pipe assembly area and the edge of the ROW.

[4] The Construction ROW width is rounded to the nearest 10 foot increments.

[5] The permanent easement includes trench top width, excavated stockpile width and pipe assembly area width. The temporary easement widths is th

[6] A 400 foot wide (200 feet on each side of pipeline route) impact zone data was collected for each proposed pipeline route. The width of the temporary and permanent easements varies depending on pipeline size and buried depth. The Impact Zone vs. Easement Width Factor is the percent of the 400 foot ROW that will actually be impacted for each of the temporary and permanent easements.

Trench Top Width =
Assume pipe trench is trapezoidal with 1:1 side slopes and bottom width of pipe diameter (feet) + 4 feet
Trench Top Width (feet) = 2 x (pipe dia. In feet + 7.0 feet) + (pipe dia. In feet + 4 feet)

Estimated County ROW Costs

1. Assume permanent easement is 80% of composite ROW cost
2. Assume temporary construction easement is 50% of composite ROW cost
3. ROW costs for permanent appurtanances (such as air vents and blow-off valves) are estimated at 25% of Average Acre Cost which is added on to the Permanent Easement Cost value below.

County	Average Cost per Acre	Permanent Easement Cost /acre	Temporary Easement Cost /acre
North Dakota			
Barnes	549	$576	$275
Burleigh	370	$389	$185
Cass	$1,059	$1,112	$530
Cavalier	470	$494	$235
Foster	$549	$576	$275
Grand Forks	$752	$790	$376
Griggs	$549	$576	$275
Kidder	370	$389	$185
Nelson	470	$494	$235
Pembina	752	$790	$376
Ransom	549	$576	$275
Richland	$1,059	$1,112	$530
Sargent	549	$576	$275
Sheridan	$370	$389	$185
Steele	549	$576	$275
Stutsman	549	$576	$275
Traill	1059	$1,112	$530
Walsh	752	$790	$376
Wells	$549	$576	$275
Minnesota			
Becker	805	$845	$403
Cass	982	$1,031	$491
Clay	955	$1,003	$478
Douglas	1116	$1,172	$558
Grant	1202	$1,262	$601
Kittson	603	$633	$302
Lake of the Woods	323	$339	$162
Otter Tail	746	$783	$373
Polk	621	$652	$311
Pope	1265	$1,328	$633
Roseau	312	$328	$156
Stevens	1439	$1,511	$720
Todd	855	$898	$428
Wadena	785	$824	$393
Wilken	1095	$1,150	$548

Appendix C – Attachment 7

Documentation on Miscellaneous Cost Estimating Resources

Report on Red River Valley Needs and Options
Computation of Assigned GDU Supply Work Costs
Prepared May, 2005

Users of the Garrison Diversion Unit (GDU) principal supply works are assigned a share of construction and OM&R costs based on the amount of capacity used. MR&I uses are reimbursable with interest and the authorized interest rate is 3.225%.

The cost allocation methodology is documented in *Garrison Diversion Unit Draft Cost Allocation Report* (Reclamation 2004). Costs in the allocation are based on October 1, 2005 price levels. The results of this cost allocation assign 83.1346% of principal supply work costs (Joint costs) to MR&I and irrigation water supply. Page A-5 of the allocation report shows an example of how the "use of facilities" method of suballocation would be applied. This table has been revised (see table 1 next page) to reflect the updated cost estimates for supply work features. Also, since alternatives under consideration in the Needs and Options Report use similar features, the table was updated using a unit capacity of 10 cubic feet per second (cfs).

To determine the total assigned GDU costs for any alternative, one would use these costs for each 10 cfs of capacity used. Costs to date were obtained from current GDU finance records. The OM&R (Operation, Maintenance and Replacement) and remaining construction costs were obtained from the Reclamation report titled *Update of GDU Principal Supply Works Costs, Draft Report* (Reclamation 2005) or current Reclamation cost estimates. These costs are summarized below. Costs of features not associated with any Red River Valley Water Supply Project alternatives were subtracted from the totals when appropriate.

Feature	Remaining Construction Cost	Annual OM&R Cost
Snake Creek Pumping Plant	$ 11,300,000	$ 266,000
McClusky Canal	$ 15,690,000	$ 1,240,000
Permanent Oper. Facilities	$ 66,000	$ 0
New Rockford Canal	$ 20,021,000	$ 394,000
Mitigation/Enhancement 1./	$ 1,000,000	$ 509,000
Audubon Refuge, mitigation	$ 2,650,000	$ 80,000
SCADA/Winter operations	$ 2./	$ 320,000
TOTAL	$ 50,727,000	$ 2,809,000
Less New Rockford Canal	$ 20,021,000	$ -394,000
Less McClusky,Mile 59-74	$ 0	$ -56,000
Less 50% Mitigation/Enhance	$ 0	$ -255,000
TOTAL for Alternatives	**$ 30,706,0,00**	**$ 2,104,000**

1./ Fifty percent of the Mitigation/Enhancement OM&R is incidental enhancement and is nonreimbursable.
2./ These costs are included in the McClusky Canal costs.

As shown in table 2, each 10 cfs of capacity used from the GDU Principal Supply Works results in a repayment requirement of $911,120 in construction costs and $11,310 in annual OM&R costs. Applying these amounts to the capacity requirements of the alternatives that involve the GDU Principal Supply Works results in the amount of costs assigned to each alternative. Costs for each of these alternatives are shown in table 2.

The original cost estimates for Garrison Diversion Unit (GDU) assigned costs to the Red River Valley Water Supply Project options were developed from *Report on Red River Valley Needs and Options Computation of Assigned GDU Supply Work Costs Prepared May, 2005.* The version of table 2 shown on the upper half of the next page is the cost estimate table from the above report. Table 2 shows the GDU assigned costs for each of the Red River Valley Water Supply Project options which use the principal supply works.

The estimate of assigned costs provided in tables 2 could not directly be used in the master RRV cost estimating spreadsheet because the spreadsheet is designed to add 30% for contractor OH&P, 15% contractor costs, 5% unlisted items, 25% contingencies and 25% non-contract costs. These costs are already included in the original assigned costs estimate so some adjustment to these values needs to be made to avoid double counting costs.

The modified version of table 2 is shown on the lower half of the following page. The table on the upper half of the page has the costs reduced by multiplying the original cost estimates by a factor of 0.42036% or (1/(1.45 * 1.05 * 1.25 * 1.25)).

Correction in Cost Estimates <u>not</u> made in Final Needs and Options Report

The *Report on Red River Valley Needs and Options Computation of Assigned GDU Supply Work Costs Prepared May, 2005,* was updated just prior to finalizing the Needs and Options Report but there was not adequate time to modify the option costs estimates with the new allocation results. These revised results are shown as the second set of table 2 costs. There is less than a 1% difference between the two versions of construction costs so there was no need to make the correction given the lateness of the revised results. These changes should be made to the cost estimates at some point in the future when the costs are re-estimated.

Garrison Diversion Unit Assigned Costs used in Final Needs and Options Report Estimates. Estimates developed in May 2005.

TABLE 2

Garrison Diversion Unit, Assigned Costs Related to the use of the Principal Supply Works

Description of Alternatives Report on Red River Valley Needs and Options	Capacity Required (cfs)	Assigned GDU Construction Costs ($)	Assigned GDU Annual OM&R Costs ($)
GDU principal supply works used for MR&I and irrigation	10	$911,120	$11,310
GDU Import to Sheyenne River, Scenario One	62	$5,648,944	$70,122
GDU Import to Sheyenne River, Scenario Two	97	$8,837,864	$109,707
GDU Import Pipeline , Scenario One	160	$14,577,920	$180,960
GDU Import Pipeline, Scenario Two	202	$18,404,624	$228,462
GDU Water Supply Replacement Pipleine, Scenario One	341	$31,069,192	$385,671
GDU Water Supply Replacement Pipeline, Scenario Two	411	$37,447,032	$464,841

TABLE 2 (modified/reduced so can be added to RRVWSP Overall Cost Estimate Spreadsheet)

Garrison Diversion Unit, Assigned Costs Related to the use of the Principal Supply Works

Factor = 0.420361248

Description of Alternatives Report on Red River Valley Needs and Options	Capacity Required (cfs)	Assigned GDU Construction Costs ($)	Assigned GDU Annual OM&R Costs ($)
GDU principal supply works used for MR&I and irrigation	10	$383,000	$11,310
GDU Import to Sheyenne River, Scenario One	62	$2,374,597	$70,122
GDU Import to Sheyenne River, Scenario Two	97	$3,715,096	$109,707
GDU Import Pipeline , Scenario One	160	$6,127,993	$180,960
GDU Import Pipeline, Scenario Two	202	$7,736,591	$228,462
GDU Water Supply Replacement Pipleine, Scenario One	341	$13,060,284	$385,671
GDU Water Supply Replacement Pipeline, Scenario Two	411	$15,741,281	$464,841

Garrison Diversion Unit Assigned Costs updated in October 2005 but were <u>not</u> used in Final Needs and Options Report estimates due to lack of time to incorporate new cost data.

TABLE 2
Garrison Diversion Unit, Assigned Costs Related to the use of the Principal Supply Works

Description of Alternatives Report on Red River Valley Needs and Options	Capacity Required (cfs)	Assigned GDU Construction Costs ($)	Assigned GDU Annual OM&R Costs ($)
GDU principal supply works used for MR&I and irrigation	10	$904,136	$7,353
GDU Import to Sheyenne River, Scenario One	62	$5,605,643	$45,589
GDU Import to Sheyenne River, Scenario Two	97	$8,770,119	$71,324
GDU Import Pipeline , Scenario One	160	$14,466,176	$117,648
GDU Import Pipeline, Scenario Two	202	$18,263,547	$148,531
GDU Water Supply Replacement Pipleine, Scenario One	341	$30,831,038	$250,737
GDU Water Supply Replacement Pipeline, Scenario Two	411	$37,159,990	$302,208

TABLE 2 (modified/reduced so can be added to RRVWSP Overall Cost Estimate Spreadsheet)
Garrison Diversion Unit, Assigned Costs Related to the use of the Principal Supply Works
Factor = 0.420361248

Description of Alternatives Report on Red River Valley Needs and Options	Capacity Required (cfs)	Assigned GDU Construction Costs ($)	Assigned GDU Annual OM&R Costs ($)
GDU principal supply works used for MR&I and irrigation	10	$380,064	$7,353
GDU Import to Sheyenne River, Scenario One	62	$2,356,395	$45,589
GDU Import to Sheyenne River, Scenario Two	97	$3,686,618	$71,324
GDU Import Pipeline , Scenario One	160	$6,081,020	$117,648
GDU Import Pipeline, Scenario Two	202	$7,677,287	$148,531
GDU Water Supply Replacement Pipleine, Scenario One	341	$12,960,173	$250,737
GDU Water Supply Replacement Pipeline, Scenario Two	411	$15,620,620	$302,208

Literature Cited

Bureau of Reclamation, 2005. *Garrison Diversion Unit Draft Cost Allocation Report, June 8, 2004*, Bureau of Reclamation, Dakotas Area Office, Bismarck, North Dakota.

Bureau of Reclamation, 2005d. *Update of Garrison Diversion Unit Principal Supply Works Costs – Draft Report*. Bureau of Reclamation, Dakotas Area Office, Bismarck, North Dakota.

Cost Estimates for Biota Water Treatment Plants
Bureau of Reclamation May 2005

The original cost estimates for biota water treatment plants (WTP) were developed from *Water Treatment Plant For Biota Removal and Inactivation , Preliminary Design & Cost Estimates, Red River Valley Water Supply Project*, North Dakota, Great Plains Region, 2005, Bureau of Reclamation, Denver Technical Service Center, Denver, Colorado. The versions of tables 9.2 and 9.3 shown on the upper half of the next two pages are the cost estimate tables from the above report. Table 9.2 shows the biota WTP and clearwell pumping station costs and table 9.3 shows the intake structure costs.

The cost estimates provided in tables 9.2 and 9.3 could not directly be used in the master RRV cost estimating spreadsheet because the spreadsheet is designed to add 30% for contractor OH&P and 15% contractor costs. These costs are already included in the original biota WTP and intake cost estimates so some adjustment to these values needs to be made to avoid double counting costs.

The modified versions of tables 9.2 and 9.3 are shown on the lower half of the following two pages. The tables on the upper half of the pages have their costs reduced by multiplying the original cost estimates by a factor of 0.6897% or (1/(1 + 0.45)). The biota WTP and intake costs actually used in the master RRV cost estimating spreadsheet are shaded in the tables.

The GDU Import to Sheyenne River Option main pipeline capacity was modified just prior to the finalizing the Needs and Options Report. The Scenario One capacity was reduce from 78 cfs to 62 cfs and the Scenario Two capacity was reduced from 120 cfs to 97 cfs. Inadequate time was available to make this capacity change in the *Water Treatment Plant For Biota Removal and Inactivation , Preliminary Design & Cost Estimates, Red River Valley Water Supply Project* report. The decision was made to finalize the above report with the original identified capacity water treatment plants and make an adjustment in the estimated cost of the GDU Import to Sheyenne River Option biota WTP in the Needs and Options Report.

Assuming a proportional relationship between WTP capacity and cost the construction and OM&R estimates were adjusted as listed below. No changes were made to tables 9.2 and 9.3.

Feature	Scenario One Construction Cost (78 cfs)	Scenario One Construction Cost (62 cfs)	Scenario Two Construction Cost (120 cfs)	Scenario Two Construction Cost (97 cfs)
Biota WTP Intake	$5,245,659	$4,169,626	$6,073,517	$4,909,426
Biota WTP	$12,464,472	$9,907,657	$19,048,825	$15,397,800

Feature	Scenario One OM&R Cost (78 cfs)	Scenario One OM&R Cost (62 cfs)	Scenario Two OM&R Cost (120 cfs)	Scenario Two OM&R Cost (97 cfs)
Biota WTP Intake	$279,000	$222,000	$365,000	$295,000
Biota WTP	$1,719,000	$1,366,000	$2,434,000	$1,967,000

Table 9.2: Water treatment plant flow and capital costs (Includes 30% Contractor OH&P and 15% Contrcator Costs)

Capital Costs	Project Alternative	Treatment Alternative							
		A – Sedimentation		C - MF		E1 – Lime Softening		E2 - NF	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Peak product Flow)cfs)	GDU to Sheyenne Import Alternative	77.7	119.8	77.7	119.8	77.7	119.8 [1]		
	Missouri to Red River Valley Import Alternative	44.1	63	44.1	63	44.1	63	44.1	63
	GDU Import Alternative	159.8	201.1	159.8	201.1	159.8	201.1		
	GDU Replacement Alternative	340.2	410.5	340.2	410.5	340.2	410.5		
TSC Sub-Total Costs	GDU to Sheyenne Import Alternative	$18,073,484	$27,620,796	$44,647,295	$58,001,878	$55,620,633	$74,920,872		
	Missouri to Red River Valley Import Alternative	$10,453,777	$14,739,862	$33,989,005	$39,984,293	$40,217,116	$48,881,594	$28,485,857	$41,979,795
	GDU Import Alternative	$36,691,876	$46,057,766	$70,690,318	$83,791,132	$93,258,392	$112,191,882		
	GDU Replacement Alternative	$77,602,446	$93,544,870	$127,915,182	$150,215,116	$175,960,608	$208,188,799		
TSC Total Costs	GDU to Sheyenne Import Alternative	$30,000,000	$45,000,000	$74,000,000	$95,000,000	$91,000,000	$123,000,000		
	Missouri to Red River Valley Import Alternative	$18,000,000	$24,000,000	$56,000,000	$65,000,000	$66,000,000	$80,000,000	$46,000,000	$69,000,000
	GDU Import Alternative	$60,000,000	$75,000,000	$116,000,000	$138,000,000	$153,000,000	$184,000,000		
	GDU Replacement Alternative	$128,000,000	$154,000,000	$210,000,000	$246,000,000	$289,000,000	$341,000,000		

Note: Original table from *Water Treatment Plant for Biota Removal and Inactivation Preliminary Design & Cost Estimates* (Reclamation May 2005)

Table 9.2: Water treatment plant flow and capital costs (**without** 30% Contractor OH&P and 15% Contrcator Costs) Factor = 0.6897

Capital Costs	Project Alternative	Treatment Alternative							
		A – Sedimentation		C - MF		E1 – Lime Softening		E2 - NF	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Peak Product Flow (cfs)	GDU to Sheyenne Import Alternative	77.7	119.8	77.7	119.8	77.7	119.8 [1]		
	Missouri to Red River Valley Import Alternative	44.1	63	44.1	63	44.1	63	44.1	63
	GDU Import Alternative	159.8	201.1	159.8	201.1	159.8	201.1		
	GDU Replacement Alternative	340.2	410.5	340.2	410.5	340.2	410.5		
TSC Sub-Total Costs	GDU to Sheyenne Import Alternative	$12,464,472	$19,048,825	$30,791,238	$40,001,295	$38,359,057	$51,669,567		
	Missouri to Red River Valley Import Alternative	$7,209,501	$10,165,422	$23,440,693	$27,575,374	$27,735,942	$33,711,444	$19,645,419	$28,951,583
	GDU Import Alternative	$25,304,742	$31,763,977	$48,751,943	$57,786,988	$64,316,132	$77,373,712		
	GDU Replacement Alternative	$53,518,928	$64,513,703	$88,217,367	$103,596,632	$121,352,143	$143,578,482		
TSC Total Costs	GDU to Sheyenne Import Alternative	$30,000,000	$45,000,000	$74,000,000	$95,000,000	$91,000,000	$123,000,000		
	Missouri to Red River Valley Import Alternative	$18,000,000	$24,000,000	$56,000,000	$65,000,000	$66,000,000	$80,000,000	$46,000,000	$69,000,000
	GDU Import Alternative	$60,000,000	$75,000,000	$116,000,000	$138,000,000	$153,000,000	$184,000,000		
	GDU Replacement Alternative	$128,000,000	$154,000,000	$210,000,000	$246,000,000	$289,000,000	$341,000,000		

Note: Table 9.2 TSC Sub-Total Costs were modified (reduced) by a factor of 0.6897 so they could be used in the overall RRVWSP Cost Estimate Spreadsheet.

Table 9.3: Intake pumping plant flow and capital costs (Includes 30% Contractor OH&P and 15% Contrcator Costs)

Capital Costs	Project Alternative	Treatment Alternative							
		A – Sedimentation		C - MF		E1 – Lime Softening		E2 - NF	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Peak Product Flow (cfs)	GDU to Sheyenne Import Alternative	77.7	119.8	77.7	119.8	77.7	119.8		
	Missouri to Red River Valley Import Alternative	44.1	63	44.1	63	44.1	63	44.1	63
	GDU Import Alternative	159.8	201.1	159.8	201.1	159.8	201.1		
	GDU Replacement Alternative	340.2	410.5	340.2	410.5	340.2	410.5		
Peak Intake Flows (cfs)	GDU to Sheyenne Import Alternative	78.5	121.0	81.8	126.1	82.6	127.3		
	Missouri to Red River Valley Import Alternative	44.5	63.6	46.4	66.3	46.9	67.0	51.3	73.4
	GDU Import Alternative	161.4	203.2	168.2	211.7	169.9	213.9		
	GDU Replacement Alternative	343.7	414.6	358.1	432.1	361.8	436.4		
TSC Sub-Total Costs	GDU to Sheyenne Import Alternative	$7,606,205	$8,806,599	$7,699,486	$8,950,423	$7,722,806	$8,986,379		
	Missouri to Red River Valley Import Alternative	$10,947,007	$15,928,116	$11,436,952	$16,627,792	$11,559,438	$16,802,711	$12,706,155	$18,474,157
	GDU Import Alternative	$9,949,621	$11,127,949	$10,141,572	$11,369,514	$10,189,560	$11,429,905		
	GDU Replacement Alternative	$15,095,427	$17,099,026	$15,504,044	$17,592,005	$15,606,198	$17,715,249		
TSC Total Costs	GDU to Sheyenne Import Alternative	$13,000,000	$15,000,000	$13,000,000	$15,000,000	$13,000,000	$15,000,000		
	Missouri to Red River Valley Import Alternative	$18,000,000	$26,000,000	$19,000,000	$28,000,000	$19,000,000	$28,000,000	$21,000,000	$30,000,000
	GDU Import Alternative	$16,000,000	$19,000,000	$16,000,000	$19,000,000	$16,000,000	$19,000,000		
	GDU Replacement Alternative	$25,000,000	$28,000,000	$25,000,000	$29,000,000	$25,000,000	$29,000,000		

Note: Original table from *Water Treatment Plant for Biota Removal and Inactivation Preliminary Design & Cost Estimates* (Reclamation May 2005)

Table 9.3: Intake pumping plant flow and capital costs (**without** 30% Contractor OH&P and 15% Contrcator Costs) Factor = 0.6897

Capital Costs	Project Alternative	Treatment Alternative							
		A – Sedimentation		C - MF		E1 – Lime Softening		E2 - NF	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Peak Product Flow (cfs)	GDU to Sheyenne Import Alternative	77.7	119.8	77.7	119.8	77.7	119.8		
	Missouri to Red River Valley Import Alternative	44.1	63	44.1	63	44.1	63	44.1	63
	GDU Import Alternative	159.8	201.1	159.8	201.1	159.8	201.1		
	GDU Replacement Alternative	340.2	410.5	340.2	410.5	340.2	410.5		
Peak Intake Flows (cfs)	GDU to Sheyenne Import Alternative	78.5	121.0	81.8	126.1	82.6	127.3		
	Missouri to Red River Valley Import Alternative	44.5	63.6	46.4	66.3	46.9	67.0	51.3	73.4
	GDU Import Alternative	161.4	203.2	168.2	211.7	169.9	213.9		
	GDU Replacement Alternative	343.7	414.6	358.1	432.1	361.8	436.4		
TSC Sub-Total Costs	GDU to Sheyenne Import Alternative	$5,245,659	$6,073,517	$5,309,990	$6,172,706	$5,326,073	$6,197,503		
	Missouri to Red River Valley Import Alternative	$7,549,660	$10,984,908	$7,887,553	$11,467,443	$7,972,026	$11,588,077	$8,762,866	$12,740,798
	GDU Import Alternative	$6,861,808	$7,674,448	$6,994,188	$7,841,044	$7,027,283	$7,882,693		
	GDU Replacement Alternative	$10,410,639	$11,792,432	$10,692,444	$12,132,417	$10,762,895	$12,217,413		
TSC Total Costs	GDU to Sheyenne Import Alternative	$13,000,000	$15,000,000	$13,000,000	$15,000,000	$13,000,000	$15,000,000		
	Missouri to Red River Valley Import Alternative	$18,000,000	$26,000,000	$19,000,000	$28,000,000	$19,000,000	$28,000,000	$21,000,000	$30,000,000
	GDU Import Alternative	$16,000,000	$19,000,000	$16,000,000	$19,000,000	$16,000,000	$19,000,000		
	GDU Replacement Alternative	$25,000,000	$28,000,000	$25,000,000	$29,000,000	$25,000,000	$29,000,000		

Note: Table 9.2 TSC Sub-Total Costs were modified (reduced) by a factor of 0.6897 so they could be used in the overall RRVWSP Cost Estimate Spreadsheet.

