Northwest Missouri Regional Water Supply Transmission System Study

Final Report

May 2010

Phase III Report

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Missouri Department of Natural Resources – Water Resources Center
Great Northwest Wholesale Water Commission
U.S. Army Corps of Engineers, Kansas City District

Prepared by:
CDM Federal Programs Corporation
9200 Ward Parkway, Suite 500
Kansas City, Missouri 64114

Bartlett & West, Inc.
250 NE Tudor Road
Lee's Summit, Missouri 64086-5696

Missouri Department of Natural Resources

CDM

US Army Corps of Engineers Kansas City District

GREAT NORTHWEST WHOLESALE WATER COMMISSION
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Acronyms

ACWWC	Atchison County Wholesale Water Commission
AWWA	American Water Works Association
CDM	CDM Federal Programs Corporation
Council	Northwest Missouri Regional Council of Governments
D/DBP	Disinfectants/Disinfection By-Products
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
GNWWWC	Great Northwest Wholesale Water Commission
GWR	groundwater rule
LT2ESWTR	Long-Term 2 Enhanced Surface Water Treatment Rule
LRAA	Locational Running Annual Average
MCL	maximum contaminant level
MGD	million gallons per day
mg/L	milligrams per liter
MDNR	Missouri Department of Natural Resources
MTBE	methyl tertiary butyl ether
No.	Number
NRCS	Natural Resources Conservation Service
O&M	operation and maintenance
OEL	operational evaluation level
PAS	Planning Assistance to States
PWS	Public Water Supply
PWSD	Public Water Supply District
RESOP	Reservoir Operation Study Computer Program
TDS	total dissolved solids
WR	Water Resources
Water Partnership	Water Partnership for Northwest Missouri

Definitions

Acidification. Routine well maintenance to remove chemical and bacteria buildup. This buildup reduces open areas of well screen and decreases pumping capacity. During the procedure, acidic solution is pumped into the well and allowed to contact the screen. The well is then developed to remove low pH water and the debris generated by the acidification.

Aquifer. A consolidated or unconsolidated subsurface water-bearing geologic formation, group of formations, or part of a formation, or other geologic deposits, capable of yielding a usable or potentially usable amount of water.

Drought of Record. The most extensive period of drought that occurred from January 1951 to December 1959. Used as a benchmark to determine the capability of surface water sources to meet current demands in the Reservoir Operation Study Computer Program.

Finished Water. Water that has completed all processes of a treatment facility and is ready to be delivered to consumers.

Firm Capacity. The optimum yield determined in recent Reservoir Operation Study Computer Program studies as the optimum yield required to meet current demands during the drought of record.

Groundwater. Water occurring beneath the surface of the ground, including underground watercourses, artesian basins, underground reservoirs and lakes, aquifers, and water in the saturated zone.

Locational Running Annual Average (LRAA). Under B/DBO Rule, the average of sample analytical results for samples taken at a particular monitoring location during the previous four calendar quarters.

Microbial Toolbox. Serves as a decision tree tool that will guide you through several steps to attain Cryptosporidium credits associated with the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

Non-transient Water Systems. Systems that provide water to people in locations such as schools, office buildings, and restaurants.

Operational Evaluation Level (OEL). The operational evaluation level is a locational running annual average threshold value for drinking water pollutants. The process is meant to help systems identify if they are in danger of exceeding the MCL. An OEL exceedance requires an operational evaluation meeting specific criteria and reporting of the evaluation to the State, but does not require systems to take corrective actions.

Reliability. The probability that a reservoir will deliver the calculated demand consistently.

Reservoir Operation Study Computer Program (RESOP). A model created by the Natural Resource Conservation Service that can assess water storage based on monthly climatic and demand data.

Revenue Requirements. The total amount of annual expenditures needed to provide finished water.

Executive Summary

This report provides a summary of water supply issues in the northwest region of Missouri. The purpose of this report is to provide decision-making tools to assist local governments in Andrew, Atchison, Buchanan, Caldwell, Clinton, Daviess, DeKalb, Gentry, Harrison, Holt, Nodaway, and Worth Counties in assessing the benefit of joining the Great Northwest Missouri Water Commission (GNWWWC).

The report includes four main topics that describe the formation of the GNWWWC and the challenges associated with both groundwater and surface water supplies.

- **Formation of the GNWWWC.** Provides a discussion of the events that led to the formation of the GNWWWC and a summary of past studies conducted for the GNWWWC.

- **Cost of Water**. Provides methodology for water supply facilities to compare costs for purchasing water from the GNWWWC or continuing to independently treat/supply water. Calculations are based on methods from the Principles of Water Rates, Fees and Charges-American Water Works Association (AWWA) Manual M1.

- **Current and Future Regulatory Issues.** Prepared by Missouri Department of National Resources staff to provide a brief description of regulatory issues that impact groundwater and surface water suppliers.

- **Drinking Water Sources.** Provides a description on the availability, reliability, and quality of current groundwater and surface water supplies and a general outlook for future supply growth for each of the 12 counties within the GNWWWC region. The section presents both a general region-wide summary and county-specific description of water supplies.

To assess the benefit of purchasing water from a regional wholesale supplier, communities should evaluate the issues presented in this report. Each county is provided an issue statement, included in the appendix of this report, outlining the local availability, reliability, and quality of water supplies. The issue statements are part of the outreach program designed to assist local governments in assessing the benefit of joining the GNWWWC.

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Section 1
Introduction

This report summarizes the overall water supply issues for northwest Missouri by describing the challenges associated with both groundwater and surface water supplies in the area. It has been prepared to assist local governments in Andrew, Atchison, Buchanan, Caldwell, Clinton, Daviess, DeKalb, Gentry, Harrison, Holt, Nodaway, and Worth Counties in assessing the benefit of joining the Great Northwest Wholesale Water Commission (GNWWWC).

This study was completed by CDM Federal Programs Corporation (CDM) and Bartlett & West, with support from the Missouri Department of Natural Resources (MDNR). The report was prepared using data from previous studies and information provided by MDNR, GNWWWC, and readily available online sources.

1.1 Study Authority

Funding for this study was provided through the U.S. Army Corps of Engineers Planning Assistance to States (PAS) Program, Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251) as amended to assist the States in the preparation of comprehensive plans for the development, utilization and conservation of water and related land resources, and Section 319 of the Water Resources Development Act of 1990 (Public Law 101-640). The MDNR, as the non-Federal sponsor of the PAS agreement, utilized State general revenue funds for 50 percent of this study's cost.

1.2 Report Format

- **Section 1 - Introduction.**
- **Section 2 - Great Northwest Wholesale Water Commission.** Provides background information about the GNWWWC and a summary on previous studies.
- **Section 3 - Cost of Water**. Provides guidance for estimating the costs associated with treating and supplying finished drinking water.
- **Section 4 - Current and Future Regulatory Issues.** Offers a summary of regulatory issues that impact surface water and groundwater supplies.
- **Section 5** - **Drinking Water Sources**. Provides a regional and county-specific summary on the availability, reliability, and quality of drinking water sources.
- **Section 6 – Issue Statements.** Issue statements have been prepared for each county using the information developed in Sections 2 through 5. The issue statements will be used as part of an outreach program to local governments to assist them in assessing the benefit of joining the GNWWWC.
- **Section 7 – References.**

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Section 2
Great Northwest Wholesale Water Commission

2.1 Background

The northwest region of Missouri faces both economic and environmental challenges in maintaining drinking water resources. These challenges are not independent of each other and require a region-wide effort for resolution. Utilizing the best quality, most reliable and readily available water sources on a regional scale could provide an economical long-term water supply for both residents and businesses in northwest Missouri.

Drinking water in the region has traditionally been obtained from a combination of groundwater wells and surface water sources. Missouri River alluvium deposits and man-made reservoirs such as Smithville Lake, Cameron, and Grindstone are the largest drinking water sources in northwest Missouri. However, there are challenges in obtaining reliable water sources when access to the Missouri River alluvium or major reservoirs is not an option.

The Missouri River alluvium covers approximately seven percent of the total land area in northwest Missouri region. Sources derived from other formations often do not sustain a long-term supply. Approximately 25 percent of drinking water systems in northwest Missouri with their own water supply have lifetime expectancy greater than 15 years (GNWWWC, 2009a). Some of the surface water and groundwater sources have also been compromised by the presence of pollutants and require additional treatment.

The tax base in the study area continues to decrease with decreasing population. This occurs at a time when improvements in water treatment infrastructure are needed to sustain the current conditions and encourage growth in the region. Not only has this infrastructure aged, requiring increased maintenance and replacement, but increasingly strict water standards require more complex treatment prior to consumption (CDM/Bartlett and West, 2009). Many drinking water facilities have surpassed their useful life and should be replaced or abandoned (GNWWWC, 2009a).

Each supplier in the region independently sources and treats their water. Due to the maintenance and construction need of the aging water infrastructure, water quality parameters, and demand, water rates in the region vary greatly. By pooling economic resources and water supply sources, the northwest Missouri region could substantially improve the availability, reliability, and quality of drinking water supplied to its customers.

2.2 Formation of Great Northwest Wholesale Water Commission

The idea for GNWWWC followed a dry 14-month period from 2003 to 2004. A group of city and county elected officials approached the Northwest Missouri Regional Council of Governments (Council) about the possibility of a regional solution to the drinking water challenges faced by many water providers in the region. In March 2005, the Council approached MDNR to develop a comprehensive water system plan for the region. The Council was promised support for a regional effort in formulation of a long-term water supply plan that would be locally driven.

An exploratory group of water experts, local elected officials, state and federal agencies, and concerned citizens was formed to begin to examine the issues of water availability and reliability in northwest Missouri. Soon the group was expanded to include representatives from a 12-county region, and became known as the Water Partnership for Northwest Missouri (Water Partnership). The 12-county regional group included representatives from water suppliers in the counties of Andrew, Atchison, Buchanan, Caldwell, Clinton, Daviess, DeKalb, Gentry, Harrison, Holt, Nodaway, and Worth, as shown in Figure 2-1 (MDNR, 2007).

Based on two initial studies, the Water Partnership determined the need to form a public water entity to implement the projects required to provide a reliable water supply in northwest Missouri. In late 2008, the Water Partnership voted to form the new legal entity called the GNWWWC. The GNWWWC was formed under Chapter 393 of the Missouri Revised State Statues. It was voted into effect by members of the Water Partnership, and is thus is a public water utility. The GNWWWC has the authority to construct and own infrastructure, issue debt on behalf of its members, receive grant proceeds and other public assistance, and purchase and sell water from retail water systems (GNWWWC, 2009b). The GNWWWC met for the first time on July 16, 2009 in the City of Savannah, Missouri with eight water providers. As of February 2010, 22 cities and water districts have joined the GNWWWC. The member cities and member city representatives as of February 2010 are presented in Table 2-1.

The GNWWWC has since assumed the responsibilities of regional planning for future water needs in the 12-county study area.

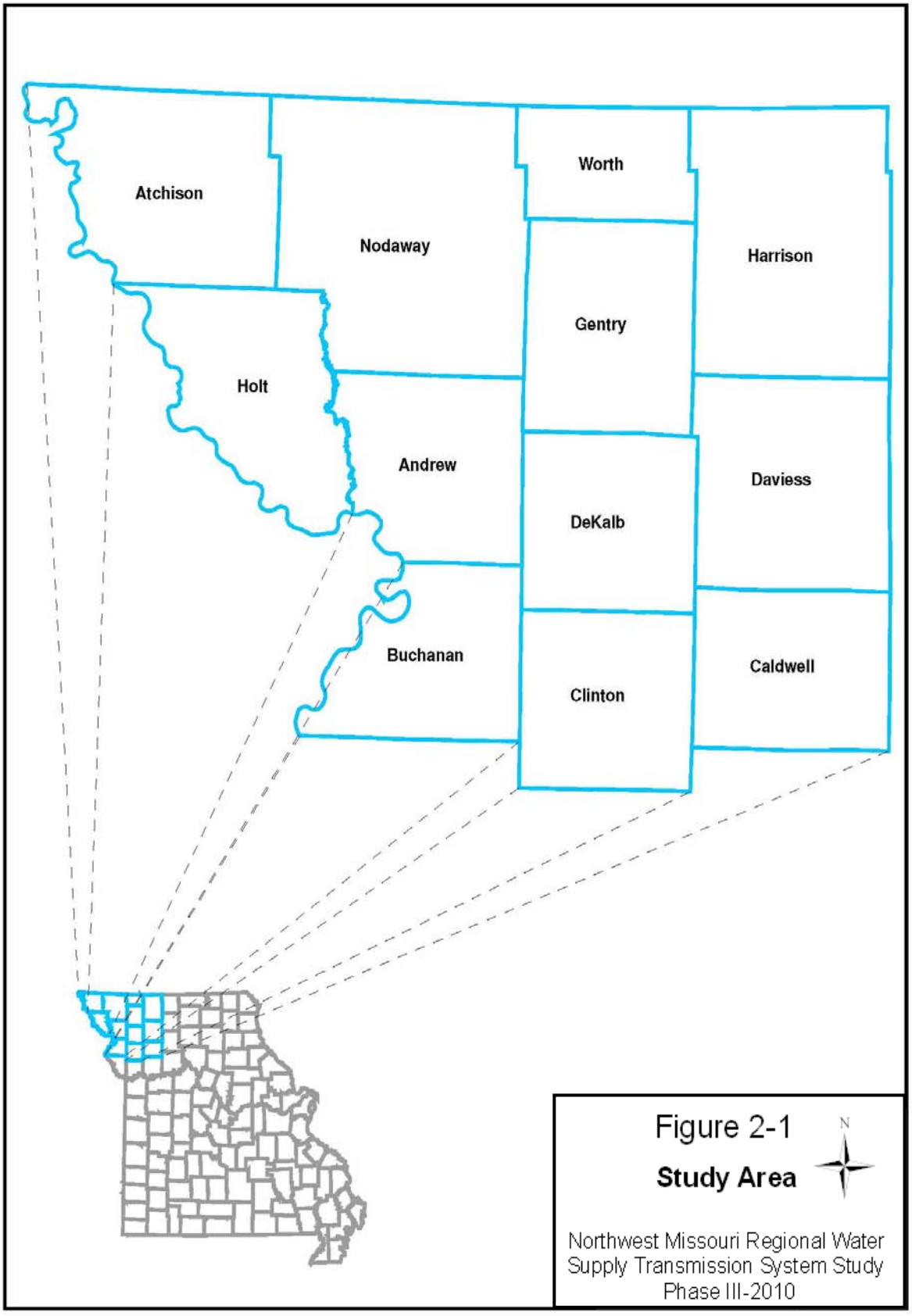


Figure 2-1

Study Area

Northwest Missouri Regional Water Supply Transmission System Study Phase III-2010

Table 2-1
Great Northwest Wholesale Water Commission Member List
February 2010

Member Name	City	County	Representative
Andrew PWSD #1	Savannah	Andrew County	Connie Field
Andrew PWSD #2	Cosby	Andrew County	Terry Campbell
Andrew PWSD #4		Andrew County	Ross Bilby
City of Bolckow	Bolckow	Andrew County	
City of Savannah	Savannah	Andrew County	Michael Fisher
Buchanan PWSD #1	Rushville	Buchanan County	Norm Ellis
City of Plattsburg	Plattsburg	Clinton County	D. J. Gehrt
Clinton PWSD #1	Trimble	Clinton County	
City of Cameron	Cameron	Clinton, DeKalb Counties	Everett Ice
City of Gallatin	Gallatin	Daviess County	Zac Johnson
Daviess PWSD #1	Pattonsburg	Daviess County	
City of Maysville	Maysville	DeKalb County	Patricia Fisher Johnson
City of Stewartsville	Stewartsville	DeKalb County	Sam Clary
DeKalb PWSD #1	Clarksdale	DeKalb County	Michael Jacobs
City of Albany	Albany	Gentry County	Derek Brown
City of Stanberry	Stanberry	Gentry County	Terry Reynolds
Gentry PWSD #1	Albany	Gentry County	Kathy Morgan
City of Maitland	Maitland	Holt County	
City of Barnard	Barnard	Nodaway County	
City of Ravenwood	Ravenwood	Nodaway County	James Teaney
Nodaway PWSD #1	Maryville	Nodaway County	Don Nothstine
City of Grant City	Grant City	Worth County	Greg Miller