OM&R Estimated Costs

Project Alternative	Scenario One			Scenario Two		
	Intake OM&R Costs	Biota WTP OM&R Costs	Total OM&R Costs	Intake OM&R Costs	Biota WTP OM&R Costs	Total OM&R Costs
GDU to Sheyenne Import Alternative	279,000	1,719,000	1,998,000	365,000	2,434,000	2,799,000
Missouri to Red River Valley Import Alternative	428,000	2,072,000	2,500,000	479,000	2,363,000	2,842,000
GDU Import Alternative	331,000	2,134,000	2,465,000	359,000	2,372,000	2,731,000
GDU Replacement Alternative	1,074,000	21,321,000	22,395,000	1,337,000	27,108,000	28,445,000

MEMO

Houston Engineering, Inc.
2505 N. University Dr.
Box 5054
Fargo, ND 58105
Ph. (701) 237-5065
Fax (701) 237-5101

Date: March 25, 2005

From: Rick R. St. Germain

To: Dean Karsky
cc: Dave Johnson

Subject: Cost Calculation Assumptions
H.E.# 3750-060 RRVWSP Alternatives

The following methods were used to calculate costs for typical pump stations, reservoirs and prv stations along the main pipelines. <u>These do not include contractor, engineering or contingency costs.</u>

<u>PUMP STATIONS</u>:

1. Assume a pump efficiency of 80%.
2. For pump stations above 3000 hp, we will apply a 20% power increase in total connected load for standby pumps.
3. For pump stations below 3000 hp, we will apply a 25% power increase in total connected load for standby pumps.
4. For pump station costs we will use this formula:
   Cost = ((62.4 x pump head x flow)/(550*0.80))x1700
   = (water horsepower/.80)x1700

Examples:
Given 4000 water horsepower required;
Total Connected Load needed at the pump station would be:
Power required = (4000/.80) x 120%
= 6000 horsepower
= 4476 kilowatts
Cost = (4000/.80) x 1700
= $8,500,000

Given 2000 water horsepower required;
Total Connected Load needed at the pump station would be:
Power required = (2000/.80) x 125%
= 3125 horsepower
= 2331 kilowatts
Cost = (2000/.8) x 1700
= $4,250,000

PRV's:

For preliminary costing purposes, we used a simple formula for estimating the cost of PRV systems using 40 cfs and $400,000 as a basis ($10,000 /cfs). The NAWS units include three 24-inch PRV with influent/effluent isolation valves, basket strainers, and hydraulic control unit water filters. These valves would be contained with an aboveground CMU building with heat ventilation, light, access etc.

$ Cost per PRV Station = flow (cfs) x $10,000

So for example, a 72 cfs flow would cost in the order of $720,000. Since the cost is a function of equipment and vault space and each valve is limited, this relationship should be reasonable for planning purposes.

RESERVOIRS:

For planning purposes, since the reservoirs in their current configuration are not intended to provide actual system raw water storage, the volume can be minimized to a size that can allow reasonable hydraulic conditions (avoid scouring, air entrainment, etc.) and be cost-effective. For this analysis we should assume approximately one (1) hour of storage volume at maximum flow in order to provide control for booster pump operation and mitigate surge problems in the pipeline and tank inlet and outlet structures.

$ Cost per Reservoir = Storage Vol. (MG) x 0.8 x 1,000,000

For example, a max flow of 411cfs with a one hour detention time has a storage volume of approximately 11 MG and reservoir costs equal to about $8,841,000.

Dean Karsky - FW: CRWUD finished water transmission and storage costs

From: "Rick St. Germain" <rick@houstonengineeringinc.com>
To: <DKARSKY@gp.usbr.gov>
Date: 5/13/2005 11:08:38 AM
Subject: FW: CRWUD finished water transmission and storage costs

Dean,

I would use the 52nd Avenue pipeline numbers. That was the basis for all the metro stuff we did. Biota pipeline would also include LOW. They are all so close I don't think it matters.
I'm not sure what you want to do with the storage numbers.

P.S. I'll get you Moorhead ASR and Buffalo numbers real soon hopefully before noon. I talked to Ed and Pat this morning. He had a memo prepared for Moorhead but we needed to add a small amount of transmission line. We also have a more detailed plan for Buffalo. Sorry this flew under the radar screen but we'll get it done.

P.S.S. Has Denver done anything with WTP costs since we seen them? If not, Ed and I should talk to you.

Rick St. Germain, Vice President

Houston Engineering, Inc. | Leave Nothing to Chance™

2505 N. University Drive
Fargo, ND 58102
Phone: 701.237.5065 / Fax: 701.237.5101
Email: rick@houstonengineeringinc.com
Website: www.houstonengineeringinc.com

From: Judel Buls [mailto:Judel.Buls@AE2S.com]
Sent: May 13, 2005 10:43 AM
To: Rick St. Germain
Cc: Nate Weisenburger
Subject: CRWUD finished water transmission and storage costs

Good Morning Rick,

I am forwarding the finished water transmission and storage costs for CRWUD, which were developed as part of the F-M Metro Water System Concept Plan.

Please note that the total cost of the towers and transmission pipeline are shared between Horace, CRWUD, and Harwood. The costs provided in the table below represent only CRWUD's portion of the costs, not the entire cost of the proposed infrastructure. In general, the costs reflect transmitting the water from the regional treatment facility to the south CRWUD tower (located near Horace) and the south CRWUD tower. In addition, it reflects transmitting water from the existing FWTP to the north CRWUD tower (located near Harwood) and the north CRWUD tower.

If you have any more questions, please feel free to contact me, and have a good afternoon!

	I-94	**South Moorhead**	**124th Ave**	**52nd Ave**
Sheyenne River				
Finished Water Transmission	$ 5,261,000	$ 5,190,000	$ 4,658,000	$ 4,758,000
Storage	$ 1,679,000	$ 1,679,000	$ 1,679,000	$ 1,679,000

Total	**$**	**6,940,000**	**$**	**6,869,000**	**$**	**6,337,000**	**$**	**6,437,000**
Biota Pipeline	$	-	$	-	$	-	$	-
Finished Water Transmission	$	5,382,000	$	5,190,000	$	4,658,000	$	4,544,000
Storage	$	1,679,000	$	1,679,000	$	1,679,000	$	1,679,000
Total	**$**	**7,061,000**	**$**	**6,869,000**	**$**	**6,337,000**	**$**	**6,223,000**
Minnesota Groundwater	$	-	$	-	$	-	$	-
Finished Water Transmission	$	5,382,000	$	5,099,000	$	4,702,000	$	4,544,000
Storage	$	1,679,000	$	1,679,000	$	1,679,000	$	1,679,000
Total	**$**	**7,061,000**	**$**	**6,778,000**	**$**	**6,381,000**	**$**	**6,223,000**

Judel Buls, PE
Design Engineer
Advanced Engineering and
Environmental Services, Inc. (AE2S)
2016 Washington Street South
Grand Forks, ND 58201
mailto:judel.buls@AE2S.com
http://www.ae2s.com/
Voice: 701.746.8087
Fax: 701.746.0370

M E M O R A N D U M

MWH

To:	Rick St. Germain, HE	**Date:**	February 4, 2005
From:	Ed Cryer (MWH)	**Reference:**	1690583.011801
Subject:	Contractor/Engineering/ Administration Costs for RRV Estimates		

I have proposed the following costs for contractor office and field overhead items and for engineering and owner administration. These costs do not include construction labor and labor overhead or sales taxes. They are multipliers of installed construction costs.

- 30% Contractor Overhead and Profit
- 15% Contract Cost
- 30% Administration and Engineering

I would justify these as follows:

30% Contract Overhead and Profit (OH&P)

This item includes the following:

• Office labor and burden and fringe benefits	8%
• Regulatory costs and permit	0.5%
• Safety program	0.5%
• Company overhead	12%
• Profit	9%
	30%

Contract Cost

• Bonds contract	2%
• Subcontractor bond markup	0.5%
• Builder risk insurance	0.5%
• Company vehicle cost	1.0%
• Superintendent field	3.0%
• Utilities (fuel, electrical, etc.)	1.5%
• Field offices and shed	1.0%
• Communications	0.5%
• Surveying	1.0%
• Secretary	0.5%
• Assistants to Superintendent	3.0%
• Misc.	0.5%
	15%

Engineering and Administration

• Owners administration, permits, environments costs	10%
• Office engineering (design)	8%
• Field engineering (construction and CMS)	10%
• Testing QA/QC	2%
	30%

These numbers are lower than the cost multipliers shown by Reclamation but are a reasonable estimate at this time.

Regards

/ps

M E M O R A N D U M

MWH

To:	Rick St. Germain	**Date:**	May 11, 2005
From:	Ed Cryer	**Reference:**	1690583.011802
Subject:	SCADA Cost RRV Project Alternatives		

Rick, as you requested by Dean, I have estimated the cost for SCADA control of the main delivery pipeline system. I only included portions of the system with pipe 12" and larger. I discussed this project with our I&C person involved with NAWS and their revised system is to use direct bury fiber optic in place of RTUs for main surface water transmission systems, so I adopted that system for the alternatives. I broke the elements out by length of fiber optics in-place by foot ($6.00), connection nodes for individual control elements (reservoir, PRV, pump station, etc.) and central control unit. See attached Table 1 for the costs.

I did the same for the well field SCADA system but use radio transmission units (RTUs) to save cost and because the system is so spread-out (Table 2). The reporting and control of the well systems (in-basin) will not have to be as reliable as the main delivery system that will convey water over the drainage divide (my assumption). System costs include cable, central processing unit (CPU), connection to facility nodes and for RTUs, antenna poles and towers. The system proposed would provide active control and monitoring of functions, facilities, and structures (security, safety etc.).

TABLE 1
Pipeline Delivery System
SCADA COST
(Assumes Fiber Optic Cable Based System)

Alternative 1 -North Dakota In Basin	
Fiber Optic Cable	$2,876,000
Nodes	100,000
Central Processing Unit (CPO)	250,000
Total	**$3,226,000**
Alternative 2 Red River	See Table 2
Alternative 3 -Lake of the Woods	
Fiber Optic Cable	$9,437,000
Nodes	150,000
CPU	250,000
Total	**$9,837,000**
Alternative 4 -GDU to Cheyenne River	
Fiber Optic Cable	$6,323,000
Nodes	125,000
CPU	250,000
Total	**$6,698,000**
Alternative -5 GDU Impact	
Fiber Optic Cable	$9,386,000
Nodes	300,000
CPU	250,000
Total	**$9,936,000**
Alternative 6 -Missouri River	
Fiber Optic Cable	$9,093,000
Nodes	250,000
CPU	250,000
Total	**$9,593,000**
Alternative 7 -GDU Replacement	
Fiber Optic Cable	$15,585,000
Nodes	475,000
CPU	250,000
Total	**$16,310,000**

TABLE 2

SCADA TELEMETRY SYSTEM RVR WELL FIELDS
OPINION OF COST TO CONSTRUCT
(Assumes A Radio (RTU) Based System For Well Fields)

Wahpeton System	**Scenario 1**	**Scenario 2**
RTUs (21-30)	$735,000	$1,050,000
MTU/Central Processing Unit	150,000	150,000
Antenna Poles (<80 Ft) 19-28	19,000	28,000
Antenna Towers (>80 Ft) 2	10,000	10,000
Total	**$914,000**	**$1,238,000**
Elk Valley System		
RTUs (54)	$1,890,000	$1,890,000
MTU/Central Processing Unit	150,000	150,000
Antenna Poles (<80 Ft) 51	51,000	51,000
Antenna Towers (>80 Ft) 3	15,000	15,000
Total	**$2,106,000**	**$2,106,000**
West Fargo South System		
RTUs (36-42)	$1,260,000	$1,470,000
MTU/ Central Processing Unit	150,000	200,000
Antenna Poles (<80 Ft) 34-40	34,000	40,000
Antenna Towers (>80 Ft) 2	10,000	10,000
Total	**$1,454,000**	**$1,720,000**
West Fargo North System		
RTUs (45)	$1,575,000	$1,575,000
MTU/Central Processing Unit	150,000	150,000
Antenna Poles (<80 Ft) 43	43,000	43,000
Antenna Towers (>80 Ft) 2	10,000	10,000
Total	**$1,778,000**	**$1,778,000**
Central Minnesota System		
RTUs (81-129)	$2,835,000	$4,515,000
MTUs /Central processing Unit	300,000	500,000
Antenna poles (<80 ft) (77-121)	77,000	121,000
Antenna Towers (>80 ft) (4-8)	20,000	40,000
Total	**$3,232,000**	**$5,176,000**
Red River Alternative By Well Fields		
Central Minnesota	$3,232,000	$5,176,000
Wahpeton	914,000	1,138 ,000
Elk Valley	2,016,000	2,106,000
West Fargo North	1,678,000	1,678,000
West Fargo South	1,450,000	1,720,000
Total	**$9,484,000**	**$12,018,000**

( ) = Number of elements

Appendix C – Attachment 8

Summary Table for Municipal, Rural, and Industrial Water Systems

Water System Summary Table

After compiling, reviewing and analyzing volumes of data, the table below was created to summarize the current and possible future status of various water users within the Red River Valley. Water users in the valley were divided into groups including municipal systems, water associations, industrial users, rural water systems, and recreational users (future golf courses). The industrial facilities are further divided into existing and future water users. Some comments within the table refer to shortages in specific years, such as 1931, which means if river flow conditions were similar to the drought in 1931, the shortage would be equal to the number identified.

A significant number of small municipalities in the valley are currently served by rural water systems. No specific analysis of these cities was performed, but an analysis of the rural water system providing the water service was conducted and is summarized in the table. The Need and Options Report assumed the smaller municipal systems, not currently served by rural water systems, would be served by a rural water system in the future. This is the trend in the water industry and will continue through the planning horizon of 2050. The rural water systems anticipated to serve these small cities is identified in the table. The process of determining which water systems would have independent treatment capability through 2050 and which systems would not is described in chapter 2, section 2.1.

Abbreviations used for rural water systems are listed below:

- AWUD - Agassiz Water Users District
- BRWD - Barnes Rural Water District
- CRWUD - Cass Rural Water Users District
- DRWD - Dakota Rural Water District
- GFTWD - Grand Forks Traill Water District
- LRWD - Langdon Rural Water District
- NVWD - North Valley Water District
- RSWUD - Ransom-Sargent Water Users District
- SWD - Southeast Water District
- TRWD - Traill Rural Water District
- TCWD - Tri-County Water District
- WRWD - Walsh Rural Water District

Water System	Current Water Provider	Future Water Provider	Comments
Municipal			
Abercrombie	SWD	SWD	No specific analysis conducted.
Absaraka	CRWUD	CRWUD	No specific analysis conducted.
Adams	LRWD	LRWD	No specific analysis conducted.
Alice	CRWUD	CRWUD	No specific analysis conducted.
Alsen	LRWD	LRWD	No specific analysis conducted.
Amenia	CRWUD	CRWUD	No specific analysis conducted.
Aneta	DRWD	DRWD	No specific analysis conducted.
Ardoch	AWUD	AWUD	No specific analysis conducted.
Argusville	CRWUD	CRWUD	No specific analysis conducted.

Water System	Current Water Provider	Future Water Provider	Comments
Arthur	CRWUD	CRWUD	No specific analysis conducted.
Arvilla	GFTWD	GFTWD	No specific analysis conducted.
Aye	CRWUD	CRWUD	No specific analysis conducted.
Backoo	NVWD	NVWD	No specific analysis conducted.
Barney	SWD	SWD	No specific analysis conducted.
Bathgate	NVWD	NVWD	No specific analysis conducted.
Blabon	DRWD	DRWD	No specific analysis conducted.
Blanchard	TRWD	TRWD	No specific analysis conducted.
Briarwood	CRWUD	CRWUD	No specific analysis conducted.
Binford	Self	DRWD	No specific analysis conducted.
Bowesmont	NVWD	NVWD	No specific analysis conducted.
Breckenridge	Self	Self	The evaluation of existing groundwater supplies indicated that Breckenridge has adequate permitted supplies through 2050. The water system is not included in any proposed alternatives except the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.6 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Brocket	TCWD	TCWD	No specific analysis conducted.
Buffalo	CRWUD	CRWUD	No specific analysis conducted.
Buxton	GFTWD	GFTWD	No specific analysis conducted.
Caledonia	TRWD	TRWD	No specific analysis conducted.
Casselton	CRWUD	CRWUD	No specific analysis conducted.
Cavalier	NVWD	NVWD	No specific analysis conducted.
Cavalier Air Force Station	NVWD	NVWD	No specific analysis conducted.
Cayuga	SWD	SWD	No specific analysis conducted.
Chaffee	CRWUD	CRWUD	No specific analysis conducted.
Clifford	TRWD	TRWD	No specific analysis conducted.
Cogswell	RSWUD	RSWUD	No specific analysis conducted.
Colfax	SWD	SWD	No specific analysis conducted.
Colgate	DRWD	DRWD	No specific analysis conducted.
Conway	WRWD	WRWD	No specific analysis conducted.
Cooperstown	Self	DRWD	Municipal water system was specifically evaluated in Table 2.4.3 and water demands were incorporated in the DRWD.
Crete	RSWUD	RSWUD	No specific analysis conducted.
Crystal	NVWD	NVWD	No specific analysis conducted.
Cummings	GFTWD	GFTWD	No specific analysis conducted.
Dahlen	TCWD	TCWD	No specific analysis conducted.
Davenport	CRWUD	CRWUD	No specific analysis conducted.
Dazey	Self	BRWD	No specific analysis conducted.
DeLamere	SWD	SWD	No specific analysis conducted.
Drayton	Self	Self	The city of Drayton is currently served from the Red River. Surface modeling results showed that Drayton would have minor shortages with the maximum being 90 ac-ft in 1937. The city's 2050 estimated water demand was modeled to assure all alternatives supplied sufficient water to meet the city's future demands. All supplemental alternatives provide the city with water from the Red River. Peak day water demands were met by river flows in some alternatives and by storage in others. Refer to section 2.6 in Chapter 2 for water demand estimates.
Durbin	CRWUD	CRWUD	No specific analysis conducted.
Dwight	SWD	SWD	No specific analysis conducted.