PWSD – Public Water Supply District

2.3 Summary of Past Work

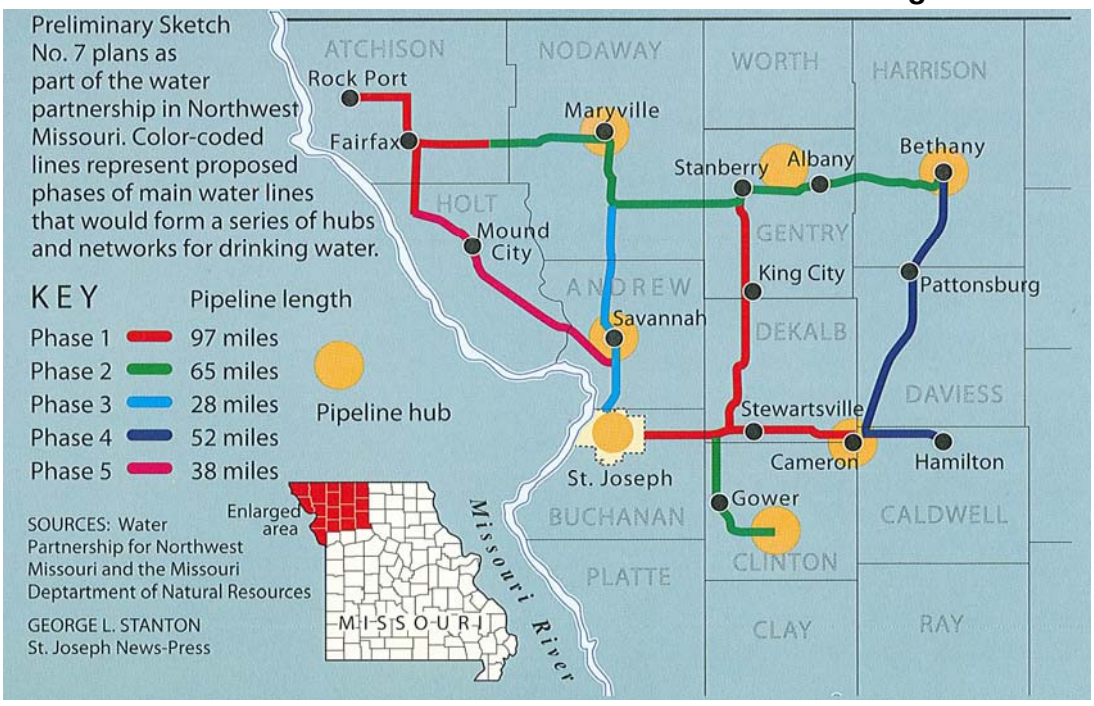
The Water Partnership desired to produce a plan that would address the growing need for a long-term, affordable, high-quality water supply, while leveraging existing infrastructure and maintaining local control over the distribution systems. Toward this goal, an initial Phase I report (MDNR, 2007) was prepared that identified the existing facilities, considered multiple resource alternatives, and defined the need. A second study, the Phase II feasibility study (CDM/Bartlett and West, 2009) provided a conceptual plan from which potential capital, operations and maintenance, and replacement cost estimates could be estimated.

2.3.1 Phase I Report

The Phase I report focused on the formation and purpose of the Water Partnership and provided a general summary of the area's available water supply. The report was written by MDNR and the production and printing costs were financed by MDNR and Northwest Missouri State University. The study reinforced the importance of reliable water sources for community development and growth. The Water Partnership evaluated options for a regional water plan that could transfer water to various existing local water facilities without creating new service lines to customers.

The Water Partnership's engineering subcommittee identified seven water systems with the potential to continue serving their current customers and also be expanded to serve new customers. These seven hubs included: Cameron, Bethany, Maryville, Missouri-American Water Company, Middle Fork Water Company, Plattsburg, and Savannah. Using these seven water systems as a base, the Water Partnership developed several proposed plans for regional water supply and transmission. The Water Partnership identified Sketch Number (No.) 7, shown in Figure 2-2, as the recommended regional plan (MDNR, 2007).

Figure 2-2
Phase I Regional Plan



2.3.2 Phase II Feasibility Report - Northwest Missouri Regional Water Supply Transmission System Study

The Phase II feasibility report (CDM/Bartlett and West, 2009), titled the Northwest Missouri Regional Water Supply System Study, and was written as a follow up to the Phase I report. Funding for the Phase II report was provided by MDNR, the Water Partnership, and the U.S. Army Corps of Engineers through the PAS Program. The MDNR as the non-federal sponsor utilized State general revenue funds for 43 percent of the Phase II study cost, seven percent of this cost was provided through donations for the Water Partnership held in trust by Northwest Missouri State University (CDM/Bartlett and West, 2009). The Phase II study estimated future water needs, developed a conceptual design and preliminary cost estimate, and estimated preliminary wholesale water rates.

A 2.6-percent annual increase in demand was used to determine the projected water need for the study area in the year 2030. This annual increase in demand was calculated using the average annual water consumption increase since 1994. Using this assumption, future infrastructure must meet the demand of 26.25 million gallons per day (MGD) for the area.

This conceptual design assumed three major water suppliers; Atchison County Wholesale Water Commission (ACWWC), Missouri-American in St. Joseph, and the City of Plattsburg, with pipeline and pumping capacity in place that would accommodate additional suppliers. The conceptual design includes 299 miles of pipeline, which ranges from 8 to 36-inches in diameter. This pipeline design includes wholesale master meters that allow each county to buy, sell, and transmit water. The proposed transmission system requires nine pump stations and six intermediate storage tanks to keep the system within reasonable pressure ranges. The piping, pumping, and storage facilities for the conceptual plan are shown in Figure 2-3.

The preliminary cost estimate (Table 2-2) included calculations of the following components:

- **Initial Construction Costs**. Costs for the construction of the pump stations, water storage facilities, and pipeline for the conceptual design were made based on similar, recent projects in the Phase II report. Assumptions are outlined in Section 8.1 of the Phase II report (CDM/Bartlett and West, 2009).

- **Treatment Plant Expansion.** Expansions at the three major water suppliers are required to meet estimated peak demands. The Plattsburg and ACWWC facilities require a 6.0 MGD expansion, while the Missouri-American plant requires a 3.0 MGD. Assumptions for cost calculations are outlined in Section 8.1 of the Phase II report (CDM/Bartlett and West, 2009).

- **Annual Operations and Maintenance Costs**. Operation and Maintenance (O&M) costs were represented by annual expenditures for staffing, energy costs, storage repainting, and pipeline maintenance and repair. Calculations were carried out

based on data from comparable systems. Assumptions for O&M calculations are outlined in Section 8.3 of the Phase II report (CDM/Bartlett and West, 2009).

- **Annual Renewal and Replacement Costs**. The Phase II report assumed complete replacement of each component at the end of its lifespan in addition to one-time project incidentals. Annual renewal and replacement calculations were conducted for pump station, storage tank, and pipeline replacement. Assumptions for these calculations are described in Section 8.2 of the Phase II report (CDM/Bartlett and West, 2009).

- **Water Purchase Costs**. Data from the ACWWC, Missouri-American, and the City of Plattsburg facilities were used to estimate water purchase costs. Purchase costs were calculated to be $2.28 for 1,000 gallons of water produced. Assumptions for this calculation are outlined in Section 8.4 of the Phase II report (CDM/Bartlett and West, 2009). The calculation for these costs is further discussed in Section 3 of this report.

Table 2-2
Conceptual Plan Preliminary Cost Estimate
(Adapted from CDM/Bartlett and West, 2009)

Initial Costs		
Initial Construction Costs	Pump Stations	$13,000,000
	Water Storage Tanks	$7,200,000
	Pipeline	$129,200,000
Treatment Plant Expansion		$22,300,000
Total-Initial Costs		**$171,700,000**
Annual Costs		
Annual O&M Costs	Staffing	$300,000
	Energy Costs	$857,400
	Storage Repainting	$60,000
	Pipeline maintenance and repair	$30,000
	Subtotal-Annual O&M Costs	***$1,247,400***
Annual Renewal and Replacement Costs	Pump Stations (20 yrs)	$388,800
	Water Storage Tanks (40 yrs)	$107,500
	Pipeline (60 yrs)	$1,300,000
	Subtotal-Renewal and Replacement Costs	***$1,796,300***
Water Purchase Costs	Cost per 1,000 gal	$2.28
	Subtotal-Water Purchase Cost (4,727 million gal)	***$10,800,000***
Total-Annual Costs		**$13,843,700**