Water System	Current Water Provider	Future Water Provider	Comments
East Grand Forks	Self	Self	The city of East Grand Forks is currently served from the Red and Red Lake Rivers. Surface modeling results showed that East Grand Forks had no shortages during the period of record. However, since modeling was conducted on a monthly time step, meeting daily demands could be an issue. Peak day water demands are met by using river flows, pipeline capacity or storage depending on the alternative. Refer to section 2.6 in Chapter 2 for water demand estimates.
Eckelson	BRWD	BRWD	No specific analysis conducted.
Edinburg	LRWD	LRWD	No specific analysis conducted.
Edmore	LRWD	LRWD	No specific analysis conducted.
Elliot	Self	RSWUD	No specific analysis conducted.
Embden	CRWUD	CRWUD	No specific analysis conducted.
Emerado	GFTWD	GFTWD	No specific analysis conducted.
Enderlin	Self	CRWUD	No specific analysis conducted.
Erie	CRWUD	CRWUD	No specific analysis conducted.
Fairdale	LRWD	LRWD	No specific analysis conducted.
Fairmount	SWD	SWD	No specific analysis conducted.
Fargo	Self	Self	The city of Fargo is currently served from the Red and Sheyenne Rivers. Surface modeling results showed that Fargo would have a maximum shortage of 24,152 ac-ft under Scenario One or 37,456 ac-ft under Scenario Two, both occurring in 1937. However, the shortages attributed to Fargo could be lower depending on how water permit priorities are modeled. See chapter 5, section 5.3 for further discussion. The city's 2050 estimated water demand was modeled to assure all alternatives supplied sufficient water to meet the city's future demands. The six supplemental alternatives provide the city with water in one of three ways; pipeline import, via the Sheyenne River, or Minnesota groundwater. Peak day water demands were met by river flows, pipeline capacity or by development of an aquifer storage and recovery system in the West Fargo South Aquifer. Refer to section 2.6 in Chapter 2 for water demand estimates.
Fingal	RSWUD	RSWUD	No specific analysis conducted.
Finley	DRWD	DRWD	No specific analysis conducted.
Forest River Colony	AWUD	AWUD	No specific analysis conducted.
Fort Ransom	BRWD	BRWD	No specific analysis conducted.
Forman	Self	RSWUD	No specific analysis conducted.
Galesburg	TRWD	TRWD	No specific analysis conducted.
Gardar	NVWD	NVWD	No specific analysis conducted.
Gardner	CRWUD	CRWUD	No specific analysis conducted.
Gilby	AWUD	AWUD	No specific analysis conducted.
Glachutt	SWD	SWD	No specific analysis conducted.
Glasston	NVWD	NVWD	No specific analysis conducted.
Grafton	Self	Self	The city of Grafton is currently served from the Red River. Surface modeling results showed that Grafton had no shortages during the period of record. However, since the modeling was conducted on a monthly time step, meeting daily demands could be an issue. Peak day water demands were met by river flows in some alternatives and by storage in others. Refer to section 2.6 in Chapter 2 for water demand estimates.

Water System	Current Water Provider	Future Water Provider	Comments
Grand Forks	Self	Self	The city of Grand Forks is currently served from the Red and Red Lake Rivers. Surface modeling results showed Grand Forks had no shortages under Scenario One and a maximum shortage of 1,927 ac-ft under Scenario Two in 1937. The city's 2050 estimated water demand was modeled to assure all alternatives supplied sufficient water to meet the city's future demands. The six supplemental alternatives provide the city water in two ways; pipeline import or via the Red River. Grand Forks had relatively small shortages, but to improve the quality of their water supply 20 cfs of capacity was provided in all supplemental alternatives that pipe water to city. Peak day water demands are met by river flows, increased pipeline capacity, or by purchasing groundwater from the Elk Valley Aquifer. Refer to section 2.6 in Chapter 2 for water demand estimates.
Grand Forks Air Force Base	City of Grand Forks	City of Grand Forks	Future water demands were included in city of Grand Forks analysis.
Grandin	TRWDD	TRWDD	No specific analysis conducted.
Great Bend	SWD	SWD	No specific analysis conducted.
Gwinner	Self	Self	The evaluation of existing groundwater supplies indicated Gwinner has adequate permitted supplies through 2050. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.6 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Hamilton	NVWD	NVWD	No specific analysis conducted.
Hampden	LRWD	LRWD	No specific analysis conducted.
Hankinson	Self	SWD	This municipal water system was specifically evaluated in Table 2.4.3 and water demands were incorporated in the SWD.
Hannaford	Self	DRWD	It was assumed this community would receive water service from DRWD in the future. No specific analysis was conducted.
Harwood	Self	CRWUD	No specific analysis conducted.
Hastings	BRWD	BRWD	No specific analysis conducted.
Hatton	GFTWD	GFTWD	No specific analysis conducted.
Havana	SWD	SWD	No specific analysis conducted.
Hensel	NVWD	NVWD	No specific analysis conducted.
Hickson	CRWUD	CRWUD	No specific analysis conducted.
Hillsboro	Self	TRWDD	This municipal water system was specifically evaluated in Table 2.4.3 and water demands were incorporated in TRWDD.
Honeyford	AWUD	AWUD	No specific analysis conducted.
Hoople	WRWD	WRWD	No specific analysis conducted.
Hope	DRWD	DRWD	No specific analysis conducted.
Horace	Self	CRWUD	No specific analysis conducted.
Hunter	CRWUD	CRWUD	No specific analysis conducted.
Inkster	CRWUD	CRWUD	No specific analysis conducted.
Jessie	DRWD	DRWD	No specific analysis conducted.
Joliette	NVWD	NVWD	No specific analysis conducted.
Johnstown	AWUD	AWUD	No specific analysis conducted.
Kathryn	Self	BRWD	No specific analysis conducted.
Kempton	TCWD	TCWD	No specific analysis conducted.
Kindred	CRWUD	CRWUD	No specific analysis conducted.
Kloten	DRWD	DRWD	No specific analysis conducted.
Lakota	Self	TCWD	No specific analysis conducted.

Water System	Current Water Provider	Future Water Provider	Comments
Langdon	Self	Self	The city of Langdon is currently served from the Pembina River and also serves the Langdon Rural Water District. Surface modeling results showed Langdon had maximum annual shortages of 340 ac-ft under Scenario One and 392 ac-ft under Scenario Two, occurring in 1940 and 1939, respectively. The city's 2050 estimated water demand was modeled at the confluence of the Pembina and Red Rivers to assure all alternatives supplied sufficient water to meet the city's future demands. These demands also include Langdon Rural Water District. All supplemental alternatives provide water from the Red River. No analysis of the hydrology of the Pembina River was conducted in this study so it is not known how long Mount Carmel Reservoir storage would last during a drought. To address this issue, adequate flows in the Red River were provided for Langdon and LRWD. Peak day water demands were met by river flows in some alternatives and by storage in others. Refer to section 2.6 in Chapter 2 for water demand estimates.
Lankin	WRWD	WRWD	No specific analysis conducted.
Larimore	Self	Self	The evaluation of existing groundwater supplies indicated Larimore has adequate permitted supplies through 2050. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.6 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Lawton	TCWD	TCWD	No specific analysis conducted.
Leroy	NVWD	NVWD	No specific analysis conducted.
Leal	BRWD	BRWD	No specific analysis conducted.
Liggerwood	Self	SWD	Municipal water system was specifically evaluated in Table 2.4.3 and water demands incorporated in SWD.
Lisbon	Self	Self	The evaluation of existing groundwater supplies indicated that Lisbon has adequate permitted supplies through 2050. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.6 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Litchville	BRWD	BRWD	No specific analysis conducted.
Luverne	DRWD	DRWD	No specific analysis conducted.
Lynchburg	CRWUD	CRWUD	No specific analysis conducted.
Mantador	SWD	SWD	No specific analysis conducted.
Manvel	AWUD	AWUD	No specific analysis conducted.
Mapleton	CRWUD	CRWUD	No specific analysis conducted.
Marion	Self	RSWUD	No specific analysis conducted.
Marshall-Polk	GFTWD	GFTWD	No specific analysis conducted.
Mayville	Self	TRWDD	Municipal water system was specifically evaluated in Table 2.4.3 and water demands were incorporated in TRWDD.
McVille	Self	DRWD	No specific analysis conducted.
Mekinock	AWUD	AWUD	No specific analysis conducted.
Michigan	TCWD	TCWD	No specific analysis conducted.
Milnor	SWD	SWD	No specific analysis conducted.
Milton	NVWD	NVWD	No specific analysis conducted.
Minto	Self	WRWD	Municipal water system was specifically evaluated in Table 2.4.3 and water demands were incorporated in WRWD.
Mooreton	SWD	SWD	No specific analysis conducted.

Water System	Current Water Provider	Future Water Provider	Comments
Moorhead	Self	Self	The city of Moorhead is currently served from the Red River in addition to the Moorhead and Buffalo Aquifers. Surface modeling results showed that Moorhead would have a maximum shortage of 874 ac-ft under Scenario One or 1,050 ac-ft under Scenario Two, both occurring in 1936. Moorhead and Fargo have the same priority date, but for modeling purposes Moorhead was given a higher water right priority because the model could not have two demand points with similar priority dates. Because of this change, some of Fargo's shortage may be assigned to Moorhead which is discussed in chapter 5, section 5.3. The city's 2050 estimated water demand was modeled to assure all alternatives supplied sufficient water to meet the city's future demands. The six supplemental alternatives provide the city water in one of three ways; pipeline import, via the Sheyenne River, or Minnesota groundwater. Peak day water demands were met by river flows, pipeline capacity, or by development of additional groundwater capacity from the Buffalo Aquifer. An aquifer storage and recovery system is also planned for the Moorhead Aquifer to guarantee sustainable use of that aquifer. Refer to section 2.6 in Chapter 2 for water demand estimates.
Mountain	NVWD	NVWD	No specific analysis conducted.
Nash	WRWD	WRWD	No specific analysis conducted.
Neche	NVWD	NVWD	No specific analysis conducted.
Nekoma	LRWD	LRWD	No specific analysis conducted.
Niagara	TCWD	TCWD	No specific analysis conducted.
Nome	RSWUD	RSWUD	No specific analysis conducted.
Northwood	GFTWD	GFTWD	No specific analysis conducted.
Oriska	BRWD	BRWD	No specific analysis conducted.
Orr	TCWD	TCWD	No specific analysis conducted.
Osnabrock	LRWD	LRWD	No specific analysis conducted.
Oxbow	Self	CRWUD	No specific analysis conducted.
Page	Self	CRWUD	No specific analysis conducted.
Park River	Self	Self	The city of Park River recently procured a new water source from the Fordville Aquifer. The evaluation of this groundwater supply indicated the city has adequate permitted supplies through 2050. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.6 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Pekin	Self	DRWD	No specific analysis conducted.
Pembina	Self	NVWD	Municipal water system was specifically evaluated in Table 2.4.3 and water demands were incorporated in NVWD.
Petersburg	TCWD	TCWD	No specific analysis conducted.
Pillsbury	DRWD	DRWD	No specific analysis conducted.
Pisek	WRWD	WRWD	No specific analysis conducted.
Portland	TRWDD	TRWDD	No specific analysis conducted.
Prairie Rose	CRWUD	CRWUD	No specific analysis conducted.
Prosper	CRWUD	CRWUD	No specific analysis conducted.
Reynolds	GFTWD	GFTWD	No specific analysis conducted.
Rogers	BRWD	BRWD	No specific analysis conducted.
Rutland	SWD	SWD	No specific analysis conducted.
Saint Benedict	CRWUD	CRWUD	No specific analysis conducted.
Saint Thomas	NVWD	NVWD	No specific analysis conducted.
Sanborn	BRWD	BRWD	No specific analysis conducted.
Sharon	DRWD	DRWD	No specific analysis conducted.
Sheldon	Self	RSWUD	No specific analysis conducted.
Sibley	DRWD	DRWD	No specific analysis conducted.

Water System	Current Water Provider	Future Water Provider	Comments
Stirum	RSWUD	RSWUD	No specific analysis conducted.
Thompson	GFTWD	GFTWD	No specific analysis conducted.
Tolna	Self	DRWD	No specific analysis conducted.
Tower City	CRWUD	CRWUD	No specific analysis conducted.
Urbana	BRWD	BRWD	No specific analysis conducted.
Valley City	Self	Self	Valley City uses Sheyenne River water to fill a pond which recharges an aquifer adjacent to the city's water treatment plant. Surface modeling results showed Valley City will have adequate supplies through 2050. Refer to section 2.6 in Chapter 2 for water demand estimates.
Verona	BRWD	BRWD	No specific analysis conducted.
Voss	WRWD	WRWD	No specific analysis conducted.
Wahpeton	Self	Self	The evaluation of existing groundwater supplies indicate Wahpeton has adequate permitted supplies through 2050. The water system is only included in the GDU Replacement Water Supply Pipeline Alternative. Refer to section 2.6 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Walcott	Self	SWD	No specific analysis conducted.
Wallalla	NVWD	NVWD	No specific analysis conducted.
Walum	BRWD	BRWD	No specific analysis conducted.
Warren	CRWUD	CRWUD	No specific analysis conducted.
Warsaw	WRWD	WRWD	No specific analysis conducted.
West Fargo	Self	Self	The city of West Fargo is currently served from the West Fargo North Aquifer. This aquifer has been determined to be inadequate for future use so it was assumed the city would need to be served by the Sheyenne River in the future. Modeling results showed the city would have a maximum shortage of 3,544 ac-ft under Scenario One or 3,680 ac-ft under Scenario Two, both occurring in 1936. The city's 2050 estimated water demand was modeled to assure all alternatives supplied sufficient water to meet the future demands. The six supplemental alternatives provide the city with water in one of three ways; pipeline import, via the Sheyenne River, or Minnesota groundwater. An aquifer storage and recovery system is proposed for the West Fargo North Aquifer to store water for use during a drought. Peak day water demands were met by river flows, pipeline capacity, or development of the same aquifer. Refer to section 2.6 in Chapter 2 for water demand estimates.
Wheatland	CRWUD	CRWUD	No specific analysis conducted.
Whitman	TCWD	TCWD	No specific analysis conducted.
Wild Rice	CRWUD	CRWUD	No specific analysis conducted.
Wimbledon	Self	BRWD	No specific analysis conducted.
Wyndmere	Self	SWD	Municipal water system was specifically evaluated in Table 2.4.3 and water demands were incorporated in SWD.
Water Associations			
Arvilla Water Users Association	GFTWD	GFTWD	No specific analysis conducted.
Brooktree Wells Inc.	Self	CRWUD	No specific analysis conducted.
Chrisan Water Users Association	Self	CRWUD	No specific analysis conducted.
Christine Water and Sewer	Self	SWD	No specific analysis conducted.
County Acres Water Company	Self	CRWUD	No specific analysis conducted.

Water System	Current Water Provider	Future Water Provider	Comments
Fradets Orchard Water System	Self	CRWUD	No specific analysis conducted.
Highland Park Subdivision	CRWUD	CRWUD	No specific analysis conducted.
Horseshoe Bend Addition	Self	CRWUD	No specific analysis conducted.
Lake Shure Home Owners Association	Self	CRWUD	No specific analysis conducted.
Meadowbrook Park Road & Water Inc.	Self	CRWUD	No specific analysis conducted.
Reiles Acres	CRWUD	CRWUD	No specific analysis conducted.
Riverdale Subdivision	Self	CRWUD	No specific analysis conducted.
Selkirk Settlement	Self	CRWUD	No specific analysis conducted.
Sleepy Hollow Water Company	Self	CRWUD	No specific analysis conducted.
Sundale Hutterian Association	Self	RSWUD	No specific analysis conducted.
Woodland Lawn Subdivision	CRWUD	CRWUD	No specific analysis conducted.
Existing Industrial Facilities			
ADM Corn Processing	Self	Self	ADM Corn Processing facility has two water sources. The groundwater source is adequate to meet future water demands. The other water source is adjacent to the Pembina River so it was modeled as a surface water supply. Modeling results showed the facility would have a maximum shortage of 225 ac-ft occurring in 1939. All of the supplemental alternatives were modeled to assure adequate flows in the Red River at the confluence with the Pembina River. This shortage is probably of less concern than other surface water shortages, as this is a groundwater source adjacent to the Pembina River and has some viability in low flow conditions. Refer to section 2.6 in Chapter 2 for water demand estimates.
American Crystal Sugar Company - Drayton	Self	Self	The American Crystal Sugar Company at Drayton uses the Red River as its water supply. Modeling results showed the facility has no shortages through the period of record. Refer to section 2.6 in Chapter 2 for water demand estimates.
American Crystal Sugar Company – East Grand Forks	Self	Self	No water demands were separately developed for this facility because they are included in the water demands for the city of East Grand Forks.
American Crystal Sugar Company - Hillsboro	Self	Self	The American Crystal Sugar Company at Hillsboro uses the Goose River as its water supply. Surface modeling results showed the facility would have a maximum shortage of 447 ac-ft occurring in 1934. The water demand was modeled on the Red River rather than the Goose River, but the shortage results are expected to be the same. All of the supplemental alternatives were modeled to assure adequate flows in the Red River at the confluence with the Goose River. Refer to section 2.6 in Chapter 2 for water demand estimates.

Water System	Current Water Provider	Future Water Provider	Comments
American Crystal Sugar Company - Moorhead	Self	Self	The American Crystal Sugar Company at Moorhead recently uses water purchased from city of Moorhead as its primary source with a minor amount of water used from the Red River. However, modeing results showed the facility would have a maximum shortage of 495 ac-ft under Scenario One or 464 ac-ft under Scenario Two, both occurring in 1936 if they return to using more Red River through their own intake. All the supplemental alternatives were modeled to assure adequate flows in the Red River for the facility. Refer to section 2.6 in Chapter 2 for water demand estimates.
Cargill Corn Processing Plant	Self	Self	The Cargill Corn Processing Plant north of Wahpeton uses the Red River as its water supply. The plant also has some conditional groundwater permits, but these were not used in the analysis because it was assumed to be unsustainable during a long drought such as the 1930s. Modeling results showed the facility would have a maximum shortage of 1,926 ac-ft under Scenario One or Two, both occurring in 1931. Two features were developed to address these shortages, additional groundwater capacity in aquifers to the southwest of the plant and a pipeline from the Fargo area. Refer to section 2.6 in Chapter 2 for water demand estimates.
Cargill, Inc. - West Fargo	Self	City of Fargo	Since the West Fargo Aquifer is not considered a reliable future water source, it was assumed Cargill would purchase all of their future water from the city of Fargo. This future water demand was included in the water demands for Fargo. Refer to section 2.6 in Chapter 2 for water demand estimates.
Cass-Clay Creameries, Inc.	Self	City of Fargo	Since the West Fargo Aquifer is not considered a reliable future water source, it was assumed Cass Clay would purchase all of their future water from the city of Fargo. This future water demand was included in the water demands for Fargo. Refer to section 2.6 in Chapter 2 for water demand estimates.
Minn-Dak Farmers Coop	Self	Self	Minn-Dak Farmers Coop uses the Wahpeton Buried Valley Aquifer as their water supply source. Evaluation of their groundwater permit revealed that in only one year out of 15 did the industry exceed their permitted allocation. Since this appears to be an isolated event, the shortage was not modeled as a surface water demand. The industrial facility has an adequate water supply through 2050 and therefore is not included in any of the supplemental alternatives. Refer to section 2.6 in Chapter 2 for water demand estimates.
RDO Foods Company	City of Grand Forks	City of Grand Forks	RDO Foods Company uses the city of Grand Forks as their primary water supply source. However, evaluation of their groundwater permit revealed they have an adequate permitted amount of water through 2050 for what they do use of groundwater and therefore is not included in any of the supplemental alternatives. Refer to section 2.6 in Chapter 2 for water demand estimates.
New Industrial Water Demands			
Cass County (Fargo)			The water demand for projected future industrial activity in Cass County was assumed to be served by surface water and was included in Fargo's analysis. Modeling results indicated Fargo would have significant future shortages. Refer to the explanation of Fargo's water needs in the Municipal section above for more information. Refer to section 2.8 in Chapter 2 for water demand estimates.

Water System	Current Water Provider	Future Water Provider	Comments
Clay County (Moorhead)			The water demand for projected future industrial activity in Clay County was assumed to be served by surface water and was included in Moorhead's analysis. Modeling results indicate Moorhead has significant future shortages. Refer to the explanation of Moorhead's water demands in the Municipal section above for more detailed information. Refer to section 2.8 in Chapter 2 for water demand estimates.
Grand Forks County (Grand Forks)			The water demand for projected future industrial activity in Grand Forks County was assumed to be served by surface water and was included in Grand Forks' analysis. Modeling results indicate Grand Forks has minor future shortages during droughts. Refer to the explanation of Grand Forks' water needs in the Municipal section above for more detailed information. Refer to section 2.8 in Chapter 2 for water demand estimates.
Richland County (Wahpeton)			The water demand for projected future industrial activity in Richland County was assumed to be served by surface water in the Wahpeton area. Modeling results show that the new industry would have an annual maximum shortage of 3,404 ac-ft under Scenario One or 6,451 ac-ft under Scenario Two, both occurring in 1931. Two features were developed to address these shortages, additional groundwater capacity in aquifers to the southwest of Wahpeton and a pipeline from the Fargo area. Refer to section 2.8 in Chapter 2 for water demand estimates.
Rural Water Systems			
Agassiz Water Users District	Self	Self	Evaluation of existing groundwater supplies indicated AWUD has adequate permitted supplies through 2050. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Barnes Rural Water District	Self	Self	Evaluation of existing groundwater supplies indicated that BRWD has adequate permitted supplies through 2050. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Cass Rural Water Users District	Self	Self	The evaluation of existing groundwater supplies indicated that CRWUD has potential annual groundwater shortages of 702 ac-ft under scenario 1 and 1,250 ac-ft under scenario 2. The study assumed that the shortage was in the Phase I service area and that the Phase II and III had adequate water supplies. To address this shortage, CRWUD was assumed to purchase water from Fargo. Modeling results show that Fargo has significant shortages in the 1930s which would include CRWUD. Fargo's 2050 estimated water demand was modeled to assure that all alternatives supplied sufficient water to meet the city's future demands. The six supplement alternatives provide water through Fargo. The replacement alternative provides water via pipeline. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in chapter 3 for groundwater analysis.