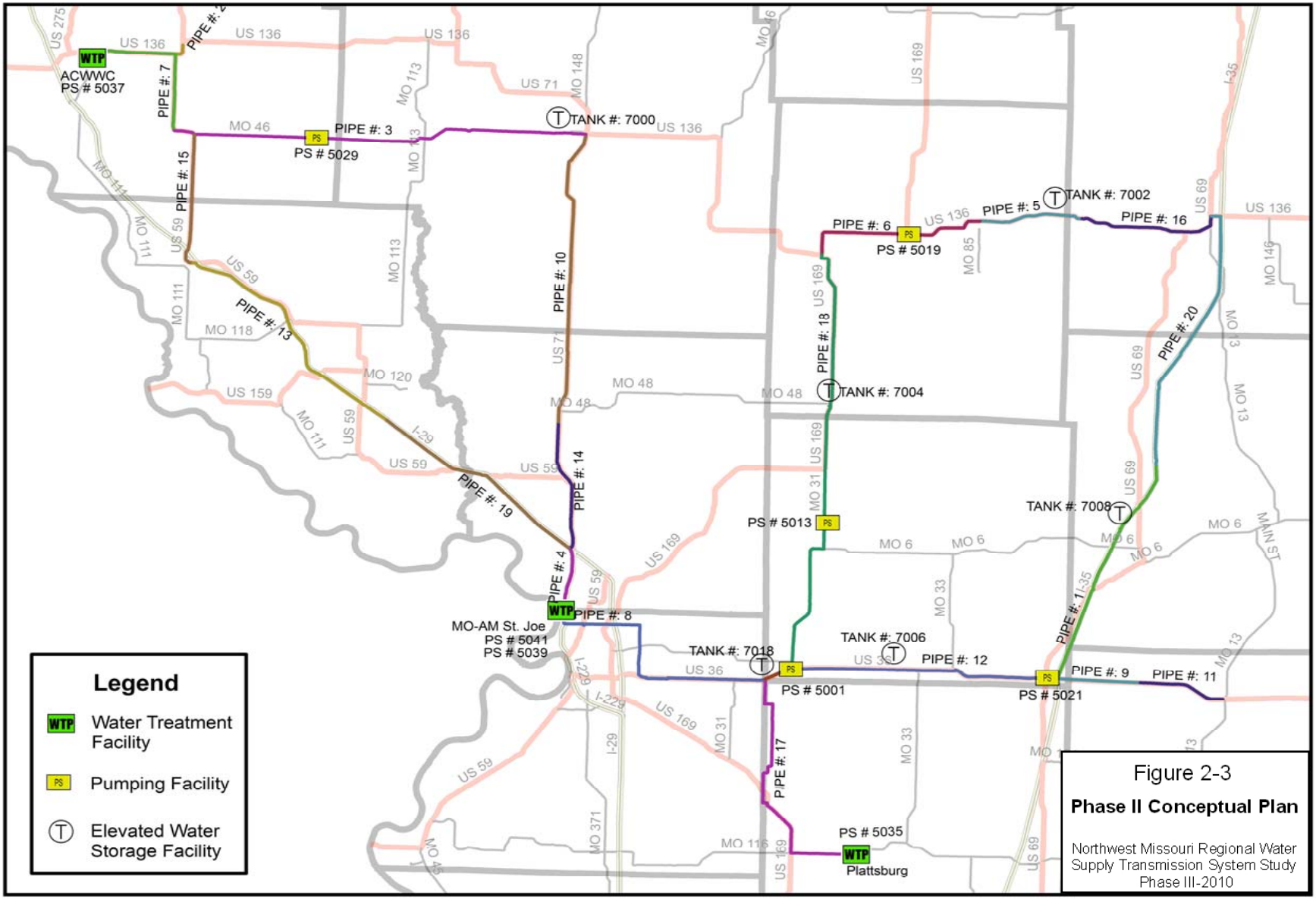
The Phase II report also provided an estimated wholesale rate requirement. Financial analysis of the rate requirement was based on three scenarios:

- **Scenario 1**. 100 percent revenue bond financing
- **Scenario 2**. 80 percent revenue bond financing and 20 percent grant funding
- **Scenario 3**. 50 percent revenue bond financing and 50 percent grant funding.

Results of the assessment are presented in Table 2-3. Further discussion of the assumptions used for this analysis is presented in Section 9 of the Phase II report (CDM/Bartlett and West, 2009).

Table 2-3
Annual Wholesale Rate Requirements
(Adapted from CDM/Bartlett and West, 2009)

Item	Scenario 1	Scenario 2	Scenario 3
Estimated Annual Debt Service	$12,474,000	$9,980,000	$6,237,000
Estimated O&M Costs (from Table 2-2)	$1,300,000	$1,300,000	$1,300,000
Estimated Annual Renewal and Replacement (from Table 2-2)	$1,800,000	$1,800,000	$1,800,000
Estimated Annual Water Purchase (from Table 2-2)	$10,800,000	$10,800,000	$10,800,000
Total Estimated Revenue Requirement	***$26,374,000***	***$23,880,000***	***$20,137,000***
Estimated Cost per 1,000 gallons	$6.17	$5.59	$4.71
Estimated Customer Monthly Wholesale Cost (5,000 gallons)	$30.87	$27.95	$23.57


ACWWC
PS # 5037
WTP
PIPE #: 7
PIPE #: 15
PS # 5029
PIPE #: 3
TANK #: 7000
PIPE #: 10
PIPE #: 13
PIPE #: 19
PIPE #: 14
PIPE #: 4
PIPE #: 8
MO-AM St. Joe
PS # 5041
PS # 5039
PS # 5019
PIPE #: 6
PIPE #: 5
TANK #: 7002
PIPE #: 16
PIPE #: 18
TANK #: 7004
PS # 5013
TANK #: 7008
PIPE #: 20
PIPE #: 1
TANK #: 7018
TANK #: 7006
PIPE #: 12
PS # 5001
PS # 5021
PIPE #: 9
PIPE #: 11
PIPE #: 17
PS # 5035
Plattsburg
US 136
US 59
US 169
US 71
US 69
US 36
I-29
I-35
MO 46
MO 111
MO 118
MO 120
MO 48
MO 6
MO 13
MO 31
MO 33
MO 85
MO 146
MO 148
US 159
MO 371
Legend
Water Treatment Facility
Pumping Facility
Elevated Water Storage Facility
Figure 2-3
Phase II Conceptual Plan
Northwest Missouri Regional Water Supply Transmission System Study
Phase III-2010

Section 3
Cost of Water

3.1 Introduction

This section provides a standard method for calculating the costs associated with treating and supplying finished water. The method is based on the American Water Works Association (AWWA) Manual of Water Supply Practices Manual M1 (AWWA, 2000). This information is useful to entities that are considering the purchase of water from the GNWWWC instead of maintaining independent treatment systems.

3.2 Cost of Producing Potable Water

Costs are based on setting rates to cover projected expenses of finished water. The AWWA Manual M1 describes a cash-needs approach for projecting revenue requirements for a utility without accounting for depreciation. Please note that the AWWA cash-needs approach was modified for use in this study to provide a predictive comparison. The modified approach is comprised of four major components that are briefly discussed below.

- **O&M Expenses**. Recurring and nonrecurring expenses to operate and maintain infrastructure associated with producing finished water.
- **Debt Service Payments.** The debt service component includes principal and interest payment on bonds, loans or other debt instruments associated with water production.
- **Contribution to Specified Reserves (Savings).** Savings or reserve accounts used to provide funds for emergency use, unexpected major repairs and routine repairs and replacement associated with potable water production.
- **Capital Expenditures.** Classified as (1) normal annual (routine) replacement of existing facilities; (2) normal annual extensions and improvements; and (3) major capital replacements and improvements associated with potable water.

Using these parameters, the cost for of producing potable water can be calculated as shown in Equation 3-1 below.

Equation 3-1
Calculation of the Cost of Finished Water using Revenue Requirements

$$\frac{Cost\ of\ Potable\ Water}{1{,}000\ Gallons} = \frac{O\&M\ Expenses + Debt\ Service\ Payment + Savings + Capital\ Expenditures}{1{,}000\ Gallons\ of\ Water\ Generated}$$

This cost of producing potable water can then be compared to the cost to purchase potable water.

3.3 Potable Water Production Costs for Hypothetical Treatment Facility in Northwest Missouri

Joining the GNWWWC will impact the cost to water systems. To quantify how the water costs will change, facility managers must be sure that they are comparing the GNWWWC wholesale rate to the current cost of producing water adjusted for depreciation. Depreciation is an annual allowance required to recover the initial capital cost of the equipment and infrastructure associated with a facility. Many distributors do not account for depreciation when calculating water rates and thus do not currently recover all costs caused by that utility.

Table 3-1 provides example cost of producing potable water for two typical, but hypothetical drinking water facilities – a surface water treatment plant and a well source with chlorination only. This cost per 1,000 gallons can best be compared to the average wholesale water rate of the GNWWWC. From Section 2.3.2 and Table 2-2, the average wholesale water rate for the GNWWWC's conceptual plan was estimated to be $2.28 per 1,000 gallons (CDM/Bartlett & West, 2009).

Table 3-1
Annual Cost of Finished Water for Example Facilities

	Treatment Facility		Source Only	
	With Depreciation	***Without Depreciation***	***With Depreciation***	***Without Depreciation***
Operations and Maintenance	––	––	––	––
Power Consumption	$180,000	$180,000	$60,000	$60,000
Chemical Consumption	$20,000	$20,000	$4,000	$4,000
Operating Staff	$150,000	$150,000	$25,000	$25,000
Miscellaneous	$110,000	$110,000	$10,000	$10,000
Savings	$25,000	$25,000	$15,000	$15,000
Capital Expenditures	$45,000	$45,000	$17,000	$17,000
Debt Service Payments	$150,000	$150,000	$20,000	$20,000
Depreciation	$175,000	––	$16,000	––
Total Annual Expenditures	$855,000	$680,000	$167,000	$151,000
Annual Finished Water Produced (x1,000 gallons)	$275,000	$275,000	$60,000	$60,000
*Cost per 1,000 gallons**	$3.11	$2.47	$2.78	$2.52

*Cost per 1,000 gallons = Total Annual Expenditures/Annual Finished Water Produced (x 1,000 gallons)

Section 4
Current and Future Regulatory Issues

4.1 Introduction

This section was prepared by MDNR and provides a brief summary of regulatory issues that impact surface water and groundwater supplies as of February 2010. Regulatory issues discussed include Stage 1 and Stage 2 Disinfectants/Disinfection By-Product (D/DBP) Rules, the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), the Groundwater Rule, the Lead and Copper Rule Short-Term Revisions, and the future Revised Total Coliform Rule.

4.2 Stage 1 and Stage 2 Disinfectants/Disinfection By-Product Rules

The Stage 1 D/DBP Rule applies to all community and nontransient noncommunity water systems that treat water with a chemical disinfectant for either primary or residual treatment. The rule sets maximum residual disinfectant levels for chlorine, chloramine and chlorine dioxide and tightens the maximum contaminant levels (MCLs) for disinfection by-products. A system is in compliance when the running annual average (computed quarterly) of samples taken in the distribution system is less than or equal to the MCLs.

The Stage 2 DBP rule builds upon Stage 1 and was published in the Federal Registrar in January 2006. Stage 2 makes a significant change to the compliance calculation of Stage 1. The rule became effective in Missouri on Ocrober 30, 2009. Under Stage 2 D/DBP, a system must be in compliance with a Locational Running Annual Average (LRAA). A LRAA requires that compliance be calculated for each monitoring location in the distribution system. This is a much more stringent standard than systems have been required to meet. Monitoring locations will be determined though a distribution system evaluation that identifies the locations with high disinfection by-product concentrations. This rule also requires each system to determine if they have exceeded an operational evaluation level. A system that exceeds an operational evaluation level is required to review their operational practices and submit a report to MDNR that identifies actions that will mitigate future high DBP levels, particularly those that may jeopardize compliance with the disinfection by-product MCLs.

Stage 2 D/DBP applies to all community and nontransient noncommunity water systems that add or deliver water that is treated with a primary or residual disinfectant other than ultraviolet light. The Stage 2 D/DBP rule affects 93 systems in northwest Missouri. This includes any community and nontransient community system that either chlorinate or buy and sell chlorinated water. The major provisions of Stage 2 D/DBP will cost affected public water systems in Missouri an average of $29,160 per system each year plus a total of $18,155,784 in one-time costs. These costs are based on national data provided by the U.S. Environmental Protection Agency (EPA) and extrapolated to Missouri based on population (McCarty, 2010). Please note that Stage 1 and Stage 2 rules are regulated throughout the whole distribution system and may be easier to attain and more cost-effective for a region-wide system than individual systems.

4.3 Long-Term 2 Enhanced Surface Water Treatment Rule

The LT2ESWTR is the fourth in a series of surface water treatment rules from the EPA. The surface water treatment rules apply to all public water systems using surface water or groundwater under the direct influence of surface water regardless of size. The LT2ESWTR became effective in Missouri on October 30, 2009.

LT2ESWTR requires that systems monitor for *Cryptosporidium* (or for small systems, *E. coli*) to determine their treatment "bin." A bin is a treatment category system based on their monitoring results. Systems falling in the lowest bin face no additional treatment requirements. Systems classified in the higher bins must provide additional treatment to further reduce *Cryptosporidium* levels. Systems must select from different treatment and management options in a "microbial toolbox" to meet their additional treatment requirements. Also, systems must review their current level of microbial treatment before making a significant change in their disinfection practice.

MDNR estimates that the rule will affect 89 public water systems in Missouri, ten of which are located in northwest Missouri. The rule will cost an estimated $475,848 for each of these ten systems, actual costs will depend on individual characteristics of the treatment facility (McCarty, 2010). Since the rule was implemented, two systems in northwest Missouri have been required to implement cryptosporidium monitoring. Depending on the results from a year of sampling (two samples per month), these systems may have to provide additional log removal for E. Coli (Timmons, 2010).

4.4 Groundwater Rule

The groundwater rule (GWR) is applicable to all public water systems in Missouri (community and noncommunity) using ground water. This also includes systems that mix surface and groundwater if the groundwater is added directly to the distribution system and provided to consumers without treatment. The GWR was published in the Federal Registrar in 2006 and requires frequent inspections of systems, triggered source water monitoring, corrective action to resolve significant deficiencies or source water fecal contamination, and compliance monitoring to ensure that treatment technology reliably achieves inactivation or removal of viruses. When a system has a significant deficiency or a fecal indicator positive source water sample, the system will be put on a compliance schedule and must implement one or more of the following actions:

- Correct all significant deficiencies.
- Provide an alternate source of water.
- Eliminate the source of contamination.
- Provide treatment that reliably achieves at least 4-log treatment of viruses (using inactivation, removal, or a state-approved combination of 4-log virus inactivation and removal).

As of December 1, 2009 all public water systems in northwest Missouri are affected by this rule.

4.5 Lead and Copper Rule Short-Term Revisions

The Lead and Copper Rule is applicable to public water systems that are classified as community water systems or non-transient, non-community water systems (e.g., systems that provide water to people in locations such as schools, office buildings, restaurants, etc.); state primacy agencies; and local and tribal governments. Facilities were required to comply by December 10, 2009. The rule modifies the following monitoring requirements:

- Requires systems to gain state approval before changing treatment
- Requires systems to notify owners/occupants of homes and buildings of monitoring; requires utilities to reconsider previously "tested-out" lines when resuming lead service line replacement programs
- Changes the content, delivery method, and timeframe of delivery for public notice
- Requires educational statements about lead in drinking water to be included in all Consumer Confidence Reports

4.6 Revised Total Coliform Rule

EPA is currently working on major revisions to the Total Coliform Rule that will affect all public water systems. The revisions require special assessments of water systems, investigation and correction of sanitary defects, and increased monitoring for high-risk small systems with unacceptable compliance history or significant non-compliance. In order to qualify for reduced monitoring, requirements for well-operated small systems should include a clean sanitary survey and at least two years of good compliance history. In addition, an annual on-site visit, a cross connection control program, or continuous disinfection may also be required. EPA expects to propose this rule in 2010 and have a final rule in place in 2012.

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Section 5
Drinking Water Sources

5.1 Introduction

The northwest region of Missouri as defined for this study consists of Andrew, Atchison, Buchanan, Caldwell, Clinton, DeKalb, Daviess, Gentry, Harrison, Holt, Nodaway, and Worth Counties. This section provides a description of the availability, reliability, and quality of sources for drinking water in this region. This description is based on underlying geologic formations and studies on current drinking water sources in northwest Missouri. These geologic formations and current sources are shown in Figure 5-1.

Figure 5-1was adapted from the October 2009 Public Drinking Water Wells Northwestern Missouri map (MDNR, 2009) that is provided in Appendix A. All data was compiled by MDNR and edited by CDM to reflect changes based the latest inspection reports, an interview with William Hills, and comments from David Williams of MDNR and GNWWWC members. In the figure, recent river alluvium deposits are shown as gray, thick glacial deposits greater than 100 feet in preglacial valleys and channels are shown in green, and glacial deposits less than 100 feet thick are shown in yellow. Discussions on how the type of geologic formation impacts water availability, reliability, and quality is presented in Sections 5.2.2, 5.3.3, and 5.4.2, respectively. Please note that in Figure 5-1 the well and reservoir locations may not be within the indicated city or county. For example, the well field for Harrison County PWSD #2 is actually located in Daviess County.