Water System	Current Water Provider	Future Water Provider	Comments
Dakota Rural Water District	Self	Self	Evaluation of existing groundwater supplies indicated DRWD has adequate permitted supplies through 2050. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Grand Forks Traill Water District	Self	Self	Evaluation of existing groundwater supplies indicated GFTWD has potential annual groundwater shortages of 605 ac-ft under Scenario One or 1,143 ac-ft under Scenario Two. To address this shortage GFTWD has two options; purchase water from Grand Forks or purchase additional groundwater capacity in the Elk Valley Aquifer. Modeling results indicate Grand Forks has minor shortages in the 1930s, which would include GFTWD. The city of Grand Forks' 2050 estimated water demand was modeled to assure all alternatives supplied sufficient water to meet the city's future demands. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Langdon Rural Water District	Self	Self	The LRWD is included in the analysis of the city of Langdon.
North Valley Water District	Self	Self	Evaluation of existing groundwater supplies indicated NVWD has adequate permitted supplies through 2050. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Ransom-Sargent Water Users District	Self	Self	Evaluation of existing groundwater supplies indicated RSWUD has adequate permitted supplies through 2050. The water system is only included in any the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Southeast Water District	Self	Self	Evaluation of existing groundwater supplies indicated that SWD has potential annual groundwater shortages of 123 ac-ft under Scenario One or 151 ac-ft under Scenario Two. SWD is already in the process of procuring additional permitted capacity in the Hankinson Aquifer to address this shortage. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Traill Rural Water District	Self	Self	Evaluation of existing groundwater supplies indicated TRWD has potential annual groundwater shortage of 83 ac-ft under Scenario One or surplus of 194 ac-ft under Scenario Two. TRWD is already in the process of procuring additional permitted groundwater capacity to address this shortage. The water system is only included in the GDU Water Supply Replacement Placement Alternative. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Tri-County Water District	Self	Self	Evaluation of existing groundwater supplies indicated TCWD has adequate permitted supplies through 2050. The water system is only included in the GDU Water Supply Replacement Pipeline Alternative. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.

Water System	Current Water Provider	Future Water Provider	Comments
Walsh Rural Water District	Self	Self	The evaluation of existing groundwater supplies indicated that WRWD has adequate permitted supplies through 2050. The water system is not included in any proposed alternatives except the Replacement alternative. Refer to section 2.7 in Chapter 2 for water demand estimates and section 3.3.1 in Chapter 3 for groundwater analysis.
Future Recreational Water Demand (Golf Courses)			
Cass County (Fargo)			The analysis conducted assumed the water demand for new golf courses in Cass County would be supplied by surface water. Modeling results indicate a maximum annual shortage of 286 ac-ft under Scenario One or 289 ac-ft under Scenario Two, both occurring in 1931. Alternatives were developed to meet these and other shortages using imports via pipeline, import to the Sheyenne River, or Minnesota groundwater. Refer to section 2.9 in Chapter 2 for water demand estimates.
Clay County (Moorhead)			The analysis conducted assumed the water demand for new golf courses in Clay County would be supplied by surface water. Modeling results indicate a maximum annual shortage of 33 ac-ft under Scenario One and Two, occurring in 1931. Alternatives were developed to meet these and other shortages using imports via pipeline, import to Sheyenne River, or Minnesota groundwater. Refer to section 2.9 in Chapter 2 for water demand estimates.
Grand Forks County (Grand Forks)			The analysis conducted assumed the water demand for new golf courses in Grand Forks County would be supplied by surface water. Modeling results indicate a maximum annual shortage of 27 ac-ft under Scenario One or 15 ac-ft under Scenario Two, both occurring in 1932. Alternatives were developed to meet these and other shortages using imports via pipeline or import to the Red River via the Sheyenne River. Refer to section 2.9 in Chapter 2 for water demand estimates.
Otter Tail County			The analysis conducted assumed the water demand for new golf courses in Otter Tail County would be supplied by surface water. Modeling results indicate a maximum annual shortage of 49 ac-ft under Scenario One and Two, both occurring in 1931. Because these water demands are outside the service area, none of the alternatives proposed were designed to meet these shortages. Refer to section 2.9 in Chapter 2 for water demand estimates.

Appendix C – Attachment 9

Drought Contingency Analysis

Drought Contingency Analysis

Introduction

Through the DEIS (Draft Environmental Impact Statement) comment process Reclamation and the State of North Dakota (represented by Garrison Diversion Conservancy District) as co-leads of the DEIS received comments regarding why drought contingency measures were not considered in the proposed action alternatives. This was in response to Reclamation's decision to not include drought contingency measures in the development of water demands in the Needs and Options Report. This decision was made for a number of reasons, but was influenced mostly by language in the DWRA (Dakota Water Resources Act). DWRA directed the Secretary of the Interior to identify the *comprehensive* water needs of the Red River Valley. Reclamation defined *comprehensive* to *not* include drought contingency measures because it would establish situations where the water users would be limited in the availability of water under some climatic circumstances. Reclamation believes the intent of DWRA was to provide options to meet the total future water needs of the Red River Valley with reductions due to water conservation measures.

In addition, all water project investigations have to weigh and balance assumptions associated with how much water is needed and how much water is available. How much water is needed (from a municipal standpoint) is driven by estimates of per capita water demand and future population projections, while future industrial water needs are estimated using economic tools. There are inherent difficulties in developing these demand estimates, but they are manageable.

The estimate of available surface water in the future, particularly during a drought period, is much more difficult. The USGS constructed a naturalized flow database (1931 – 2001) for Reclamation's use in analyzing historic flow data. It quickly became apparent that the flow years during the 1930s were the critical event to verify whether 2050 water demands could be served during those drought conditions. Hydrologic modeling results showed that significant water shortages would occur in the Red River Valley during the 1930s unless additional water supplies were located. The hydrologic model assumed that all water in the Red River and Sheyenne River was available for use. In other words, the flows in the rivers could be effectively withdrawn to zero flow if needed. Modeling results show this would happen at key locations on the Red River such as Fargo, North Dakota and Moorhead, Minnesota.

Water users have raised the concern that rivers can not be effectively drained to zero flow and the hydrology analysis is cutting things to close. There is a concern that if the USGS naturalized flow database has errors (less water than USGS estimated) and/or it is not possible to withdraw water to zero flow in the river, there would not be enough water designed into the proposed action alternatives (except the GDU Water Supply Replacement Pipeline Alternative) to meet the future water needs in a 1930s style drought.

In response to this concern, Reclamation did not include drought contingency measures in the water demand estimates. Drought contingency measures were reserved as a safety measure if the following situations happened that were not accounted for in the Needs and Options Report analysis.

- Future water demands are higher because of unexpected population growth or increased (above historic) per capita water use.
- The occurrence of a drought is more severe than the historic drought of the 1930s.
- Possible unknowns in surface water hydrologic modeling
    - Smaller flows during the 1930s than estimated by USGS because gaging station data were limited as compared to present number of sites.
    - Losses to groundwater are higher in the Sheyenne River or other locations than accounted for in the naturalized flow database.
    - Water can not be effectively drawn down to zero in the Sheyenne and Red Rivers.

If any one of these situations were to occur, drought contingent measures would need to be employed by the local governments or water systems to avoid water shortages.

Drought Contingency Estimating Methods

The development of two water demand scenarios in the Needs and Options Report allows for a sensitivity analysis to compare how change in water demand influences the cost of the alternatives. Two water demands and corresponding construction cost estimates were developed for each alternative. These two data points provide a relationship between change in water demand and construction costs for each alternative. Once this water demand/cost relationship is quantified, then various levels of drought contingencies can be evaluated. This gives decision-makers the information they need to determine how much they are willing to pay for levels of water supply reliability.

The most robust drought contingency plan in the Red River Valley was developed by the city of Fargo in 2003, *City of Fargo Drought Management Plan (2003)*. A few other cities have similar plans, but Fargo's plan was used for this analysis because Fargo is the largest water user and their plan can reasonably applied to other systems. The plan established various water reduction levels based on different climatic and water supply conditions. Five phases were identified in the plan, with phase one having no reduction and phase five being the most severe. Phase five has a goal of 30%+ water reduction.

Drought Contingency Water Reduction Results

When comparing water demand reduction and associated cost savings, there are two different water demands to use as the basis for comparison total maximum annual *surface* water demand and *total* maximum annual water demand. Table 1 shows the water demand estimates for Scenario One and Two. Approximately 90% of the total water demand in the Red River Valley is supplied by surface water under both scenarios. Table 2 shows the estimated construction costs presented in the Needs and Options Report for each alternative and water demand scenario.

Table 1 – Scenario One and Scenario Two Water Demands.

Water Demand	Scenario One (ac-ft)	Scenario Two (ac-ft)	Water Demand Difference (ac-ft)
Total Maximum Annual Surface Water Demand	101,024	128,270	27,246
Total Maximum Annual Water Demand	113,702	142,380	28,678

Table 2 - Alternative Construction Cost Estimates (2005 Price Level).

Option	Scenario One Cost	Scenario Two Cost
North Dakota In-Basin	$557,859,000	$637,891,000
Red River Basin	$549,166,000	$750,150,000
Lake of the Woods	$937,228,000	$1,112,579,000
GDU Import to Sheyenne River	$434,052,000	$585,002,000
GDU Import Pipeline	$1,202,248,000	$1,407,721,000
Missouri River Import to Red River Valley	$875,378,000	$1,013,951,000
GDU Water Supply Replacement Pipeline	$2,226,667,000	$2,518,023,000

Column 2 in table 3 shows the cost difference between the Scenario One and Two for each alternative. Column 3 shows the difference in *surface* water demand between Scenario One and Two at 27,246 ac-ft, which is the same for all alternatives as shown in table 1. The last column shows the change in construction cost per 1,000 ac-ft of water demand. For example, if there were a water demand reduction of 1,000 ac-ft in the North Dakota In-Basin Alternative, that would save $2,937,000. One aspect of this analysis shows that some alternatives are more sensitive to changes in water demand than others. For example, the North Dakota In-Basin is least sensitive to water demand at $2,937,000 per 1,000 ac-ft while the most sensitive is the GDU Water Supply Replacement Pipeline Alternative at $10,694,000 per 1,000 ac-ft.

Table 3 - Construction Cost Sensitivity Analysis – Maximum Annual Surface Water Demand.

Option	Cost Difference Scenario One vs. Scenario Two	Water Demand Difference Scenario One vs. Scenario Two (ac-ft)	Change in Cost per 1,000 ac-ft
North Dakota In-Basin	$80,032,000	27,246	$2,937,000
Red River Basin	$200,984,000	27,246	$7,377,000
Lake of the Woods	$175,351,000	27,246	$6,436,000
GDU Import to Sheyenne River	$150,950,000	27,246	$5,540,000
GDU Import Pipeline	$205,473,000	27,246	$7,541,000
Missouri River Import to Red River Valley	$138,573,000	27,246	$5,086,000
GDU Water Supply Replacement Pipeline	$291,356,000	27,246	$10,694,000

Table 4 shows a similar sensitivity analysis that uses the *total* maximum annual water demand as the basis of comparison for construction costs. Column 3 in table 4 shows the difference in *surface* water demand between Scenarios One and Two at 28,678 ac-ft, which slightly larger than for the surface water demand in table 3. The least sensitive alternative is the North Dakota In-Basin at a construction cost savings of $2,791,000 per 1,000 ac-ft of water demand reduction. The most sensitive alternative is the GDU Water Supply Replacement Pipeline Alternative at a construction cost savings of $10,160,000 per 1,000 ac-ft of water demand reduction.

Table 4 - Construction Cost Sensitivity Analysis - Total Maximum Annual Water Demand.

Option	Cost Difference Scenario One vs. Scenario Two	Water Demand Difference Scenario One vs. Scenario Two (ac-ft)	Change in Cost per 1,000 ac-ft
North Dakota In-Basin	$80,032,000	28,678	$2,791,000
Red River Basin	$200,984,000	28,678	$7,008,000
Lake of the Woods	$175,351,000	28,678	$6,114,000
GDU Import to Sheyenne River	$150,950,000	28,678	$5,264,000
GDU Import Pipeline	$205,473,000	28,678	$7,165,000
Missouri River Import to Red River Valley	$138,573,000	28,678	$4,832,000
GDU Water Supply Replacement Pipeline	$291,356,000	28,678	$10,160,000

The results from either sensitivity analysis could be used for further investigations, but the *total* maximum annual water demand analysis (table 4) was selected because the results were more conservative (lower change in cost per 1,000 ac-ft). The resulting change in cost per 1,000 ac-ft figures from table 4 was used in the following analysis.

Alternative Construction Costs Reduction Results due to Drought Contingency

Table 5 shows the drought levels included in the *City of Fargo Drought Management Plan (2003).* Five phases or levels would be implemented depending on the severity of drought conditions. The Phase 1 drought is for normal climatic conditions with a 0% water demand reduction goal. Phases 2 through 5 address increasing levels of drought with water demand reduction goals of 5% - 10% (Phase 2), 10% - 20% (Phase 3), 20% - 30% (Phase 4), and 30% or

Table 5 – City of Fargo Drought Management Plan.

Drought Levels	Demand Reduction Goal (%)	Demand Reduction used in Analysis (%)
Phase I – Normal Conditions	0%	0%
Phase 2 – Drought Advisory	5% - 10%	7.5%
Phase 3 – Drought Watch	10% - 20%	15%
Phase 4 – Drought Warning	20% - 30%	25%
Phase 5 – Drought Emergency	30%+	35%

more (Phase 5). Since the Fargo drought management plan showed demand reduction goals in ranges, the third column of the table was added to show specific water demand reduction goals used in this analysis. While a drought management plan could be monitored or implemented at different timescales, a monthly timescale was used in this analysis.

Table 6 compares demand reduction goal to the actual demand reduction projections. Tables 7 through 14 show the estimated drought contingency water demand reduction for 7.5% (tables 7 and 8), 15% (tables 9 and 10), 25% (tables 11 and 12) and 35% (tables 13 and 14) levels for Scenarios One and Two, respectively. Using table 7 and Scenario One as an example, assuming that drought measures are normally applied to summer months, a 7.5% reduction in water demand was estimated for May through October (shaded in green). The lowest water demand month, after the 7.5% reduction was applied, was October at 8,246 ac-ft. Looking at the rest of the months in the year, three other months (March, April and November) had higher water demands at 8,393 ac-ft, 8,578 ac-ft and 8,602 ac-ft, respectively, than what was now being used in October at 8,246 ac-ft. It is unreasonable to have April and November water demands higher than a summer month, so the March, April and November (shaded in yellow) water demands were reduced to 8,246 ac-ft. This same process was used for all investigated drought reduction levels and water demand scenarios.

The net water reduction for the 7.5% drought reduction goal for Scenario One was 5,699 ac-ft (shaded in blue) from a starting total of 113,702 ac-ft. This results in an effective annual reduction of 5.0%. The goal was 5% - 10% water demand reduction in this Phase 2 example. The reason it did not result in a reduction closer to 7.5% was because the type of drought measures used under a Phase 2 drought level did not achieve the same results in the winter as the summer due to limited landscape watering. This is a reasonable result and is to be expected in a northern climate. The higher drought levels (Phases 3, 4 and 5) resulted in water demand reductions closer to the percentage goal as shown in table 6.

Table 6 – Comparison Between Demand Reduction Goal and Projected Demand Reduction.

Drought Levels	Demand Reduction Goal (%)	Demand Reduction used in Analysis (%)	Projected Scenario One Demand Reduction (%)	Projected Scenario Two Demand Reduction (%)
Phase I – Normal Conditions	0%	0.0%	0%	0%
Phase 2 – Drought Advisory	5% - 10%	7.5%	5.0%	5.2%
Phase 3 – Drought Watch	10% - 20%	15.0%	11.7%	12.1%
Phase 4 – Drought Warning	20% - 30%	25.0%	21.9%	22.3%
Phase 5 – Drought Emergency	30%+	35.0%	32.3%	32.7%

Tables 15 (Scenario One) and 16 (Scenario Two) show the cost savings of each of the four drought reduction phases. For example, if an occasional 7.5% water demand reduction would be acceptable, a range of $15.9 to $57.9 million could be saved in construction costs for an option to meet the Scenario One water demands. The construction cost savings would range from $20.5 to $74.7 million for an option sized to meet Scenario Two water demands.

Phase 2 – Drought Advisory Drought Contingency Goal =	7.5%

Table 7 - Scenario One Total Water Demands (acre-feet).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (ac-ft)
Total Demands	7,805	7,335	8,393	8,578	9,937	11,955	13,214	11,080	9,760	8,915	8,602	8,130	113,702
With Drought Contingency	7,805	7,335	8,246	8,246	9,191	11,058	12,223	10,249	9,028	8,246	8,246	8,130	108,002
Demand Change	0	0	147	332	745	897	991	831	732	669	356	0	5,699
Change as percent													5.0%

Table 8 - Scenario Two Total Water Demands (acre-feet).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (ac-ft)
Total Demands	9,967	9,319	10,594	10,817	12,462	14,780	16,232	13,760	12,142	11,151	10,825	10,334	142,381
With Drought Contingency	9,967	9,319	10,315	10,315	11,527	13,671	15,014	12,728	11,231	10,315	10,315	10,315	135,051
Demand Change	0	0	279	502	935	1,108	1,217	1,032	911	836	510	0	7,331
Change as percent													5.1%

Phase 3 – Drought Watch Drought Contingency Goal =	15%

Table 9 - Scenario One Total Water Demands (acre-feet).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (ac-ft)
Total Demands	7,805	7,335	8,393	8,578	9,937	11,955	13,214	11,080	9,760	8,915	8,602	8,130	113,702
With Drought Contingency	7,577	7,335	7,577	7,577	8,446	10,162	11,232	9,418	8,296	7,577	7,577	7,577	100,352
Demand Change	227	0	816	1,001	1,491	1,793	1,982	1,662	1,464	1,337	1,024	553	13,349
Change as percent													11.7%

Table 10 - Scenario Two Total Water Demands (acre-feet).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (ac-ft)
Total Demands	9,967	9,319	10,594	10,817	12,462	14,780	16,232	13,760	12,142	11,151	10,825	10,334	142,381
With Drought Contingency	9,478	9,319	9,478	9,478	10,592	12,563	13,797	11,696	10,321	9,478	9,478	9,478	125,159
Demand Change	488	0	1,116	1,338	1,869	2,217	2,435	2,064	1,821	1,673	1,346	855	17,222
Change as percent													12.1%

Phase 4 – Drought Warning Drought Contingency Goal =	25%

Table 11 - Scenario One Total Water Demands (acre-feet).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (ac-ft)
Total Demands	7,805	7,335	8,393	8,578	9,937	11,955	13,214	11,080	9,760	8,915	8,602	8,130	113,702
With Drought Contingency	6,686	6,686	6,686	6,686	7,453	8,966	9,910	8,310	7,320	6,686	6,686	6,686	88,760
Demand Change	1,119	649	1,707	1,892	2,484	2,989	3,303	2,770	2,440	2,229	1,916	1,444	24,941
Change as percent													21.9%

Table 12 - Scenario Two Total Water Demands (acre-feet).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (ac-ft)
Total Demands	9,967	9,319	10,594	10,817	12,462	14,780	16,232	13,760	12,142	11,151	10,825	10,334	142,381
With Drought Contingency	8,363	8,363	8,363	8,363	9,346	11,085	12,174	10,320	9,106	8,363	8,363	8,363	110,575
Demand Change	1,603	956	2,231	2,453	3,115	3,695	4,058	3,440	3,035	2,788	2,461	1,970	31,807
Change as percent													22.3%

Phase 5 – Drought Emergency Drought Contingency Goal =	35%

Table 13 - Scenario One Total Water Demands (acre-feet).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (ac-ft)
Total Demands	7,805	7,335	8,393	8,578	9,937	11,955	13,214	11,080	9,760	8,915	8,602	8,130	113,702
With Drought Contingency	5,794	5,794	5,794	5,794	6,459	7,771	8,589	7,202	6,344	5,794	5,794	5,794	76,925
Demand Change	2,010	1,541	2,599	2,784	3,478	4,184	4,625	3,878	3,416	3,120	2,807	2,335	36,776
Change as percent													32.3%

Table 14 - Scenario Two Total Water Demands (acre-feet).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (ac-ft)
Total Demands	9,967	9,319	10,594	10,817	12,462	14,780	16,232	13,760	12,142	11,151	10,825	10,334	142,381
With Drought Contingency	7,248	7,248	7,248	7,248	8,100	9,607	10,551	8,944	7,892	7,248	7,248	7,248	95,831
Demand Change	2,718	2,071	3,346	3,569	4,362	5,173	5,681	4,816	4,250	3,903	3,576	3,085	46,550
Change as percent													32.7%

Table 15 - Construction Cost Reduction (Cost Savings) with Drought Contingency - Scenario One.