Information on reliability is based on the recent facility assessments (Hills, 2007; Hills, 2009), and the Missouri State Water Plan Series (Miller and Vandike, 1997). Information on source availability and quality comes from reports prepared by the MDNR for county and statewide water assessments and are listed below.

- Studies by MDNR on the groundwater possibilities by county, conducted from 1956 to 1960 (Water Resources Report [WR]-3 to WR-18). Studies were not conducted for counties lacking viable water supply.
- Inspection reports of water systems conducted between 2003 and 2006 by MDNR.
- The Phase I and Phase II reports prepared for the Water Partnership for Northwest Missouri.

5.2 Regional Water Availability

5.2.1 Surface Water Availability

One of the largest surface water sources in northwest Missouri is Smithville Lake, part of which is located in Clinton County. Smithville Lake provides drinking water to the City of Kansas City, the City of Smithville, and the City of Plattsburg. Other substantial surface water sources include Mozingo Lake in the City of Maryville, Grindstone Reservoir and Cameron Lakes near the City of Cameron.

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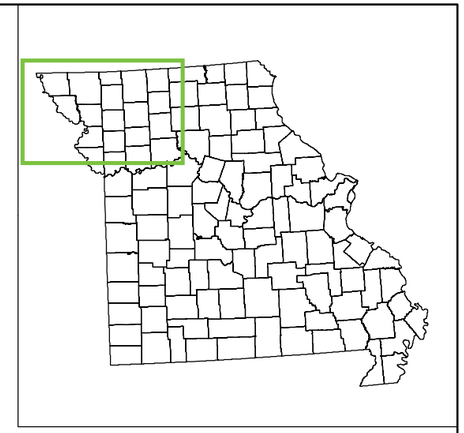
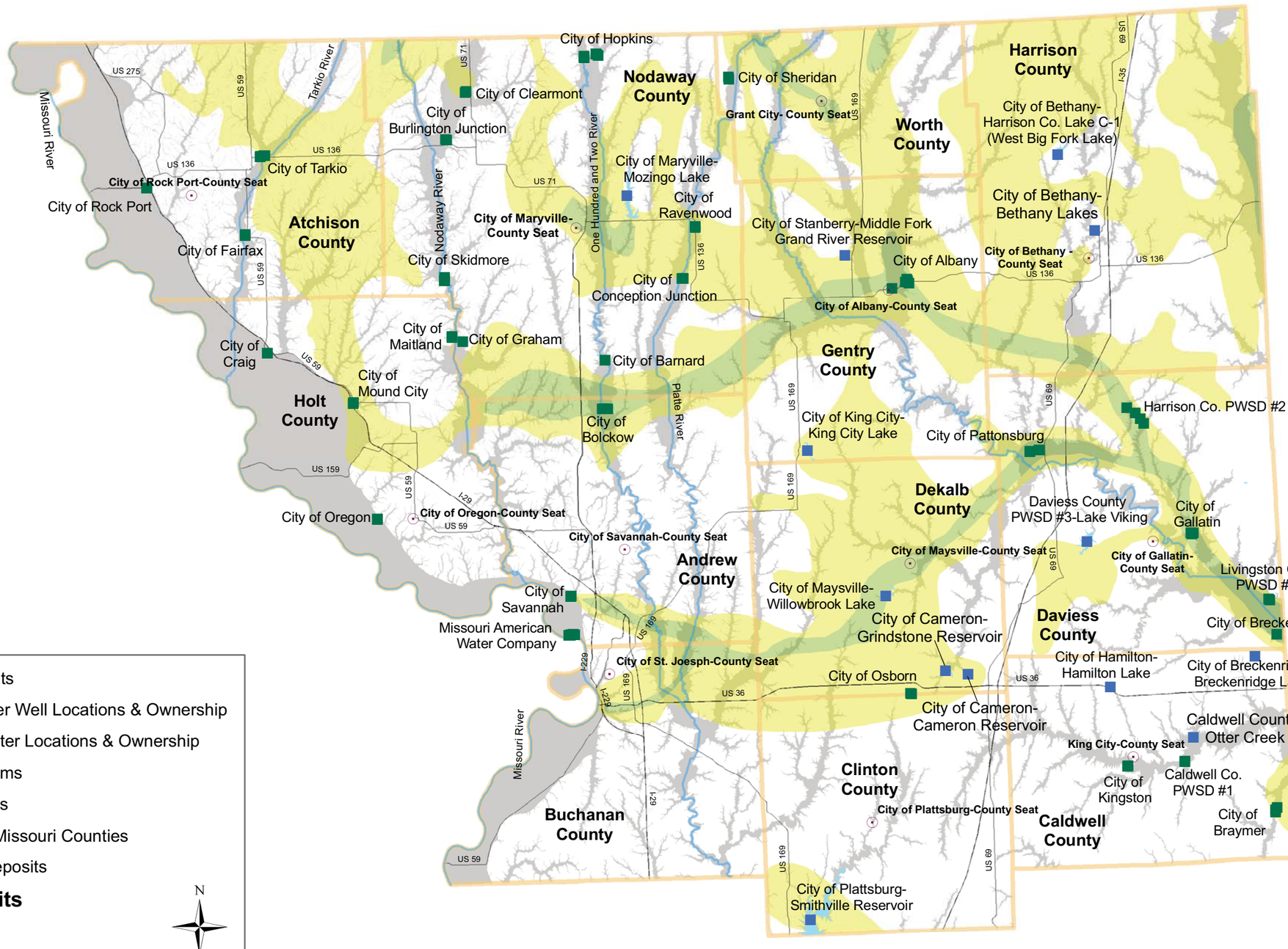




County Seats

Groundwater Well Locations & Ownership

Surface Water Locations & Ownership

Major Streams

Major Roads

Northwest Missouri Counties

Alluvium Deposits

Glacial Deposits

10 - 100 ft

>100 ft

N

1 inch equals 50,000 feet

0 50,000 100,000 Feet

Figure 5-1

Active Drinking Water Sources

Northwest Missouri Regional Water Supply Transmission System Study Phase III-2010

Historically, the Missouri River, the One Hundred and Two River, and other smaller rivers have been used either directly or indirectly as a water source (Hills, 2010). Currently, no water producers use rivers as an independent water source. Facilities may, however, use rivers to supplement water supply. The Mozingo Reservoir in the City of Maryville was constructed to receive supplemental flows from the One Hundred and Two River. Other cities have discontinued their use of smaller rivers as an independent supply source due to the unreliability of river flow.

5.2.2 Groundwater Sources Availability

5.2.2.1 Geologic Formations in the Northwest Region of Missouri

Northwest Missouri is located in the Dissected Till Plains sub-province of the Central Lowlands physiographic province. This area is characterized by thick Pleistocene-age glacial sediments and recent alluvial deposits. These sediments overlie Pennsylvanian-age and older bedrock formations. Prior to the onset of glacial activity rolling hills and numerous valleys were developed throughout northern Missouri. Glaciers extended as far south as the Missouri River carrying boulders, gravel, sand, silt and clay derived en route from areas to the north. The weight of the ice and abrasive nature of the debris altered the existing landscape. Glacial deposits up to 300 feet thick were deposited in some areas. Glacial drift is well sorted stratified material that was transported and deposited by melt water. In areas were these sediments were deposited in preglacial valleys and channels, the glacial materials are relatively clean and consist mostly of sand with some gravel. Glacial till deposits are heterogeneous and non-stratified material that was transported by the ice. Erosion has greatly modified the landscape since the last period of glaciation. In some areas the glacial material has been completely removed leaving Pennsylvanian bedrock exposed at the surface.

The extensive preglacial drainage system in northwest Missouri was rerouted or covered by glacial activity. The Grand River, which today traverses the area from northwest to southeast, is thought to be the approximate path of the preglacial Missouri River. Glacial movement rerouted the ancestral river, and moved it into its present channel along the northwestern edge of the state. Prior to glaciation, all of these drainage systems had alluvial deposits underlying their floodplains, with the larger streams having more extensive alluvial deposits than the smaller ones. These drainage systems were filled with glacial deposits.