Option	Phase 2 7.5% Demand Reduction Goal	Phase 3 15% Demand Reduction Goal	Phase 4 25% Demand Reduction Goal	Phase 5 35% Demand Reduction Goal
North Dakota In-Basin	$15,907,000	$37,257,000	$69,612,000	$102,642,000
Red River Basin	$39,941,000	$93,551,000	$174,790,000	$257,727,000
Lake of the Woods	$34,845,000	$81,617,000	$152,492,000	$224,849,000
GDU Import to Sheyenne River	$30,001,000	$70,270,000	$131,292,000	$193,590,000
GDU Import Pipeline	$40,835,000	$95,647,000	$178,706,000	$263,501,000
Missouri River Import to Red River Valley	$27,539,000	$64,503,000	$120,517,000	$177,702,000
GDU Water Supply Replacement Pipeline	$57,905,000	$135,627,000	$253,405,000	$373,646,000

Table 16 - Construction Cost Reduction (Cost Savings) with Drought Contingency - Scenario Two.

Option	Phase 2 7.5% Demand Reduction Goal	Phase 3 15% Demand Reduction Goal	Phase 4 25% Demand Reduction Goal	Phase 5 35% Demand Reduction Goal
North Dakota In-Basin	$20,512,000	$48,068,000	$88,772,000	$129,921,000
Red River Basin	$51,504,000	$120,695,000	$222,901,000	$326,222,000
Lake of the Woods	$44,934,000	$105,298,000	$194,466,000	$284,607,000
GDU Import to Sheyenne River	$38,687,000	$90,659,000	$167,430,000	$245,039,000
GDU Import Pipeline	$52,658,000	$123,398,000	$227,895,000	$333,531,000
Missouri River Import to Red River Valley	$35,512,000	$83,219,000	$153,690,000	$224,930,000
GDU Water Supply Replacement Pipeline	$74,669,000	$174,979,000	$323,156,000	$472,948,000

Tables 17 (Scenario One) and 18 (Scenario Two) show the overall reduced construction cost of each option under the four drought reduction phases. The second column shows the cost of the options with 0% water demand reduction, and columns 3 through 6 show corresponding reductions in costs of the five phases of demand reduction.

Table 17 - Alternative Construction Cost with Drought Contingency - Scenario One.

Option	0% Demand Reduction Goal	Phase 2 7.5% Demand Reduction Goal	Phase 3 15% Demand Reduction Goal	Phase 4 25% Demand Reduction Goal	Phase 5 35% Demand Reduction Goal
North Dakota In-Basin	$557,859,000	$541,952,000	$520,602,000	$488,247,000	$455,217,000
Red River Basin	$549,166,000	$509,225,000	$455,615,000	$374,376,000	$291,439,000
Lake of the Woods	$937,228,000	$902,383,000	$855,611,000	$784,736,000	$712,379,000
GDU Import to Sheyenne River	$434,052,000	$404,051,000	$363,782,000	$302,760,000	$240,462,000
GDU Import Pipeline	$1,202,248,000	$1,161,413,000	$1,106,601,000	$1,023,542,000	$938,747,000
Missouri River Import to Red River Valley	$875,378,000	$847,839,000	$810,875,000	$754,861,000	$697,676,000
GDU Water Supply Replacement Pipeline	$2,226,667,000	$2,168,762,000	$2,091,040,000	$1,973,262,000	$1,853,021,000

Table 18 - Alternative Construction Cost with Drought Contingency - Scenario Two.

Option	0% Demand Reduction Goal	Phase 2 7.5% Demand Reduction Goal	Phase 3 15% Demand Reduction Goal	Phase 4 25% Demand Reduction Goal	Phase 5 35% Demand Reduction Goal
North Dakota In-Basin	$637,891,000	$617,379,000	$589,823,000	$549,119,000	$507,970,000
Red River Basin	$750,150,000	$698,646,000	$629,455,000	$527,249,000	$423,928,000
Lake of the Woods	$1,112,579,000	$1,067,645,000	$1,007,281,000	$918,113,000	$827,972,000
GDU Import to Sheyenne River	$585,002,000	$546,315,000	$494,343,000	$417,572,000	$339,963,000
GDU Import Pipeline	$1,407,721,000	$1,355,063,000	$1,284,323,000	$1,179,826,000	$1,074,190,000
Missouri River Import to Red River Valley	$1,013,951,000	$978,439,000	$930,732,000	$860,261,000	$789,021,000
GDU Water Supply Replacement Pipeline	$2,518,023,000	$2,443,354,000	$2,343,044,000	$2,194,867,000	$2,045,075,000

Figures 1 (Scenario One) and 2 (Scenario Two) shows the numeric results from tables 17 and 18 graphically. The figures show how construction costs can be reduced by including different levels of drought contingency in the alternatives. The caution however is that higher level drought contingency measures will significantly limit water availability to commercial and industrial sectors resulting in regional economic impacts as discussed in the next section.

The graphed lines are basically parallel to each other. If a particular alternative was the third most expensive, even with some level of drought contingencies, it was still the third most expensive to construct at different level of demand reduction. The exception to this observation is the Red River Basin Alternative under Scenario One. This alternative is very sensitive to cost and is the least expensive alternative with 35% drought contingency measures. The reason this alternative is sensitive to cost, is because as more water demand is needed additional wells further east into Minnesota are required at a proportionally higher cost.

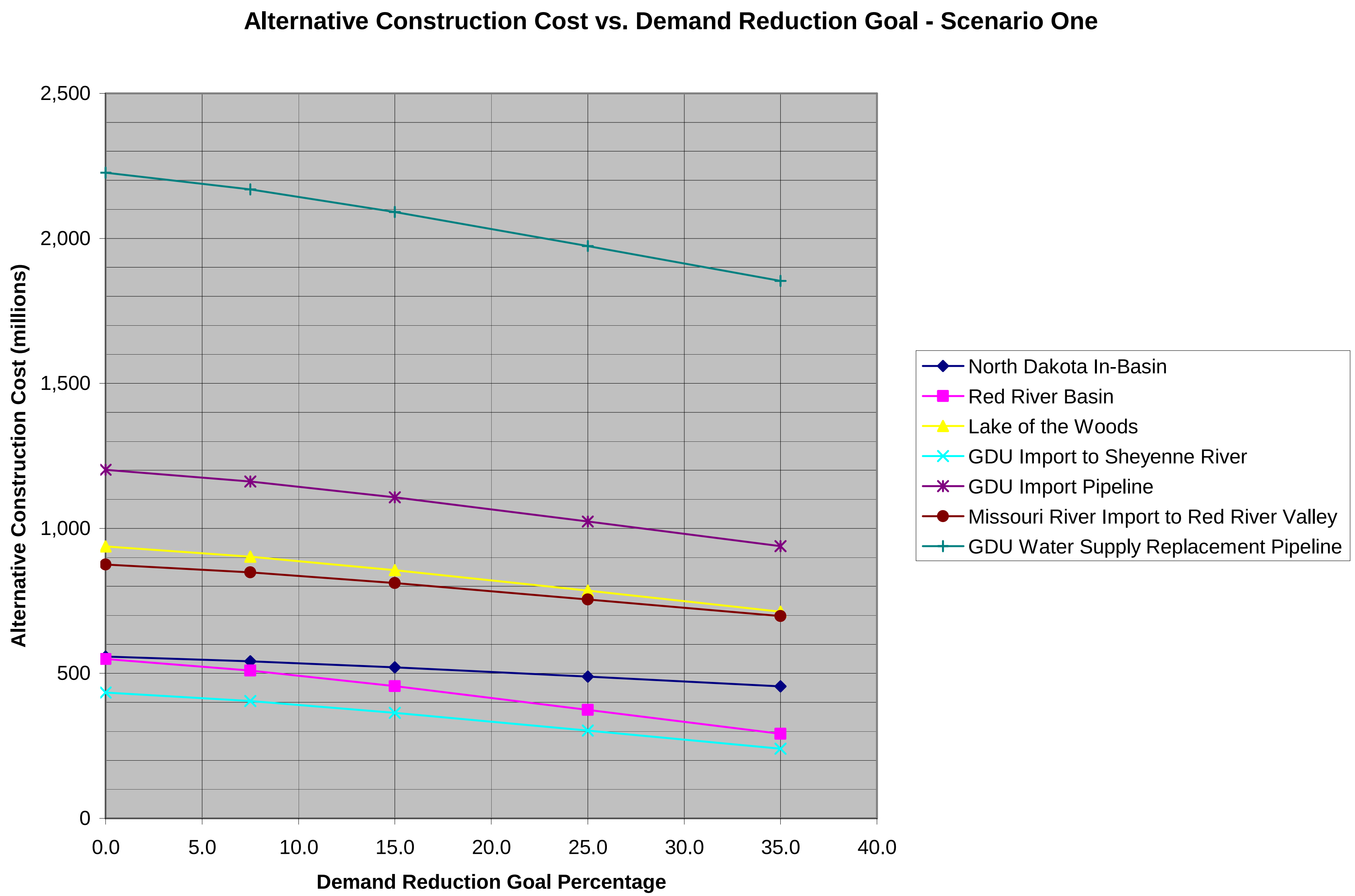

Figure 1 – Alternative Construction Cost vs. Demand Reduction Goal – Scenario One.

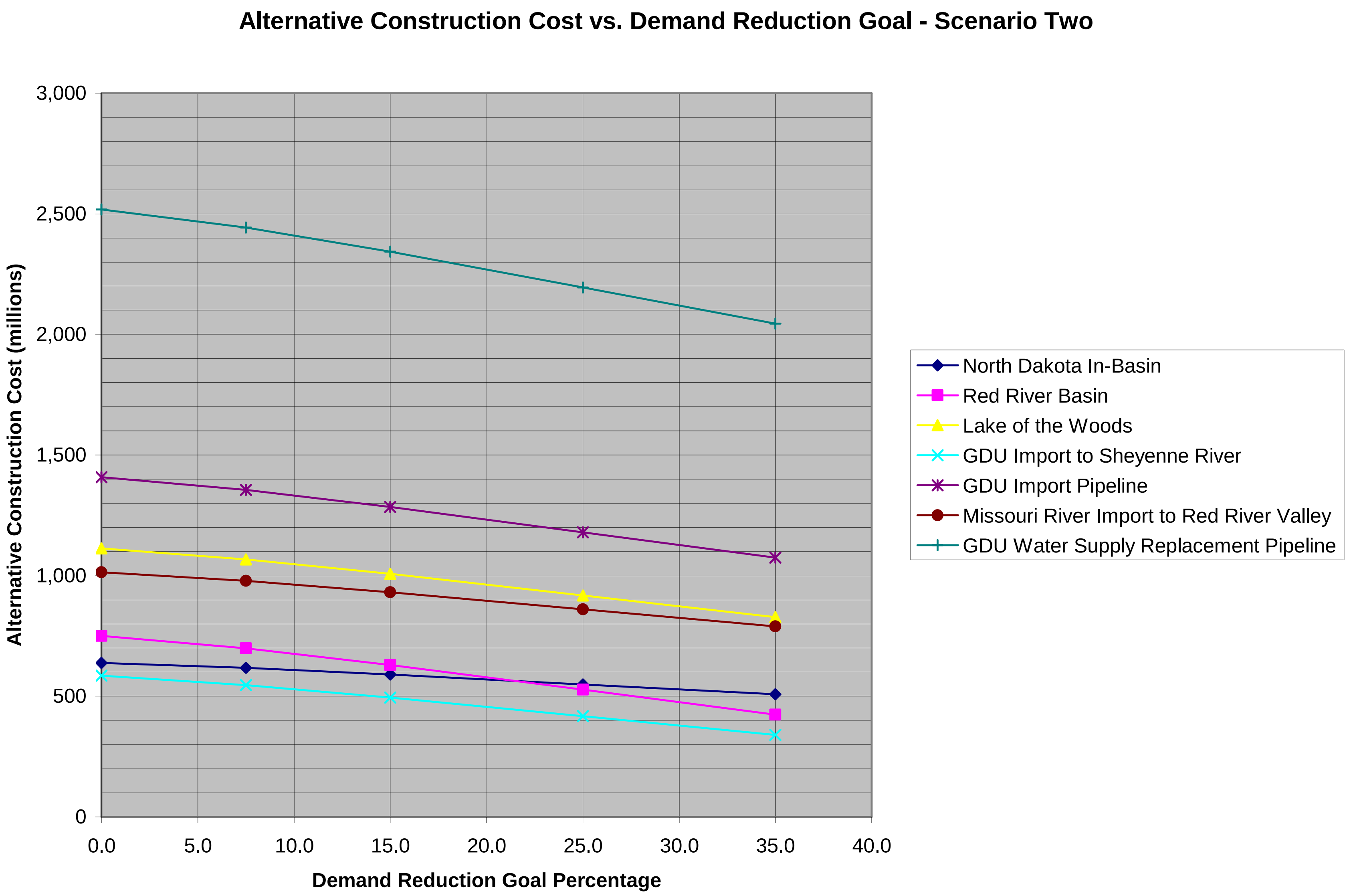

Figure 2 – Alternative Construction Cost vs. Demand Reduction Goal – Scenario Two.

Potential Economic Effects From the Implementation Of Drought Contingency Measures

Implementation of drought contingency measures would potentially have a similar effect as a drought on economic activity, commercial output, employment, and income with some important differences. As water supply restrictions are imposed on the demand side in response to shortages, commercial activities would be expected to be adversely affected. However, drought contingency measures could conceptually be implemented to try and minimize the economic impacts of water shortages.

These measures may allow flexibility in providing water supplies to sectors that rely heavily on water as a production input and could provide warnings of coming shortages, which would allow businesses, industry, and residents to better prepare for shortages. Therefore, the economic impacts from water supply reductions associated with drought contingencies may be significantly less than the impacts associated with an unprepared water supply system. It should also be noted that the impacts would vary considerably depending on the length of time drought contingency plans are implemented. The geographic scope of this analysis is the 13 eastern counties in North Dakota and the Minnesota cities of East Grand Forks, Moorhead and Breckenridge.

General Effects of Water Supply Shortages

The general economic related effects of water supply shortages include:

- Loss to industries directly dependent on agricultural production (e.g., machinery and fertilizer manufacturers, food processors, dairies, etc.)
- Unemployment from drought-related declines in production
- Strain on financial institutions (foreclosures, credit risk, capital shortfalls)
- A reduced tax base for federal, state, and local governments
- Loss to manufacturers and sellers of various types of equipment
- Losses related to recreation activities: hunting and fishing, bird watching, etc.
- Revenue shortfalls to water suppliers.

Specific costs and losses to agricultural producers and other resources include:

- Annual and perennial crop losses and associated lost income
- Reduced productivity/revenues from range/pasture land
- Impaired productivity of forest land
- Damage to fish habitat

The Effect of Supply Shortages on Commercial Activities

In order to evaluate the potential economic effects of water supply shortages, the relationship between water supplies and commercial output for different sectors needs to be understood. The impact of a water shortage on economic activities depends on the magnitude of the shortage, the importance of water as an input to various commercial activities, and the length of the shortage. A commercial water users' production decision becomes a problem of profit maximization under constrained water availability. Under drought conditions the production decision can be complicated by the following factors.

- The degree to which water supply constraints are binding production;
- Uncertainty about the adequacy of future supplies;
- Future plans of a business to expand and increase output;

- Extent to which conservation methods have already been adopted and could be adopted further;
- Cost of conservation; and
- The extent to which a strategy could be chosen that would lower the risk of interrupted production due to a water shortage.

A study completed for the California Urban Water Agencies (Spectrum Economics 1991) discussed the decisions that business managers need to make to minimize production costs during periods of drought. Examples of these decisions include minimizing the costs of obtaining water from alternate water sources, reducing water use per unit of good or service produced, or reducing the level of production. The preferred method of dealing with a water shortage would be to implement relatively inexpensive conservation methods while maintaining output. This is what is typically observed when a drought is not severe and is of short duration. However, when a drought becomes severe and the most painless conservation methods have already been implemented, then a reduction in output will most likely occur. The study provides estimates of the reduction in output that could occur as a result of water supply shortages of various magnitudes.

The study included a survey of commercial/industrial water users. The survey requested information on water use and the implementation of conservation methods under different water supply scenarios. The survey targeted industries that would be most affected by changes in water supplies and industries that are part of the most important sectors of the local economy. Data gathered were used to estimate output elasticities for water. An output elasticity for water measures is the percentage change in output for a business or industry that would occur as a result of a percentage change in the water input. For example, if a 1% reduction in available water results in a 0.5% reduction in output, then the output elasticity for water is 0.5. An elasticity greater than 1 indicates water is a very important input and the change in output is greater than a change in available water supplies. An elasticity less than 1 indicates other inputs can be substituted for water and output changes less than the change in water supplies.

Elasticities estimated from the survey data varied according to the magnitude of the water supply shortage. The elasticities were calculated for shortages between 0% and 15% and between 15% and 30% of a full water supply. The estimated elasticities for various production sectors or SIC (Standard Industrial Classifications) codes are presented in table 19. The impact of water supplies on production is summarized qualitatively in table 20.

Table 19 - Estimated Output Elasticities for Water by Sector.

SIC Code	Description of Sector	Elasticity 0% to 15%	Elasticity 15% to 30%
201	Meat Packing	0.00	0.00
203	Preserved Fruits and Vegetables	0.27	0.35
205	Bakery Products	0.70	0.90
208	Beverages	0.69	1.14
209	Misc. Food and Kindred Production	0.24	0.49
265	Paperboard Containers and Boxes	0.40	0.70
281	Industrial Inorganic Chemicals	0.12	0.20
283	Drugs	0.01	0.31

SIC Code	Description of Sector	Elasticity 0% to 15%	Elasticity 15% to 30%
284	Soap, Cleansers, and Toilet Goods	0.38	1.39
285	Paints and Allied Products	0.76	0.97
291	Petroleum Refining	0.44	0.85
327	Concrete, Gypsum, and Plaster Production	0.17	0.19
344	Fabricated Metal Production	0.15	0.41
357	Computer and Office Equipment	0.18	0.27
366	Communication Equipment	0.00	0.01
367	Electronic Components and Accessories	0.07	0.33
371	Motor Vehicles	0.00	0.00
372	Aircraft and Parts	0.07	0.30
376	Aerospace	0.00	0.14

Source: California Urban Water Agencies, *Cost of Industrial Water Shortages*, Spectrum Economics, Nov. 1991.

Table 20 - Impact of Water Shortages on Output.

Highest	Moderately High	Small but Significant	Zero
Bakery prod. Beverages Paint & allied prod.	Preserved Fruits & Vegetables Misc. Food and related prod. Soap, cleansers, and related Petroleum refining	Industrial chemicals Concrete, gypsum, & plaster prod. Fabricated metal production Computer and office equipment Drugs (15% - 30%)	Meat Packing Drugs (0% - 15%) Communication Motor Vehicles Aerospace

In another study, Goddard and Fiske (2005) evaluated the impacts and degree of hardship that water shortages impose on municipal water systems. The study was conducted for Santa Cruz, California, and evaluated the potential impacts from water shortages ranging from 10% to 60% of a full supply. The survey included about 1,900 commercial business accounts and 45 industrial accounts. The study indicated a wide variation in production impacts associated with various water supply shortages. A summary of shortage impacts is presented in table 21.

Table 21 - Impact of Various Shortages on Production.

	Shortage Percentage	Business Impact[a]
BUSINESS SHORTAGE		
Mild	4%	1
Moderate	13%	2
Serious	22%	4
Severe	27%	4-5
Critical	33%	6
Extreme	48%	6
INDUSTRIAL SHORTAGE		
Mild	5%	2
Moderate	15%	3
Serious	25%	5
Severe	30%	5
Critical	35%	6
Extreme	50%	6

Note a: 1=Little or no impact (0% reduced revenue)
2=Some impact (5% reduced revenue)
3=Intermediate impact (15% reduced revenue)
4=Considerable impact (25% reduced revenue)
5=Major impact (33% reduced revenue)
6=Catastrophic impact (100% reduced revenue)

Impacts of Drought Contingency

Given the information presented above, the impact of implementing drought contingency goals as identified in the city of Fargo's plan can be roughly estimated. Based on the results of the Spectrum Economics study and the Goddard and Fiske study, it is likely that a drought contingency goal of 7.5% will have a very small economic impact on the regional economy. A drought contingency goal of 7.5% is estimated to translate into a 5.0% to 5.1% water demand reduction. The average output impact of a 5% water supply reduction indicated by the California studies is essentially zero.

A drought contingency goal of 15% is estimated to translate into a 11.7% to 12.1% reduction in water demands. This represents a significantly greater potential impact on regional economic activity. A 12% reduction in available supplies is a marginal area where negative production output effects can start to occur, depending on the type of industry affected and the length of time drought contingencies are imposed. The overall average effect could be about a 5% reduction in commercial revenues during the period the drought contingencies are in effect.

A drought contingency goal of 25% is estimated to translate into a 21.9% to 22.3% reduction in water demands. The California studies indicate that a mandatory actual reduction in water use of approximately 22% is likely to translate into a nearly proportional decrease in business revenues on average over all businesses. This represents a potentially large regional economic impact from imposing drought contingency goals. The impacts would vary greatly depending on the sector.

A drought contingency goal of 35% would translate into a 32.3% to 32.7% reduction in water demands. This level of reduction would translate into very substantial regional economic impacts, ranging from 30% to 50% or more depending on the sector affected.