Bedrock Aquifer

The Pennsylvanian- age bedrock that underlies glacial deposits in northwest Missouri consists of relatively thin limestone, sandstone, and shale units with occasional coal seams. These units generally become thicker to the northwest and are up to 1,800 feet thick in the Forest City Basin. In general, the vertical and horizontal permeability of the Pennsylvanian units is poor. As a result these units typically yield low quantities of water. Recharge to the Pennsylvanian rock from overlying glacial drift and precipitation is very poor. Thus, these deposits are not considered to be a viable source of groundwater. The quality of water obtained from these formations is usually marginal at best. Deeper units generally contain progressively more mineralized groundwater (Miller and Vandike, 1997).

Glacial Drift Aquifer

Glacial materials provide the most widespread groundwater resources. However, in northwest Missouri, there are limited deposits of glacial materials. The areas with the highest potential yields are drift-filled preglacial valleys where pre-Pleistocene alluvial deposits were covered with glacial drift. The preglacial valleys in northwest Missouri are shown in dark green shading in Figure 5-1.

The average yield from glacial materials can range from less than 5 gallons per minute (gpm) to 500 gpm depending on thickness, composition and other factors. In the northwest region of Missouri, yields from glacial materials are typically lower than in other regions of the state For example, Livingston County, which lies just east of Daviess County outside of the study area, has wells in a preglacial channel that produce 500 to 1,000 gpm. The same channel underlies the City of Gallatin and north-central Daviess County. Gallatin wells produce 250 to 300 gpm per well. The well field for Harrison County PWSD #2 is also located in the same preglacial channel, but wells produce only 100 to 150 gpm (Vandike, 2010).

In some areas, the alluvial deposits found in these preglacial drainage systems yield from 100 to 500 gpm. These preglacial alluvial deposits are limited in area extent and are found in narrow linear trends. The preglacial alluvial valleys can contain more than 100 feet of clean sand and gravel. The glacial drift of northwest Missouri is a complex geologic deposit that can vary in thickness and texture over a relatively short distance. It is often necessary to drill several test holes to locate the most water-productive materials. The following counties have municipal wells in these preglacial valleys: Andrew, Gentry, and Daviess.

The direction of groundwater flow in the shallow glacial sediments is a factor that is controlled by the present-day surface topography and the direction of flow in the deeper glacial sediments is controlled by the preglacial topography impressed on the Pennsylvanian bedrock beneath the drift. Water bearing zones may be perched or isolated within impermeable zoned due to the nature of the deposits. Groundwater flow in glacial material is generally very slow. The water quality of the shallow glacial deposits is much better than the underlying bedrock deposits. Groundwater in the buried, preglacial channels generally tends to be of poorer quality than the shallow glacial sediments due to the poor recharge potential and local leakage of water from adjacent bedrock formations.

Recent River Alluvium

Alluvium deposits exist throughout northwest Missouri as shown in Figure 5-1. All counties in the study area have wells in alluvium deposits. In general, alluvial sediments tend to be progressively finer as the distance from the mouth of the river increases. Alluvial deposits from major streams and their tributaries tend to be finer-grained and much less permeable than the Missouri River alluvium. The deposits from stream valleys were derived from the weathering of the glacial drift. Since the shallow glacial sediments are predominately clay, silt and fine sand, the eroded material transported into the tributary streams tends to be fine grained.

The thickness of the alluvial material in the major streams in this region ranges from a few feet in headwater reaches to approximately 60 feet in the southern part of the region. The saturated thickness of the material ranges from 10 feet in the north to about 45 feet in the south. There are relatively few wells or test holes that penetrate river alluvium in the study area. In general, the most favorable alluvium deposits are associated with the Missouri River and lower parts of the Grand and Chariton rivers.

Eight counties in the study area pull water from recent alluvium deposits for drinking water. These include Andrew, Atchison, Caldwell, Daviess, Harrison, Holt, Nodaway, and Worth Counties.

Missouri River Alluvium

The Missouri River alluvium is a very important and widely used water source in Missouri. The Missouri River has carved a valley that contains up to about 150 feet of highly-permeable alluvial sediments that is up to 11 miles wide in some areas of northwest Missouri. The average thickness of the Missouri River alluvium in the northwestern portion of the state is approximately 90 feet. It generally consists of several feet of clay and silt near the surface, underlain by sand and gravel.

Wells drilled into the Missouri River alluvium account for approximately 18 percent of the total groundwater wells in the study area. Wells completed in the Missouri River alluvium have the potential to yield 2,000 gpm (Miller and Vandike, 1997). However, as the Missouri River alluvium underlies only the very western part of the study region, it is not feasible for rural communities that aren't located directly on the alluvium to develop a well field and then transport the raw water. Long-distance water conveyance becomes more affordable for larger service populations (Vandike, 2010).

5.2.2.2 Hydrologic Potential of Geologic Formations in the Northwest Region of Missouri

Groundwater sources in northwest Missouri are derived from water stored in the thick Pleistocene-age glacial sediments and recent alluvial deposits. These geologic formations are shown in Figure 5-1. The locations of existing drinking water sources-both surface and ground are also shown on Figure 5-1. The thickest water-bearing formation is the preglacial valley fill deposits, shown in green on Figure 5-1. These deposits are greater than 100 feet thick and produce more water than the glacial till/drift formations. Figure 5-1 shows the glacial till formations less than 100 feet thick in yellow and the recent alluvium deposits in gray.

The hydrologic potential of the geologic formations in northwest Missouri are outlined in Table 5-1. This table presents the geologic deposits in chronological order by series; from the oldest and deepest Pennsylvanian-aged bedrock layer to the more recent glacial and alluvium deposits. The yield estimates in Table 5-1 are based on 1950s test drilling studies and no actual wells were constructed. These yield estimates were made based only on drillers experience and examination of cuttings and the yields may be over-estimated (Vandike, 2010).

In general, the Missouri River alluvium and the preglacial deposits are the largest producers of groundwater in the northwest region of Missouri. More than 60 percent of the study area's deep glacial till aquifer is located in Harrison County, while Nodaway, Gentry, DeKalb, and Atchison County each contain more than 10 percent of northwest Missouri's shallow glacial deposits. Alluvium deposits associated with the Missouri River, Nodaway River, and One Hundred and Two River in Holt, Nodaway, and Atchison Counties may also produce moderate quantities of water.

Table 5-1
Hydrological Potential of Geologic Formations
(adapted from Brookshire 1997)

System	Series	Formation	Physical Characteristics of Formation	Hydrologic Potential of Formation
Quaternary	Recent	Missouri River Alluvium and other Alluvium Deposits	Sand and gravel with interbedded silt and clay deposited by stream action	Yields 30 to 500 gpm where sufficient thickness of saturated permeable sand and gravel is present
	Pleistocene	Glacial Till or Drift (10 to 100-ft depths)	Heterogeneous mixture of clay, silt, sand, gravel, and boulder-size material	2 to 50 gpm available to well where clean, permeable sand and gravel are present
		Preglacial Valley Fill (> 100-ft depths)	Sand and gravel with interbedded silt and clay deposited by stream action	Preglacial alluvium may yield as much as 500 gpm where saturated thickness and permeabilities allow
Pennsylvanian	Virginian	Wabunsee Group	Shale, siltstone, and sandstone	Not considered to be water bearing. Very small quantities of water (1/2 to 1 gpm) may be obtained locally from the limestone sequences
		Shawnee Group	Thick limestone formations with intervening shale beds	
		Douglas Group	Dominantly clastic formations. Shale, sandstone, and thin limestone	
	Missourian	Pedee Group	A thick sequence of shale with limestone at the top	Small amounts of a water (1 to 3 gpm) local from thicker formations
		Lansing Group	Two thick limestone sequences separated by shale and sandstone	
		Kansas City Group	Thick limestone formations with intervening shale, some sandstone beds, black, fissle shale in lower part	Not generally water bearing
		Pleasanton Group	Thick shale sequence with sandstone in lower part. Few thin limestone beds and siltstones. Scattered coal beds	
	Desmoinesian	Marmaton Group	Shale, limestone, clay, and coal beds	
		Cherokee Group	Sandstone, siltstone, and shale	Small yields (1 to 3 gpm) of potable water at depths less than 100-ft in outcrop area

[1]Yields based only on drillers experience and examination of cuttings, no actual wells were constructed

5.3 Regional Water Reliability

5.3.1 Drought Susceptibility

Missouri is hydrologically diverse with average annual rainfall (34 to >46 inches), runoff (5 to 20 inches), and lake evaporation (36 to 44 inches) varying across the state. The 12-county study area has the lowest average annual rainfall (34 to 36 inches) and, therefore, the lowest amount of runoff (5 to 7 inches) in the state. The average annual lake evaporation rate in the study area ranges from 38 to 42 inches.