Based on the current level of economic activity in the counties included in the Red River Valley region and the estimated impacts discussed above, the impacts of imposing drought contingency goals and water supply reductions can be estimated. It should be stressed that there could be a great deal of variation in potential impacts depending on how the reductions are imposed on different sectors. Rough annual impact estimates from drought contingency goals are shown in table 22. These represent negative impacts.

Table 22 - Approximate Annual Impacts from Imposing Drought Contingency Goals.

Drought Contingency Goal	Impact Economic Decline	Approximate Annual Regional Impacts
7.5%	0%	$0
15%	5%	$492 million
25%	22%	$2.16 billion
35%	35%	$3.45 billion

The economic impact values shown in table 22 only represent implementation of drought contingency measures for a single year. The Needs and Options Report identified the 1930s drought as the critical hydrologic event for which all project alternatives were are designed. The

1930s drought was a 10-year event that would require significant water use reduction measures if no project were constructed.

Tables 23 (Scenario One) and 24 (Scenario Two) show the estimated water demand shortages for each year during the 1930s style drought. Based on the results from table 22, the last column in each table shows the estimated economic impact from implementation of the drought contingency measures in that year. The total estimated impact over the 10-year 1930s style drought would be $13.4 billion under Scenario One and $20.7 billion under Scenario Two.

There could be a great deal of variability in these impact cost estimates. The cumulative affect from consecutive years of drought are not accounted for in the analysis. For example, an industry may have moderate reduction in output (lost revenue) during one-year due to reduced water availability; however, if that situation persisted for multiple years, the industry may eventually go bankrupt so the economic impact is a 100% loss for that industry. Other industries may have some water use flexibility and be able to adapt to less water availability reducing the, which would reduce economic impact on their business.

Table 23 – Cumulative Economic Impact during 1930s Style Drought – Scenario One.

Year	Water Demand Shortage (ac-ft)	Water Demand Shortage[1] (%)	Approximate Annual Regional Impacts (millions $)
1931	9,060	8.0%	$30.7
1932	11,110	9.8%	$149.0
1933	14,628	12.9%	$352.0
1934	36,424	32.0%	$3,067.5
1935	14,717	12.9%	$357.1
1936	33,216	29.2%	$2,703.5
1937	26,961	23.7%	$1,945.2
1938	24,307	21.4%	$1,555.8
1939	18,603	16.4%	$719.0
1940	31,561	27.8%	$2,515.7
Total			$13,395.5

[1] Percentage based on 113,702 ac-ft annual water demand.

Table 24 – Cumulative Economic Impact during 1930s Style Drought – Scenario Two.

Year	Water Demand Shortage (ac-ft)	Water Demand Shortage[1] (%)	Approximate Annual Regional Impacts (millions $)
1931	13,812	9.7%	$144.4
1932	23,828	16.7%	$781.5
1933	29,352	20.6%	$1,428.6
1934	53,015	37.2%	$3,738.3
1935	27,398	19.2%	$1,199.7
1936	52,343	36.8%	$3,677.4
1937	44,397	31.2%	$2,957.5
1938	37,125	26.1%	$2,298.6
1939	29,972	21.1%	$1,501.3
1940	44,902	31.5%	$3,003.2
Total			$20,730.5

[1] Percentage based on 142,380 ac-ft annual water demand.

Conclusions

Based on this analysis it is estimated that little economic impact would result from implementing drought contingency goals at a level of 7.5% or less. Water demand reductions above 7.5% start to create negative economic impacts. For example, 15% demand reduction or shortage has about $492 million of annual regional impact (table 22), while the same demand reduction potentially provides a one-time alternative construction savings of $37 million to $175 million (tables 15 and 16). The $492 million is only an annual regional economic impact estimate. The cumulative impact through a 1930s style drought could be 10 times as great or $4.9 billion. Balancing the desire to reduce construction costs while limiting potential economic impacts associated with the implementation of drought contingency measures is a difficult challenge for water managers. This analysis shows that from an economic impact standpoint, implementation of drought contingency goals above 7.5% could have severe economic costs far outweighing any short-term construction cost savings.

Appendix C – Attachment 10

Aquatic Needs Analysis

Analysis of North Dakota Game and Fish Department Recommended Flows Red River Valley Water Supply Project

The North Dakota Game and Fish Department (NDGFD) provided recommendations for aquatic life minimum instream flows for the Sheyenne and Red Rivers in a letter dated September 28, 2005. The NDGFD stated their concern that Reclamation had failed to consider or incorporate regimes which closely mimic the natural hydrograph into the design of the options. Their recommended seasonal flows for both the Red River and the Sheyenne River are as follows:

- A minimum release of 23 cfs from Baldhill Dam year-round.
- A minimum spring flush of 215 cfs for a period of 48 – 72 hours from the 6th – 10th of April. (Note: This value was not derived by the Tennant method but rather was developed by taking the median unregulated April flow during the 1931 – 1940 time frame.)
- April flows shall average a minimum of 69 cfs below Baldhill Dam.
- Year round instream flows of 68 cfs at Fargo on the Red River. (Note: This instream flow is not intended to require supplemental flows, rather it is the base flow in the river when permits denied further withdrawal.)
- Year round instream flows of 23 cfs below the Fargo intake on the Sheyenne River.

There are a number of ways of improving aquatic communities in the Red River Valley beyond establishing minimum instream flow requirements. These include addressing water quality degradation associated with non-point source pollution and habitat restoration along the Sheyenne and Red Rivers and their tributaries. This analysis focuses on flow augmentation as recommended by the NDGFD. Other opportunities to improve the aquatic habitat may be investigated in the draft EIS.

Hydrologic Modeling of NDGFD Recommended Flows

A StateMod hydrologic model run was developed for each alternative (including No Action) for both water demand Scenarios One and Two. To simplify the analysis of minimum flow targets for aquatic life, each alternative was analyzed using Scenario Two water demands only. Scenario Two water demands were used because it puts the highest demands on natural flow.

The minimum instream flows or targets proposed by the NDGFD are not a consumptive demand, but do influence whether water can be withdrawn from the river for MR&I needs. For example in the model, the 68 cfs minimum flow requirement at Fargo results in Fargo (and Moorhead) not being able to withdraw water from the Red River if the flow falls below 68 cfs. That does not mean that the flow will always be at least 68 cfs, because that is a function of available natural flow. It does mean that Fargo (and Moorhead) can not withdraw water below that flow rate and must turn to other sources of water to meet their needs. Whether the state of North Dakota can legally stop Moorhead from withdrawing water at a flow below 68 cfs is a question to be answered outside the scope of this analysis. The model run was setup based on the assumption that Minnesota water systems will adhere to the minimum flow requirements set by North Dakota.

Results from each model run will provide the size of water supply needed to meet the Scenario Two water demands for each alternative including the aquatic flow targets. These results can be directly compared to the original modeling results to determine the additional capacity needed for each alternative to meet the NDGFD recommended flows.

Hydrologic Modeling Results with NDGFD Recommended Flows

Table 1 shows a comparison of the original modeling results and the results including the NDGFD instream flow recommendation under Scenario Two water demands. The No Action Alternative results are shown as a maximum annual MR&I shortage in acre-feet since no conveyance system would be constructed in this alternative. The other option results are displayed as a maximum flow rate in cfs required by the option's features to meet the demand. Not all options can be modified to meet the minimum instream flows recommended by the NDGFD.

Table 1 – Hydrologic Modeling Results with and without NDGFD Recommended Flows.

Option	Major Water Supply Feature	Capacity of Major Water Supply Feature without NDGFD Flows (cfs) [1]	Capacity of Major Water Supply Feature with NDGFD Flows (cfs) [1]	Capacity Change (%)
No Action	none	53,000 ac-ft	61,000 ac-ft	NA
North Dakota In-Basin	Grand Forks to Lake Ashtabula Pipeline	71 cfs	Capacity cannot be increased to meet NDGFD flows without additional water supply features	NA
Red River Basin	Minnesota Groundwater and Pipeline	72 cfs	Capacity cannot be increased to meet NDGFD flows without additional water supply features	NA
Lake of the Woods	Lake of the Woods Pipeline	96 cfs	189 cfs	96.9%
GDU Import to Sheyenne River	McClusky Canal to Lake Ashtabula Pipeline	97 cfs	122 cfs	25.8%
GDU Import Pipeline	McClusky Canal to Fargo and Grand Forks Pipeline	202 cfs	295 cfs	46.0%
Missouri River Import to Red River Valley	Bismarck to Fargo Pipeline	63 cfs	93 cfs	44.4%
GDU Water Supply Replacement Pipeline	Replacement Pipeline	411 cfs	411 cfs	0%

[1] Results in cfs include 5% for water losses.
NA – Not applicable

No Action Alternative
The No Action Option increases the maximum annual shortage from 53,000 ac-ft to 61,000 ac-ft. The 8,000 ac-ft increased shortage to MR&I systems is a result of reserving more water in the Sheyenne and Red Rivers for aquatic habitat.

North Dakota In-Basin Alternative
The North Dakota In-Basin Alternative as originally modeled (without the NDGFD recommended flows) under Scenario Two water demands required that Lake Ashtabula be drawn down below the 28,000 ac-ft fish and wildlife conservation pool to 2,000 ac-ft (almost dead pool) to meet MR&I needs. Given this situation, when the additional recommended flows was included in modeling no increased capacity above 71 cfs was possible due to limited flows below Grand Forks. Additional analysis showed that a 28 cfs source imported into Lake Ashtabula would need to be developed to meet the recommended flows even with the reservoir regularly drawn down to 2,000 ac-ft capacity during the 1930s drought. As the analysis in chapter three shows, no reasonable in-basin water source adjacent to Lake Ashtabula of this capacity exists so the cost of this additional water supply feature(s) was not estimated in this analysis.

Red River Basin Alternative
Modeling results show that increasing the capacity of the Red River Basin Alternative's main water supply feature, Minnesota groundwater, would provide insufficient improvement in meeting the NDGFD recommended flows. Modeling results show there is not enough natural flow in the rivers during a 1930s drought to meet the NDGFD recommended flows no matter how large the direct supply of water is to the MR&I systems. The primary problem is meeting the year-round minimum release of 23 cfs from Baldhill Dam and a minimum year-round instream flow of 23 cfs below the Fargo intake on the Sheyenne River. The only way this alternative could meet the NDGFD recommended flows would be to identify an additional 28 cfs continuous water source to import into Lake Ashtabula. Like the North Dakota In-Basin Alternative, no reasonable in-basin water source adjacent to Lake Ashtabula of this capacity exists; therefore, no additional modeling or feature cost estimates were conducted.

Lake of the Woods Alternative
Modeling results show that by increasing the capacity of the Lake of the Woods Alternative's main pipeline from 96 cfs to 189 cfs the option can meet the NDGFD recommended instream flows. This results in providing nearly all of the maximum month and peak day demands to the cities of Grand Forks, Fargo, West Fargo and Moorhead through the main pipeline. To make this work within the model, Lake Ashtabula was drawn down below the 28,000 ac-ft fish and wildlife conservation pool periodically through the 1930s with the lowest pool volume decreasing to 2,000 ac-ft. If Lake Ashtabula was to be maintained at 28,000 ac-ft, as the option was originally modeled, the option would not meet the aquatic need no matter how large the import pipeline was designed. If the 28,000 ac-ft pool had to be preserved only an additional import into Lake Ashtabula would meet the aquatic need. Like previous options, no reasonable in-basin water source adjacent to Lake Ashtabula of that capacity exists, so no additional modeling or feature cost estimates were conducted for maintaining the 28,000 ac-ft pool.

GDU Import to Sheyenne River Alternative
Modeling results show that the GDU Import to Sheyenne River Alternative's conveyance pipeline would need to be increased from 97 cfs to 122 cfs to meet the NDGFD recommended

flows. This increase in capacity is small because the alternative was originally designed to meet peak day water demands through Lake Ashtabula and the surface water system. Unlike the previous options investigated, this alternative is capable of meeting the NDGFD recommended flows because it is designed to release water into Lake Ashtabula. This option also maintains the 28,000 ac-ft fish and wildlife conservation pool at all times.

GDU Import Pipeline Alternative

Modeling results of this alternative are the same as the Lake of the Woods Alternative. To meet the NDGFD recommended flows, the import pipeline capacity would need to be increased by 93 cfs or from 202 cfs to 295 cfs. . However, in the model, Lake Ashtabula had to be drawn down below the 28,000 ac-ft fish and wildlife conservation pool periodically through the 1930s with the lowest pool volume decreasing to 2,000 ac-ft. If Lake Ashtabula was to be maintained at 28,000 ac-ft, as the alternative was originally modeled, it would not meet the NDGFD recommended flows no matter how large the import pipeline was designed. If the 28,000 ac-ft pool had to be preserved only an import into Lake Ashtabula would meet the NDGFD recommended flows. This alternative could be modified to release Project water into Lake Ashtabula at a continual rate of 28 cfs, since the conveyance system is located in the Lake Ashtabula area. However, no modeling was conducted to determine the capacity of this release or the cost of this additional feature.

Missouri River Import to Red River Valley Alternative

Modeling results would be similar to the results of the North Dakota In-Basin Alternative where an import of 28 cfs (29.4 cfs with 5% losses) would be required to meet the NDGFD recommended flows. Therefore, this alternative's conveyance pipeline would need to be increased from 63 cfs to 93 cfs. Like the GDU Import to Sheyenne River Alternative, this alternative is capable of meeting the NDGFD recommended flows because it is designed to release water into Lake Ashtabula. The capacity of this alternative increased more than the GDU Import to Sheyenne River Alternative because it was optimized to meet the MR&I needs and there was little additional flexibility to meet the aquatic need without just adding more capacity. This alternative also maintains the 28,000 ac-ft fish and wildlife conservation pool within Lake Ashtabula.

GDU Water Supply Replacement Pipeline Option

Modeling results show that the aquatic need can be met without increasing the capacity of the GDU Water Supply Replacement Pipeline Option. However, to make this work Lake Ashtabula had to be drawn down below the 28,000 ac-ft conservation pool periodically through the 1930's with the lowest pool volume at 2,000 ac-ft. If Lake Ashtabula had to be held at 28,000 ac-ft, as the option was originally modeled, the option would <u>not</u> meet the aquatic need no matter how large you made the import pipeline into the valley. If the 28,000 ac-ft pool had to be preserved only an additional import of a continual 28 cfs into Lake Ashtabula would meet the aquatic need. The alternative could be modified to release Project water into Lake Ashtabula since the conveyance system is located in the Lake Ashtabula area, but no modeling was conducted to determine the capacity of this release or the cost of this additional feature.

Construction Costs Associated with NDGFD Recommended Flows

Table 1 shows that some options can be modified to meet the NDGFD recommended flows while others do not have that capability. The Lake of the Woods, GDU Import to Sheyenne

River, GDU Import Pipeline, and Missouri River Import to Red River Valley alternatives can be resized to increase the volume of water imported into the valley. The GDU Import to Sheyenne River and the Missouri River Import to Red River Valley alternatives can meet the NDGFD recommended flows and maintain the 28,000 ac-ft fish and wildlife conservation pool in Lake Ashtabula through the 1930s. The Lake of the Woods and GDU Import Pipeline can meet the NDGFD recommended flows, but Lake Ashtabula must be drawn down below the conservation pool frequently during the 1930s. Table 2 shows the original Scenario Two construction cost estimates for each option, the revised costs with additional construction to meet the NDGFD recommended flows and the cost difference. Operation, maintenance and replacement (OM&R) costs would also increase with the addition of NDGFD recommended flows, but that analysis was not conducted in this evaluation.

Table 2 – Construction Cost Estimates with and without NDGFD Recommended Flows – Scenario Two.

Option	Option Construction Cost without NDGFD Flows	Additional Construction Cost to Meet NDGFD Flows	Option Construction Cost with NDGFD Flows
No Action	NA	NA	NA
North Dakota In-Basin	$637,891,000	NA	Additional water supply features required
Red River Basin	$750,150,000	NA	Additional water supply features required
Lake of the Woods	$1,112,579,000	$500,046,000	$1,612,625,000
GDU Import to Sheyenne River	$585,002,000	$107,929,000	$692,931,000
GDU Import Pipeline	$1,407,721,000	$442,902,000	$ 1,850,623,000
Missouri River Import to Red River Valley	$1,013,951,000	$192,674,000	$1,206,625,000
GDU Water Supply Replacement Pipeline	$2,518,023,000	$0	$2,518,023,000

NA – Not applicable

The least costly alternative, which meets both the MR&I need and the NDGFD recommended flows is the GDU Import to Sheyenne River Alternative at $692.9 million. The GDU Water Supply Replacement Pipeline Alternative meets the NDGFD recommended flows without any cost increase, but it would be much more expensive to construct ($2.5 billion). The first three options in table 2 do not have cost estimates because the features of these options cannot be modified to meet the NDGFD recommended flows.

The other three options that can meet the NDGFD recommended flows are considerably more expensive than the GDU Import to Sheyenne River Alternative. These options also have much higher additional costs to meet the NDGFD recommended instream flows, ranging from $192.7 to $500 million.

Conclusions

The only two options that could meet both Reclamation's basic aquatic need and the NDGFD recommended instream flows, at an addional cost, are the GDU Import to Sheyenne River and Missouri River Import to Red River Valley options. Both of these options retain a minimum level in Lake Ashtabula of 28,000 ac-ft in a 1930s drought. The GDU Water Supply Replacement Pipeline Alternative would not have an additional cost to meet the recommended flows, but storage in Lake Ashtabula would drop below the conservation pool to meet the NDGFD recommended flows. The Lake of the Woods and GDU Import Pipeline alternatives can also meet the NDGFD recommended flows at a significantly higher cost, but the options have to use Lake Ashtabula's conservation pool to meet the NDGFD recommended flows. The No Action, North Dakota In-Basin and Red River Basin alternatives as designed do not meet the NDGFD recommended flows.

Appendix C – Attachment 11

Financial Analysis

Red River Valley Water Supply Project
Financial Analysis of Alternatives

Introduction

The Needs and Options Report (Report on the Red River Valley Water Needs and Options, Reclamation 2005) provided the estimated construction and OM&R (operation, maintenance and replacement) costs for each of the alternatives under consideration in the DEIS (Draft Environmental Impact Statement). This analysis used those alternative costs to develop average per household water service rates required to repay project costs. This water service rate data was used in the environmental justice analysis in the DEIS to determine if there are any unfair financial impacts to income disadvantaged Red River Valley residents.

Tables 1 and 2 summarize the estimated construction and O&MR costs for each alternative for Scenario One and Two, respectively. Financial analysis will not be conducted on the No-Action Alternative because it does not meet the purpose and the need of the project as defined in chapter one of the EIS.

Table 1 - Summary of Alternative Cost Estimates – Scenario One.

Alternative	Construction Cost (2005 Dollars)*	Annual OM&R Cost*
No Action	$24,307,000	$1,023,000
North Dakota In-Basin	$557,859,000	$6,686,000
Red River Basin	$549,166,000	$7,481,000
Lake of the Woods	$937,228,000	$7,774,000
GDU Import to Sheyenne River	$434,052,000	$3,819,000
GDU Import Pipeline	$1,202,248,000	$5,330,000
Missouri River Import to Red River Valley	$875,378,000	$9,897,000
GDU Water Supply Replacement Pipeline	$2,226,667,000	$25,435,000

* Values are rounded to the nearest $1,000.

Table 2 - Summary of Alternative Cost Estimates – Scenario Two.

Alternative	Construction Cost (2005 Dollars) *	Annual OM&R Cost*
No Action	$24,307,000	$1,023,000
North Dakota In-Basin	$637,891,000	$7,515,000
Red River Basin	$750,150,000	$8,869,000
Lake of the Woods	$1,112,579,000	$8,765,000
GDU Import to Sheyenne River	$585,002,000	$4,978,000
GDU Import Pipeline	$1,407,721,000	$6,310,000
Missouri River Import to Red River Valley	$1,013,951,000	$10,991,000
GDU Water Supply Replacement Pipeline	$2,518,023,000	$31,674,000

* Values are rounded to the nearest $1,000.

Financial Analysis Assumptions

In the process of conducting this analysis, key assumptions were identified and used throughout. Each assumption used is described below.

Term of Financial Analysis
A term of 40 years was selected based on the assumption that repayment of any financial obligations would start in 2010 and end by 2050. This is the design horizon for the proposed alternatives.

Allocation of Project Costs
Financing of the alternatives can be done in a number of ways. This analysis assumed the project would be funded in accordance with DWRA (Dakota Water Resources Act), as summarized below.

- The cost of construction of biota water treatment plants (WTP) is a federal expense (federal grant), which would be non-reimbursable. This is based on the premise that compliance with the Boundary Waters Treaty of 1909 is a federal responsibility.

- DWRA authorized up to $200 million in federal loans for Project construction. The interest rate applied for use of GDU (Garrison Diversion Unit) facilities for MR&I (municipal, rural, and industrial) water supplies is 3.225%, which was the rate in 1965 when the Project was authorized. Since the 2000 enactment of DWRA, the indexed cost of the original $200 million is assumed to be $250 million.

- Any Project costs above the biota WTP and $250 million of federal loans would be financed by water users using municipal bonds. The interest rate used for non-federal cost share is 5%, which approximates the bonding rate for Fargo, North Dakota.

- Biota WTP OM&R costs would be funded by the federal government and considered non-reimbursable. All other OM&R costs are reimbursable by project recipients.

- DWRA requires that the repayment of costs for existing GDU supply facilities (Principal Supply Works) is to be based only on the proportion of the used capacity of each feature used by the Project. The GDU construction and OM&R costs for each alternative are provided in the Financial Analysis Attachments. DWRA also requires that assigned costs of GDU supply facilities (construction and OM&R) be repaid at 3.225%. Although some alternatives provide improved a basic aquatic need and improved flow rates for recreation, and/or water quality, no construction costs were allocated to these incidental benefits.

Number of Households to Allocate Costs
A key factor in determining the per household repayment rates is quantifying the number of households that reimbursable costs would be applied to. From a reimbursable standpoint, there are three major groups of water users that would bear the costs of the proposed alternatives; individual water users (households), commercial businesses and industries. To determine the cost per household, the commercial and industrial portion of water use was converted in terms of equivalent households. Commercial use was estimated at 30% of the total water demand for

both Scenarios One and Two. Industrial water demand was estimated at 30% for Scenario One and 40% for Scenario Two. The rate was increased by 10% between the two scenarios, because Scenario Two had higher estimated future industrial water demands as compared to Scenario One.

To determine the number of households an estimate of how many persons reside in each household is required. The number of persons per household was estimated at 2.4, based on the results presented in the *Water Conservation Potential Assessment*, (Reclamation 2004).

The alternatives were designed based on population projections through a 2050 planning horizon. However, the 2050 population was not used to estimate the number of households, because the financial analysis assumed that repayment would begin in 2010. A significant portion of the 2050 population does not currently exist so they can not be assessed a service charge for the project. The number of households in 2010 could be used in the calculation, but this would result in higher per household water service costs. This is not reasonable because the number of households will increase over time. The service population in 2030 was chosen for the financial analysis because it splits the difference between using the 2010 and 2050 populations. The Scenario One 2030 service population was projected in C*urrent and Future Population of the Red River Valley Region 2000 through 2050 (Reclamation 2003).* The Scenario Two 2030 service population was estimated based on population change from 2000 U.S. Census Bureau data and water user provided 2050 population projections. Table 3 shows the estimated 2030 service population projections for Scenarios One and Two in the second and fourth columns. The third and fifth columns show the estimated number of equivalent households. To determine per household repayment costs the annual repayment costs, discussed later, are divided by the number of households.

Six of the seven proposed alternatives in the Needs and Options Report would supplement current water supplies to meet the predicted water shortage. The seventh alternative, the GDU Water Supply Replacement Pipeline, would replace all existing MR&I water supplies in the service area with water imported from the Missouri River. Population projections for the supplemental alternatives are smaller because water is only provided to water systems with shortages. For example, most of the water systems currently using groundwater were determined to have adequate water supplies through the year 2050 so these populations are not included for the supplemental alternatives in this financial analysis.

Table 3 – 2030 Service Population Projections for Scenario One and Two.

Alternative	Scenario One 2030 Service Population Projection	Scenario One 2030 Equivalent Households	Scenario Two 2030 Service Population Projection	Scenario Two 2030 Equivalent Households
North Dakota In-Basin Red River Basin Lake of the Woods GDU Import to Sheyenne River GDU Import Pipeline Missouri River Import to Red River Valley	332,458	**282,702**	396,232	**393,087**
GDU Water Supply Replacement Pipeline	392,732	**333,956**	466,724	**463,020**

Interest During Construction

During construction of any option, interest costs will be incurred and accounted for in a financial analysis. These costs factor in the value of money between the start of construction when funds are borrowed and the completion of various construction contracts. The analysis assumed that IDC (interest during construction) would equal 7% of construction costs for federal financing and 10.85% for non-federal financing.

Financial Analysis Results

Tables 4 and 5 show the breakdown of construction and OM&R costs for each alternative for Scenarios One and Two, respectively. The first rows of data are the construction costs, excluding costs related to the biota WTP. The next row is the assigned reimbursable costs for the Garrison Diversion Unit Principal Supply Works (PSW). These costs are based on the amount of capacity of the PSW required to serve the project alternatives. Three of the seven proposed alternatives use the PSW. Biota WTP costs are included in the next row. These costs are assumed to be a Federal grant and non-reimbursable. Some WTP costs in the GDU Water Supply Replacement Pipeline Alternative are associated with producing drinking water to meet SDWA (Safe Drinking Water Act) standards. These costs are reimbursable and are included in the table.

Annual OM&R costs are shown in the bottom half of tables 4 and 5. These annual costs include OM&R of GDU PSW, OM&R of reimbursable investments, OM&R of non-reimbursable biota WTPs and OM&R of other treatment required to comply with SDWA.

Table 6 provides an example of how construction and OM&R costs are assigned and the resulting per household cost estimates for Scenarios One and Two, respectively. The GDU Water Supply Replacement Pipeline Alternative, Scenario One, is used in this example because it involved the most complex analysis. Other alternatives are less complicated because they have fewer types of allocated costs. Detailed spreadsheets for each alternative are provided in the attachments.

Table 6 includes row numbers to assist in describing the table. Rows 1 through 6 show the breakdown of construction costs. This same data are found in table 4. Row 8 shows the estimated cost of interest during construction. Row 9 identifies the total investment costs. Row 11 shows the annual investment costs using the Federal loan rate of 3.225%. This data, while not used in the analysis, provides decision makers with the annual cost if the total project would be financed at 3.225% over 40 years. Row 13 shows the total annual OM&R costs which are also shown in table 4 above. Row 15 shows the total annual cost of the project. Rows 17-50 separate the costs into reimbursable and non-reimbursable costs such that the estimates monthly household cost can be calculated.

Table 4 – Allocated Construction and OM&R Costs per Alternative ($ in thousands) – Scenario One.

Costs	North Dakota In-Basin	Red River Basin	Lake of the Woods	GDU Import to Sheyenne River	GDU Import Pipeline	Missouri River Import to Red River Valley	GDU Water Supply Replacement Pipeline
Construction, excluding Biota WTP	557,859	549,166	937,228	394,957	1,111,261	840,267	1,881,547
GDU Assigned Costs	0	0	0	5,606	14,466	0	30,831
Biota WTP Construction	0	0	0	33,489	76,521	35,111	153,000
Other Treatment, SDWA	0	0	0	0	0	0	161,289
Construction, Total	**557,859**	**549,166**	**937,228**	**434,052**	**1,202,248**	**875,378**	**2,226,667**
Annual OM&R, GDU	0	0	0	46	118	0	251
Annual OM&R, Reimbursable Investments	6,686	7,481	7,774	2,185	2,747	7,397	2,789
Annual OM&R, Non-reimbursable Biota WTP	0	0	0	1,588	2,465	2,500	9,282
Annual OM&R, Other Treatment, SDWA	0	0	0	0	0	0	13,113
Annual OM&R, Total	**6,686**	**7,481**	**7,774**	**3,819**	**5,330**	**9,897**	**25,435**

Table 5 – Allocated Construction and OM&R Costs per Alternative ($ in thousands) – Scenario Two.

Costs	North Dakota In-Basin	Red River Basin	Lake of the Woods	GDU Import to Sheyenne River	GDU Import Pipeline	Missouri River Import to Red River Valley	GDU Water Supply Replacement Pipeline
Construction, excluding Biota WTP	637,891	750,150	1,112,579	527,923	1,295,637	963,636	2,110,239
GDU Assigned Costs	0	0	0	8,770	18,264	0	37,160
Biota WTP Construction	0	0	0	48,309	93,820	50,315	182,000
Other Treatment, SDWA	0	0	0	0	0	0	188,624
Construction, Total	**637,891**	**750,150**	**1,112,579**	**585,002**	**1,407,721**	**1,013,951**	**2,518,023**
Annual OM&R, GDU	0	0	0	71	149	0	302
Annual OM&R, Reimbursable Investments	7,515	8,869	8,765	2,664	3,430	8,149	2,927
Annual OM&R, Non-reimbursable Biota WTP	0	0	0	2,263	2,731	2,842	11,810
Annual OM&R, Other Treatment, SDWA	0	0	0	0	0	0	16,635
Annual OM&R, Total	**7,515**	**8,869**	**8,765**	**4,978**	**6,310**	**10,991**	**31,674**

Rows 17 through 22 show separate reimbursable investment costs. Row 18 shows the reimbursable costs of the GDU Principal Supply Works plus interest during construction. Row 19 shows the portion of the project financed with a Federal loan of $250 million and an additional $17.5 million for interest during construction. Row 20 shows the portion of this alternative funded using municipal bonds at 5% percent plus interest during construction. Row 21 shows the portion of the biota WTP cost that is related to providing treated drinking water and is considered a reimbursable cost plus interest during construction. Row 22 provides the total reimbursable investment costs. These costs are the responsibility of the water users and are repaid through monthly service charges.

Rows 24 through 27 show the non-reimbursable investment costs. The only Federal grant or non-reimbursable costs assumed in the analysis are those associated with the biota WTPs. DWRA does not specifically authorize other grants for the Red River Valley Water Supply Project.

Rows 29 through 35 show the annual reimbursable costs. These are the annualized costs of the investment costs shown in rows 17 through 22. It should be noted that different interest rates are used depending on the source of funding. Federal funding is provided as a loan at 3.225% while municipal bonds have an annual interest rate of 5.0%.

Rows 37 through 41 show the annualized costs of non-reimbursable costs which are a Federal grant. These costs include the annual construction costs (row 38) and OM&R costs (row 39) of the biota WTP.

Row 43 through 46 shows the reimbursable and non-reimbursable costs broken down by household and cost per 1,000 gallons. The annual repayment costs in rows 35 (reimbursable) and 41 (non-reimbursable) are divided by the number of households estimated to exist in the year 2030 under Scenario One which is 282,702 (see table 3) and by 12 (months in a year) to arrive at a monthly per household repayment rate. In this example, the monthly repayment rate for a household would be about $33.02 or $5.50 per 1,000 gallons; assuming 6,000 gallons per month of typical water use. The GDU Water Supply Replacement Pipeline Alternative was the most expensive alternative so the per month household repayment rates are very high compared to other alternatives as shown in table 7.

Not used in the per household rate analysis, but worthy of discussion is the estimated cost of water for future industries which is shown in rows 48 through 50. Row 49 shows that for this alternative the cost per ac-ft of water is $1,793. A large food-processing plant could use up to 2,000 ac-ft of water annually resulting in a cost of approximately $3,587,000 per year as shown in row 50.

Table 7 shows the estimated per household and per 1,000 gallon repayment costs for each alternative under Scenario One and Scenario Two water demands. The household repayment rate under Scenario One ranges from $7.03 to $33.02 per month. Under Scenario Two the rate is $7.01 to $26.88 per month. These are the amounts a typical household would pay in addition to their present monthly water bill. The table also provides estimated repayment rates based on 1,000 gallon increments. The 1,000 gallon incremental cost was calculated using the per household costs and dividing by 6, assuming a typical household uses about 6,000 gallons per month.

Table 6 – Financial Analysis Example –GDU Water Supply Replacement Pipeline Alternative – Scenario One.

Row #	*Amounts in thousands excluding household costs*		
1	**Construction Costs**		
2	Construction, excluding Biota WTP	$1,881,547	
3	GDU Assigned Costs	$30,831	
4	Biota WTP	$153,000	
5	Other Treatment, SWDA	$161,289	
6	***Subtotal***	$2,226,667	
7			
8	IDC, Federal Rate	$155,867	
9	**Total Investment Costs**	$2,382,534	
10			
11	Annual Investment Costs, Federal Rate	$106,856	
12			
13	Annual OM&R	$25,435	
14			
15	**Total Annual Costs**	$132,291	
16			
17	**Total Reimbursable Investment Costs**		
18	GDU PSW + IDC Federal Rate	$32,989	
19	GDU Federal Financing on Construction + IDC Federal Rate	$267,500	
20	Grant Portion (State Share) + IDC non-Federal Rate	$1,808,570	
21	Other Treatment, SWDA + IDC non-Federal Rate	$178,789	
22	**Total Reimbursable Investment Costs**	$2,287,848	
23			
24	**Total Non-reimbursable Investment Costs**		
25	Biota Treatment Plant + IDC Federal Rate	$163,710	
26	Grant Portion (Federal Share) + IDC Federal Rate	$0	
27	**Total Non-reimbursable Investment Costs**	$163,710	
28			
29	**Annual Reimbursable Costs**		
30	GDU Supply + IDC Federal Rate	$1,480	
31	GDU Federal Financing on Construction + IDC Federal Rate	$11,997	
32	OM&R, except Biota	$3,040	
33	Grant Portion (State Share) + IDC non-Federal Rate	$105,400	
34	Other Treatment, SWDA + IDC non-Federal Rate	$10,419	
35	**Total Annual Reimbursable Costs**	$132,337	
36			
37	**Annual Non-reimbursable Costs**		
38	Biota WTP + IDC Federal Rate	$7,342	
39	OM&R, on Biota WTP	$9,282	
40	Grant Portion (Federal Share) + IDC Federal Rate	$0	
41	**Total Annual Non-reimbursable Costs**	$16,624	
42			
43	**Household Costs**	Dollars/Month	$ per 1000 gal.
44	Reimbursable MR&I Cost	$33.02	$5.50
45	Non-reimbursable MR&I Costs	$4.15	$0.69
46	**Total**	**$37.17**	**$6.20**
47			
48	Reimbursable Cost per Acre Foot		
49	Cost Per Acre Foot	$1,793	
50	Assuming Industry Uses 2,000 ac-ft of Water per Year	$3,586,801	

Table 7 – Per Month Household and per 1,000 Gallon Repayment Rates – Scenarios One and Two.

Alternatives	Scenario One		Scenario Two	
	Dollars/Month	$ per 1,000 Gallons	Dollars/Month	$ per 1,000 Gallons
North Dakota In-Basin	$11.37	$1.89	$9.45	$1.57
Red River Basin	$11.44	$1.91	$11.27	$1.88
Lake of the Woods	$18.91	$3.15	$16.21	$2.70
GDU Import to Sheyenne River	$7.03	$1.17	$7.01	$1.17
GDU Import Pipeline	$20.99	$3.50	$17.81	$2.97
Missouri River Import to Red River Valley	$16.96	$2.83	$14.04	$2.34
GDU Water Supply Replacement Pipeline	$33.02	$5.50	$26.88	$4.48

Modification of Financial Assumptions and Resulting Changes

Results shown in table 7 would change if some or all of the assumptions used in the analysis were modified. Following is a description of assumptions that could change and an explanation of how this may impact the overall repayment results.

Additional Federal Grants
No Federal grants except for the biota WTPs were assumed in the analysis. However, the State of North Dakota under DWRA does have a State MR&I grant program funded with Federal appropriations. The state currently uses these funds to provide non-reimbursable grants to other MR&I projects. If the Red River Valley Water Supply Project received additional grant funding, the per household repayment would be reduced.

Tiered Repayment Rate Structure
A tiered repayment rate structure could be implemented which would provide different rate tiers depending on need. The water systems with greatest potential shortages would pay a rate higher than shown in table 7 while other water systems with less serious needs would pay a lower rate. The same overall repayment requirements would exist, but the rates would be adjusted based on need.

State of North Dakota Grants
The State of North Dakota has historically provided some non-reimbursable grant funding to assist MR&I projects. While historically the amount of funding available is small compared to other sources of funding, securing state grant funding would reduce per household repayment costs.

Federal Financed Portion
Typically the annual repayment required for the Federally financed portion is based on actual use. This results in extending the repayment period beyond 40 years and would reduce the household rates for that portion of the project financing.

Financial Analysis Attachments

Tables A through G show the financial analysis calculation for each alternative under water demand Scenarios One and Two. Results from these tables were summarized in table 7. The spreadsheets were developed in Microsoft Excel and used the financial assumptions described earlier in the text. Table H shows the estimated GDU assigned costs related to use of the Principal Supply Works for Scenarios One and Two.

Table A – Financial Analysis North Dakota In-Basin Alternative – Scenarios One and Two.

North Dakota In-Basin

Amounts in thousands excluding household costs

Scenario 1

Construction Costs		
Construction, excluding Biota	$557,859	
GDU Assigned Costs	$0	
Biota Plant	$0	
Subtotal	$557,859	
IDC, Federal Rate	$39,050	
Total Investment Costs	$596,909	
Annual Investment Costs, Federal Rate	$26,771	
Annual OM&R	$7,481	
Total Annual Costs	$34,252	
Total Reimbursable Investment Costs		
GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$267,500	
Grant Portion (State Share) + IDC State Rate	$341,262	
Total Reimbursable Investment Costs	$608,762	
Total Non-reimbursable Investment Costs		
Biota Treatment Plant + IDC Federal Rate	$0	
Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Non-reimbursable Investment Costs	$0	
Annual Reimbursable Costs		
GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$11,997	
OM&R, except Biota	$6,686	
Grant Portion (State Share) + IDC State Rate	$19,888	
Total Annual Reimbursable Costs	$38,571	
Annual Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$0	
OM&R, on Biota Plant	$0	
Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Annual Non-reimbursable Costs	$0	
Household Costs	Dollars/Month	$ per 1000 gal.
Reimbursable MR&I Cost	$11.37	$1.89
Non-reimbursable Supply Costs	$0.00	$0.00
	$11.37	**$1.89**
Reimbursable Cost per Acre Foot		
Cost Per Acre Foot	$617	
Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$1,234,960	

Scenario 2

Construction Costs		
Construction Costs	$637,891	
GDU Assigned Costs	$0	
Biota Plant	$0	
Subtotal	$637,891	
IDC, Federal Rate	$44,652	
Total Investment Costs	$682,543	
Annual Investment Costs, Federal Rate	$30,612	
Annual OM&R	$8,869	
Total Annual Costs	$39,481	
Total Reimbursable Investment Costs		
GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$267,500	
Grant Portion (State Share) + IDC State Rate	$429,977	
Total Reimbursable Investment Costs	$697,477	
Total Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$0	
Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Non-reimbursable Investment Costs	$0	
Annual Reimbursable Costs		
GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$11,997	
OM&R, except Biota	$7,515	
Grant Portion (State Share) + IDC State Rate	$25,058	
Total Annual Reimbursable Costs	$44,571	
Annual Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$0	
OM&R, on Biota Plant	$0	
Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Annual Non-reimbursable Costs	$0	
Household Costs	Dollars/Month	$ per 1000 gal.
Reimbursable MR&I Cost	$9.45	$1.57
Non-reimbursable Supply Costs	$0.00	$0.00
	$9.45	**$1.57**
Industry Costs		
Cost Per Acre Foot	$513	
Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$1,026,304	

Inputs Used for the Financial Analysis

GDU Interest Rate	3.225%
Municipal Bonding Rate	5.000%
Interest During Construction, Federal Rate	7.000%
Interest During Construction, State Rate	10.850%
Years of Annualization	40
GDU Federal Financing	$250,000

1000 Gallons per house per month	6	
	Scenario 1	Scenario 2
Total Equivalent Households, Alternatives 1 to 6	282,702	393,087
Total Equivalent Households, Alternative Replacement	333,956	463,020
Reimbursable Portion		
Nonreimbursable - Federal share	0%	
Reimbursable - State share	100%	

Table B – Financial Analysis Red River Basin Alternative – Scenarios One and Two.

Red River Basin

Amounts in thousands excluding household costs

Scenario 1			Scenario 2		
Construction Costs			Construction Costs		
Construction, excluding Biota	$549,166		Construction Costs	$750,150	
GDU Assigned Costs	$0		GDU Assigned Costs	$0	
Biota Plant	$0		Biota Plant	$0	
Subtotal	$549,166		*Subtotal*	$750,150	
IDC, Federal Rate	$38,442		IDC, Federal Rate	$52,511	
Total Investment Costs	$587,608		**Total Investment Costs**	$802,661	
Annual Investment Costs, Federal Rate	$26,354		Annual Investment Costs, Federal Rate	$35,999	
Annual OM&R	$7,481		Annual OM&R	$8,869	
Total Annual Costs	$33,835		**Total Annual Costs**	$44,868	
Total Reimbursable Investment Costs			Total Reimbursable Investment Costs		
GDU Supply + IDC Federal Rate	$0		GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$267,500		GDU Federal Financing on Construction + IDC Federal Rate	$267,500	
Grant Portion (State Share) + IDC State Rate	$331,626		Grant Portion (State Share) + IDC State Rate	$554,416	
Total Reimbursable Investment Costs	$599,126		**Total Reimbursable Investment Costs**	$821,916	
Total Non-reimbursable Costs			Total Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$0		Biota Treatment Plant + IDC Federal Rate	$0	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Non-reimbursable Investment Costs	$0		**Total Non-reimbursable Investment Costs**	$0	
Annual Reimbursable Costs			Annual Reimbursable Costs		
GDU Supply + IDC Federal Rate	$0		GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$11,997		GDU Federal Financing on Construction + IDC Federal Rate	$11,997	
OM&R, except Biota	$7,481		OM&R, except Biota	$8,869	
Grant Portion (State Share) + IDC State Rate	$19,327		Grant Portion (State Share) + IDC State Rate	$32,310	
Total Annual Reimbursable Costs	$38,805		**Total Annual Reimbursable Costs**	$53,177	
Annual Non-reimbursable Costs			Annual Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$0		Biota Treatment Plant + IDC Federal Rate	$0	
OM&R, on Biota Plant	$0		OM&R, on Biota Plant	$0	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Annual Non-reimbursable Costs	$0		**Total Annual Non-reimbursable Costs**	$0	
Household Costs	Dollars/Month	$ per 1000 gal.	Household Costs	Dollars/Month	$ per 1000 gal.
Reimbursable MR&I Cost	$11.44	$1.91	Reimbursable MR&I Cost	$11.27	$1.88
Non-reimbursable Supply Costs	$0.00	$0.00	Non-reimbursable Supply Costs	$0.00	$0.00
	$11.44	**$1.91**		**$11.27**	**$1.88**
Reimbursable Cost per Acre Foot			Industry Costs		
Cost Per Acre Foot	$621		Cost Per Acre Foot	$612	
Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$1,242,434		Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$1,224,472	

Inputs Used for the Financial Analysis				
		1000 Gallons per house per month	6	
GDU Interest Rate	3.225%		Scenario 1	Scenario 2
Municipal Bonding Rate	5.000%	Total Equivalent Households, Alternatives 1 to 6	282,702	393,087
Interest During Construction, Federal Rate	7.000%	Total Equivalent Households, Alternative Replacement	333,956	463,020
Interest During Construction, State Rate	10.850%			
Years of Annualization	40	Reimbursable Portion		
GDU Federal Financing	$250,000	Nonreimbursable - Federal share	0%	
		Reimbursable - State share	100%	

Table C – Financial Analysis Lake of the Woods Alternative – Scenarios One and Two.

Lake of the Woods					
Amounts in thousands excluding household costs	**Scenario 1**			**Scenario 2**	
Construction Costs			Construction Costs		
Construction, excluding Biota	$937,228		Construction Costs	$1,112,579	
GDU Assigned Costs	$0		GDU Assigned Costs	$0	
Biota Plant	$0		Biota Plant	$0	
Subtotal	$937,228		*Subtotal*	$1,112,579	
IDC, Federal Rate	$65,606		IDC, Federal Rate	$77,881	
Total Investment Costs	$1,002,834		**Total Investment Costs**	$1,190,460	
Annual Investment Costs, Federal Rate	$44,977		Annual Investment Costs, Federal Rate	$53,392	
Annual OM&R	$7,774		Annual OM&R	$8,765	
Total Annual Costs	$52,751		**Total Annual Costs**	$62,157	
Total Reimbursable Investment Costs			Total Reimbursable Investment Costs		
GDU Supply + IDC Federal Rate	$0		GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$267,500		GDU Federal Financing on Construction + IDC Federal Rate	$267,500	
Grant Portion (State Share) + IDC State Rate	$761,792		Grant Portion (State Share) + IDC State Rate	$956,169	
Total Reimbursable Investment Costs	$1,029,292		**Total Reimbursable Investment Costs**	$1,223,669	
Total Non-reimbursable Costs			Total Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$0		Biota Treatment Plant + IDC Federal Rate	$0	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Non-reimbursable Investment Costs	$0		**Total Non-reimbursable Investment Costs**	$0	
Annual Reimbursable Costs			Annual Reimbursable Costs		
GDU Supply + IDC Federal Rate	$0		GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$11,997		GDU Federal Financing on Construction + IDC Federal Rate	$11,997	
OM&R, except Biota	$7,774		OM&R, except Biota	$8,765	
Grant Portion (State Share) + IDC State Rate	$44,396		Grant Portion (State Share) + IDC State Rate	$55,724	
Total Annual Reimbursable Costs	$64,167		**Total Annual Reimbursable Costs**	$76,486	
Annual Non-reimbursable Costs			Annual Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$0		Biota Treatment Plant + IDC Federal Rate	$0	
OM&R, on Biota Plant	$0		OM&R, on Biota Plant	$0	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Annual Non-reimbursable Costs	$0		**Total Annual Non-reimbursable Costs**	$0	
Household Costs	Dollars/Month	$ per 1000 gal.	Household Costs	Dollars/Month	$ per 1000 gal.
Reimbursable MR&I Cost	$18.91	$3.15	Reimbursable MR&I Cost	$16.21	$2.70
Non-reimbursable Supply Costs	$0.00	$0.00	Non-reimbursable Supply Costs	$0.00	$0.00
	$18.91	**$3.15**		**$16.21**	**$2.70**
Reimbursable Cost per Acre Foot			Industry Costs		
Cost Per Acre Foot	$1,027		Cost Per Acre Foot	$881	
Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$2,054,471		Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$1,761,205	

Inputs Used for the Financial Analysis				
		1000 Gallons per house per month	6	
GDU Interest Rate	3.225%		Scenario 1	Scenario 2
Municipal Bonding Rate	5.000%	Total Equivalent Households, Alternatives 1 to 6	282,702	393,087
Interest During Construction, Federal Rate	7.000%	Total Equivalent Households, Alternative Replacement	333,956	463,020
Interest During Construction, State Rate	10.850%			
Years of Annualization	40	Reimbursable Portion		
GDU Federal Financing	$250,000	Nonreimbursable - Federal share	0%	
		Reimbursable - State share	100%	

Table D – Financial Analysis GDU Import to Sheyenne River Alternative – Scenarios One and Two.

GDU Import to Sheyenne River

Amounts in thousands excluding household costs

Scenario 1			Scenario 2		
Construction Costs			Construction Costs		
Construction, excluding Biota	$394,957		Construction Costs	$527,923	
GDU Assigned Costs	$5,606		GDU Assigned Costs	$8,770	
Biota Plant	$33,489		Biota Plant	$48,309	
Subtotal	$434,052		*Subtotal*	$585,002	
IDC, Federal Rate	$30,384		IDC, Federal Rate	$40,950	
Total Investment Costs	$464,436		**Total Investment Costs**	$625,952	
Annual Investment Costs, Federal Rate	$20,830		Annual Investment Costs, Federal Rate	$28,074	
Annual OM&R	$3,819		Annual OM&R	$4,978	
Total Annual Costs	$24,649		**Total Annual Costs**	$33,052	
Total Reimbursable Investment Costs			Total Reimbursable Investment Costs		
GDU Supply + IDC Federal Rate	$5,998		GDU Supply + IDC Federal Rate	$9,384	
GDU Federal Financing on Construction + IDC Federal Rate	$267,500		GDU Federal Financing on Construction + IDC Federal Rate	$267,500	
Grant Portion (State Share) + IDC State Rate	$160,685		Grant Portion (State Share) + IDC State Rate	$308,078	
Total Reimbursable Investment Costs	$434,183		**Total Reimbursable Investment Costs**	$584,962	
Total Non-reimbursable Costs			Total Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$35,833		Biota Treatment Plant + IDC Federal Rate	$51,691	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Non-reimbursable Investment Costs	$35,833		**Total Non-reimbursable Investment Costs**	$51,691	
Annual Reimbursable Costs			Annual Reimbursable Costs		
GDU Supply + IDC Federal Rate	$269		GDU Supply + IDC Federal Rate	$421	
GDU Federal Financing on Construction + IDC Federal Rate	$11,997		GDU Federal Financing on Construction + IDC Federal Rate	$11,997	
OM&R, except Biota	$2,231		OM&R, except Biota	$2,715	
Grant Portion (State Share) + IDC State Rate	$9,364		Grant Portion (State Share) + IDC State Rate	$17,954	
Total Annual Reimbursable Costs	$23,862		**Total Annual Reimbursable Costs**	$33,087	
Annual Non-reimbursable Costs			Annual Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$1,607		Biota Treatment Plant + IDC Federal Rate	$2,318	
OM&R, on Biota Plant	$1,588		OM&R, on Biota Plant	$2,263	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Annual Non-reimbursable Costs	$3,195		**Total Annual Non-reimbursable Costs**	$4,581	
Household Costs	Dollars/Month	$ per 1000 gal.	Household Costs	Dollars/Month	$ per 1000 gal.
Reimbursable MR&I Cost	$7.03	$1.17	Reimbursable MR&I Cost	$7.01	$1.17
Non-reimbursable Supply Costs	$0.94	$0.16	Non-reimbursable Supply Costs	$0.97	$0.16
	$7.98	**$1.33**		**$7.99**	**$1.33**
Reimbursable Cost per Acre Foot			Industry Costs		
Cost Per Acre Foot	$382		Cost Per Acre Foot	$381	
Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$763,994		Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$761,886	

Inputs Used for the Financial Analysis

GDU Interest Rate	3.225%	1000 Gallons per house per month	6	
Municipal Bonding Rate	5.000%		Scenario 1	Scenario 2
Interest During Construction, Federal Rate	7.000%	Total Equivalent Households, Alternatives 1 to 6	282,702	393,087
Interest During Construction, State Rate	10.850%	Total Equivalent Households, Alternative Replacement	333,956	463,020
Years of Annualization	40	Reimbursable Portion		
GDU Federal Financing	$250,000	Nonreimbursable - Federal share	0%	
		Reimbursable - State share	100%	

Table E – Financial Analysis GDU Import Pipeline Alternative – Scenarios One and Two.

GDU Import Pipeline

Amounts in thousands excluding household costs

	Scenario 1		Scenario 2	
Construction Costs				
Construction, excluding Biota (Scenario 1) / Construction Costs (Scenario 2)	$1,111,261		$1,295,637	
GDU Assigned Costs	$14,466		$18,264	
Biota Plant	$76,521		$93,820	
Subtotal	$1,202,248		$1,407,721	
IDC, Federal Rate	$84,157		$98,540	
Total Investment Costs	$1,286,405		$1,506,261	
Annual Investment Costs, Federal Rate	$57,695		$67,556	
Annual OM&R	$5,330		$6,310	
Total Annual Costs	$63,025		$73,866	
Total Reimbursable Investment Costs				
GDU Supply + IDC Federal Rate	$15,479		$19,542	
GDU Federal Financing on Construction + IDC Federal Rate	$267,500		$267,500	
Grant Portion (State Share) + IDC State Rate	$954,708		$1,159,089	
Total Reimbursable Investment Costs	$1,237,686		$1,446,131	
Total Non-reimbursable Costs				
Biota Treatment Plant+IDC Federal Rate	$81,877		$100,387	
Grant Portion (Federal Share) + IDC Federal Rate	$0		$0	
Total Non-reimbursable Investment Costs	$81,877		$100,387	
Annual Reimbursable Costs				
GDU Supply + IDC Federal Rate	$694		$876	
GDU Federal Financing on Construction + IDC Federal Rate	$11,997		$11,997	
OM&R, except Biota	$2,865		$3,579	
Grant Portion (State Share) + IDC State Rate	$55,639		$67,550	
Total Annual Reimbursable Costs	$71,195		$84,002	
Annual Non-reimbursable Costs				
Biota Treatment Plant + IDC Federal Rate	$3,672		$4,502	
OM&R, on Biota Plant	$2,465		$2,731	
Grant Portion (Federal Share) + IDC Federal Rate	$0		$0	
Total Annual Non-reimbursable Costs	$6,137		$7,233	
Household Costs	Dollars/Month	$ per 1000 gal.	Dollars/Month	$ per 1000 gal.
Reimbursable MR&I Cost	$20.99	$3.50	$17.81	$2.97
Non-reimbursable Supply Costs	$1.81	$0.30	$1.53	$0.26
	$22.80	**$3.80**	**$19.34**	**$3.22**
Reimbursable Cost per Acre Foot (Scenario 1) / Industry Costs (Scenario 2)				
Cost Per Acre Foot	$1,140		$967	
Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$2,279,489		$1,934,279	

Inputs Used for the Financial Analysis

GDU Interest Rate	3.225%
Municipal Bonding Rate	5.000%
Interest During Construction, Federal Rate	7.000%
Interest During Construction, State Rate	10.850%
Years of Annualization	40
GDU Federal Financing	$250,000

	Scenario 1	Scenario 2
1000 Gallons per house per month	6	
Total Equivalent Households, Alternatives 1 to 6	282,702	393,087
Total Equivalent Households, Alternative Replacement	333,956	463,020
Reimbursable Portion		
Nonreimbursable - Federal share	0%	
Reimbursable - State share	100%	

Table F – Financial Analysis Missouri River Import to Red River Valley Alternative – Scenarios One and Two.

Missouri River Import to Red River Valley

Amounts in thousands excluding household costs

Scenario 1			Scenario 2		
Construction Costs			Construction Costs		
Construction, excluding Biota	$840,267		Construction Costs	$963,636	
GDU Assigned Costs	$0		GDU Assigned Costs	$0	
Biota Plant	$35,111		Biota Plant	$50,315	
Subtotal	$875,378		*Subtotal*	$1,013,951	
IDC, Federal Rate	$61,276		IDC, Federal Rate	$70,977	
Total Investment Costs	$936,654		**Total Investment Costs**	$1,084,928	
Annual Investment Costs, Federal Rate	$42,009		Annual Investment Costs, Federal Rate	$48,659	
Annual OM&R	$9,897		Annual OM&R	$10,991	
Total Annual Costs	$51,906		**Total Annual Costs**	$59,650	
Total Reimbursable Investment Costs			Total Reimbursable Investment Costs		
GDU Supply + IDC Federal Rate	$0		GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$267,500		GDU Federal Financing on Construction + IDC Federal Rate	$267,500	
Grant Portion (State Share) + IDC State Rate	$654,311		Grant Portion (State Share) + IDC State Rate	$791,066	
Total Reimbursable Investment Costs	$921,811		**Total Reimbursable Investment Costs**	$1,058,566	
Total Non-reimbursable Costs			Total Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$37,569		Biota Treatment Plant + IDC Federal Rate	$53,837	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Non-reimbursable Investment Costs	$37,569		**Total Non-reimbursable Investment Costs**	$53,837	
Annual Reimbursable Costs			Annual Reimbursable Costs		
GDU Supply + IDC Federal Rate	$0		GDU Supply + IDC Federal Rate	$0	
GDU Federal Financing on Construction + IDC Federal Rate	$11,997		GDU Federal Financing on Construction + IDC Federal Rate	$11,997	
OM&R, except Biota	$7,397		OM&R, except Biota	$8,149	
Grant Portion (State Share) + IDC State Rate	$38,132		Grant Portion (State Share) + IDC State Rate	$46,102	
Total Annual Reimbursable Costs	$57,526		**Total Annual Reimbursable Costs**	$66,248	
Annual Non-reimbursable Costs			Annual Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$1,685		Biota Treatment Plant + IDC Federal Rate	$2,415	
OM&R, on Biota Plant	$2,500		OM&R, on Biota Plant	$2,842	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Annual Non-reimbursable Costs	$4,185		**Total Annual Non-reimbursable Costs**	$5,257	
Household Costs	Dollars/Month	$ per 1000 gal.	Household Costs	Dollars/Month	$ per 1000 gal.
Reimbursable MR&I Cost	$16.96	$2.83	Reimbursable MR&I Cost	$14.04	$2.34
Non-reimbursable Supply Costs	$1.23	$0.21	Non-reimbursable Supply Costs	$1.11	$0.19
	$18.19	**$3.03**		**$15.16**	**$2.53**
Reimbursable Cost per Acre Foot			Industry Costs		
Cost Per Acre Foot	$921		Cost Per Acre Foot	$763	
Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$1,841,849		Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$1,525,462	

Inputs Used for the Financial Analysis				
		1000 Gallons per house per month	6	
GDU Interest Rate	3.225%		Scenario 1	Scenario 2
Municipal Bonding Rate	5.000%	Total Equivalent Households, Alternatives 1 to 6	282,702	393,087
Interest During Construction, Federal Rate	7.000%	Total Equivalent Households, Alternative Replacement	333,956	463,020
Interest During Construction, State Rate	10.850%			
Years of Annualization	40	Reimbursable Portion		
GDU Federal Financing	$250,000	Nonreimbursable - Federal share	0%	
		Reimbursable - State share	100%	

Table G – Financial Analysis GDU Water Supply Replacement Pipeline Alternative – Scenarios One and Two.

GDU Water Supply Replacement Pipeline

Amounts in thousands excluding household costs

	Scenario 1			**Scenario 2**	
Construction Costs			Construction Costs		
Construction, excluding Biota	$1,881,547		Construction Costs	$2,110,239	
GDU Assigned Costs	$30,831		GDU Assigned Costs	$37,160	
Biota Plant	$153,000		Biota Plant	$182,000	
Other Treatment, SWDA	$161,289		Other Treatment, SWDA	$188,624	
Subtotal	$2,226,667		*Subtotal*	$2,518,023	
IDC, Federal Rate	$155,867		IDC, Federal Rate	$176,262	
Total Investment Costs	$2,382,534		**Total Investment Costs**	$2,694,285	
Annual Investment Costs, Federal Rate	$106,856		Annual Investment Costs, Federal Rate	$120,838	
Annual OM&R	$25,435		Annual OM&R	$31,674	
Total Annual Costs	$132,291		**Total Annual Costs**	$152,512	
Total Reimbursable Investment Costs			Total Reimbursable Investment Costs		
GDU Supply + IDC Federal Rate	$32,989		GDU Supply + IDC Federal Rate	$39,761	
GDU Federal Financing on Construction + IDC Federal Rate	$267,500		GDU Federal Financing on Construction + IDC Federal Rate	$267,500	
Grant Portion (State Share) + IDC State Rate	$1,808,570		Grant Portion (State Share) + IDC State Rate	$2,062,075	
Other Treatment, SWDA + IDC State Rate	$178,789		Other Treatment, SWDA + IDC State Rate	$209,090	
Total Reimbursable Investment Costs	$2,287,848		**Total Reimbursable Investment Costs**	$2,578,426	
Total Non-reimbursable Costs			Total Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$163,710		Biota Treatment Plant + IDC Federal Rate	$194,740	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Non-reimbursable Investment Costs	$163,710		**Total Non-reimbursable Investment Costs**	$194,740	
Annual Reimbursable Costs			Annual Reimbursable Costs		
GDU Supply + IDC Federal Rate	$1,480		GDU Supply + IDC Federal Rate	$1,783	
GDU Federal Financing on Construction + IDC Federal Rate	$11,997		GDU Federal Financing on Construction + IDC Federal Rate	$11,997	
OM&R, except Biota	$3,040		OM&R, except Biota	$3,229	
Grant Portion (State Share) + IDC State Rate	$105,400		Grant Portion (State Share) + IDC State Rate	$120,174	
Other Treatment, SWDA + IDC State Rate	$10,419		Other Treatment, SWDA + IDC State Rate	$12,185	
Total Annual Reimbursable Costs	$132,337		**Total Annual Reimbursable Costs**	$149,369	
Annual Non-reimbursable Costs			Annual Non-reimbursable Costs		
Biota Treatment Plant + IDC Federal Rate	$7,342		Biota Treatment Plant + IDC Federal Rate	$8,734	
OM&R, on Biota Plant	$9,282		OM&R, on Biota Plant	$11,810	
Grant Portion (Federal Share) + IDC Federal Rate	$0		Grant Portion (Federal Share) + IDC Federal Rate	$0	
Total Annual Non-reimbursable Costs	$16,624		**Total Annual Non-reimbursable Costs**	$20,544	
Household Costs	Dollars/Month	$ per 1000 gal.	Household Costs	Dollars/Month	$ per 1000 gal.
Reimbursable MR&I Cost	$33.02	$5.50	Reimbursable MR&I Cost	$26.88	$4.48
Non-reimbursable Supply Costs	$4.15	$0.69	Non-reimbursable Supply Costs	$3.70	$0.62
	$37.17	**$6.20**		**$30.58**	**$5.10**
Reimbursable Cost per Acre Foot			Industry Costs		
Cost Per Acre Foot	$1,793		Cost Per Acre Foot	$1,460	
Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$3,586,801		Assuming Industry Uses 2,000 Acre-Ft. of Water per Year	$2,919,962	

Inputs Used for the Financial Analysis

		1000 Gallons per house per month	6	
GDU Interest Rate	3.225%		Scenario 1	Scenario 2
Municipal Bonding Rate	5.000%	Total Equivalent Households, Alternatives 1 to 6	282,702	393,087
Interest During Construction, Federal Rate	7.000%	Total Equivalent Households, Alternative Replacement	333,956	463,020
Interest During Construction, State Rate	10.850%			
Years of Annualization	40	Reimbursable Portion		
GDU Federal Financing	$250,000	Nonreimbursable - Federal share	0%	
		Reimbursable - State share	100%	

Table H – GDU Assigned Costs Related to use of Principal Supply Work – Scenarios One and Two.

Alternative	Capacity Required (cfs)	Assigned GDU Construction Costs ($)	Assigned GDU Annual OM&R Costs ($)
Incremental GDU Principal Supply Works Costs (10 cfs) [1]	10	$904,136	$7,353
GDU Import to Sheyenne River, Scenario One	62	$5,605,644	$45,589
GDU Import to Sheyenne River, Scenario Two	97	$8,770,120	$71,324
GDU Import Pipeline , Scenario One	160	$14,466,178	$117,648
GDU Import Pipeline, Scenario Two	202	$18,263,550	$148,531
GDU Water Supply Replacement Pipleine, Scenario One	341	$30,831,042	$250,738
GDU Water Supply Replacement Pipeline, Scenario Two	411	$37,159,995	$302,209

[1] Costs were originally estimated at a capacity of 10 cfs which was used as the basis for estimating the other alternative capacity costs.

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