The Missouri Drought Response Plan (Miller and Hays, 1995) divided the state into three regions prioritized according to drought susceptibility, and defined as follows.

- **Region A**. Low drought susceptibility. Surface and groundwater resources are generally adequate for domestic, municipal, and agricultural needs.

- **Region B.** Moderate drought susceptibility. Groundwater resources are adequate to meet domestic and municipal water needs. However, due to required well depths, irrigation wells are very expensive.

- **Region C.** Severe drought vulnerability. Surface water sources usually become inadequate during extended drought. Groundwater resources are normally poor, and typically supply enough water only for domestic needs. Irrigation is generally not feasible. When irrigation is practical, groundwater withdrawal may affect other users.

A majority of the 12-county study area is located in Region C as shown in Figure 5-2. Only areas along the Missouri River are not considered highly drought susceptible. Most streams in this region do not receive appreciable groundwater recharge and during periods of drought these streams are generally reduced in flow.

During the drought of 1988-89, water supplies for several municipalities were severely taxed, some to exhaustion. Other water users were forced to face severe economic losses (Miller and Hays, 1995). An August 26, 2003 Associate Press article by Amy Shafer in the Columbia Missourian contained the following accounts of the drought impact in northwestern Missouri:

- Gov. Bob Holden on Monday asked the federal government to declare 39 western Missouri, drought-stricken counties disaster areas.

- Holden asked for the following counties to be declared disasters: Andrew, Atchison, Barton, Bates, Benton, Buchanan, Caldwell, Carroll, Cass, Cedar, Chariton, Clay, Clinton, Cooper, Daviess, DeKalb, Gentry, Grundy, Harrison, Henry, Hickory, Holt, Jackson, Johnson, Lafayette, Linn, Livingston, Mercer, Morgan, Nodaway, Pettis, Platte, Putnam, Ray, St. Clair, Saline, Sullivan, Vernon, and Worth.

- Because of the drought, many communities in northwest Missouri have called for voluntary or mandatory restrictions on water use.

Figure 5-2

Drought Susceptibility

Northwest Missouri Regional Water Supply Transmission System Study
Phase III-2010

- Daviess County Public Water Supply District No. 1 placed some of its users under water use restrictions as demand increased in the last week because of high temperatures. The district asked residents south of Pattonsburg, including those in Weatherby, Winston, and Altamont, to stop filling swimming pools and stop watering lawns and gardens.

- McIntosh, of the Department of Natural Resources, said the Grand River, near Gallatin, has dropped to a level expected only once every 50 years. If such hot, dry conditions continue for another week, McIntosh said, the river is expected to drop to a level seen only once every 100 years.

5.3.2 Surface Water Source Reliability

Active surface water sources are located in Caldwell, Clinton, Daviess, DeKalb, Gentry, Harrison, and Nodaway Counties. Since the 2007 Phase I Report, three surface water facilities have been deactivated in Andrew, Daviess, and Harrison Counties. Each of these surface water sources can become jeopardized by reduced source water capacity during drought (Hills, 2009). This was confirmed by the Reservoir Operation Study Computer Program (RESOP) studies conducted by MDNR to determine the ability of the surface water sources to meet current demands under drought conditions. Analyses were conducted using rainfall data from the drought of record from 1951-1959 (Edwards et al. 2005).This and other reliability issues provided by input from GNWWWC members and Hills (2009) are summarized in Table 5-2.

5.3.3 Groundwater Source Reliability

The reliability of groundwater as a drinking water source is dependent on the aquifer type, aquifer thickness, and recharge capability. Continued availability is also contingent upon the quality of the well screen and wall materials used in well construction, subsequent well treatment, and sustainable pump rates.

Thick alluvium and glacial deposits are generally the most reliable source of groundwater. The most prominent source in the study area is contained in the Missouri River alluvium along the northwest border of the study area. Strips of preglacial drift run throughout Andrew, Buchanan, Daviess, DeKalb, Harrison, Gentry, and Worth Counties. Glacial deposits that range from 10 to 100 feet in depth are located in a majority of counties in the study area. Wells constructed in shallow glacial drift are generally less reliable and may experience seasonal variation in water level. Water-bearing zones in these areas that seem adequate for well development may be surrounded by impermeable material and thus have a very low recharge capability (Miller and Vandike, 1997).

Several municipal groundwater systems have reported recent well closures due to low yields and reduced capacity. These facilities are located in Andrew, Caldwell, Daviess, Holt, Nodaway, and Worth counties as shown in Table 5-3 (Hills, 2007). Since the Phase I Report, three groundwater facilities have closed and six are considering the purchase of water from other sources. This is indicative that groundwater source capacity cannot sustain the pumping rates required to meet customer demands.

Table 5-2
Municipal Surface Water Supply Reliability Issues

County	Location-Lake Name	# Lakes	Activity	Reliability Issues
Andrew	City of Savannah-Savannah Reservoir	1	Inactive	Not an active source, the City now only uses groundwater well source
Buchanan	City of Dearborn-Dearborn Reservoir	1	Emergency Supply Only	At risk of not meeting current demands during drought of record without additional sources
Caldwell	City of Breckenridge-Breckenridge Lake	1	Active	Lake fed by glacial deposit well, limited capacity, capable of meeting current demands during drought of record, may purchase water from Livingston County
	City of Hamilton-Hamilton Reservoir	1	Active	Reduced raw water capacity with drought, at risk of not meeting current demands during drought of record without additional sources
Clinton	City of Cameron-Grindstone Reservoir & Cameron Reservoirs	3	Active	Issues with disinfection byproducts, at risk of not meeting current demands during drought of record without additional sources
	City of Plattsburg-Smithville Reservoir	1	Active	Treatment challenges
Clinton	City of Cameron- Cameron Reservoir #1	1	Inactive	Silting problems
Daviess	Daviess County PWSD #3-Lake Viking	1	Active	Capable of meeting current demands during drought of record
	City of Jamesport-Jamesport Community Lake	1	Inactive	At risk of not meeting current demands during drought of record without additional sources, now purchases water from Livingston County
DeKalb	City of Maysville-Willowbrook Lake	3	Active	Silting problems, inadequate treatment system, capable of meeting current demands during drought of record
Gentry	City of King City-King City Reservoirs	4	Active	Capable of meeting current demands during drought of record
	City of Stanberry-Middle Fork Grand River Reservoir	1	Active	Capable of meeting current demands during drought of record
Harrison	City of Bethany-Harrison County Lake C-1 and Bethany Lakes	3	Active	Limited treated water capacity, capable of meeting demands during drought of record, risk of disinfection byproducts
	City of Ridgeway-Rockhouse Lake	1	Process of deactivation	Capable of meeting current demands during drought of record, in process of purchasing water from Harrison County PWSD #2
	Harrison County PWSD #1-Eagleville Lake	1	Process of deactivation	At risk of not meeting current demands during drought of record without additional sources, silting problems, water quality issues, shallow depth, in process of purchasing water from Harrison County PWSD #2
Nodaway	City of Maryville-Mozingo Lake	1	Active	Limited treatment capacity, capable of meeting current demands during drought of record

Table 5-3
Municipal Groundwater Supply Reliability Issues

County	Location	Number of Active Wells	Recent Well Closures (#-Reason)	Reliability Issues
Andrew	City of Bolckow	4	2-no yield	Recent well closures due to loss of water availability
	City of Savannah	3	NR	First well is over 50 years old, second well 20 years old, new well near first well, only using half capacity of treatment plant
	City of Fillmore	0	2-no yield	Poor water quality and little production
	City of Rosendale	0	4-no yield	Two wells have not produced water since the flood of 1993, limited yield from other well, wells prone to surface flooding
Atchison	City of Fairfax	2	4-NR	Reaching end of life expectancy
	City of Rock Port	3	NR	NR
	City of Tarkio	4	5-reduced capacity	NR
Buchanan	City of St. Joseph Missouri - American	7	1-NR	NR
Caldwell	City of Braymer	4	1-NR	NR
	City of City of Breckenridge-Breckenridge Lake Lake	1	NR	Source is nearly exhausted
	Caldwell CO PWSD #1	2	NR	NR
	City of Kingston	3	NR	NR
	City of Polo	0	5-reduced capacity	Treatment facilities are outdated, low production from wells
Daviess	City of Gallatin	3	1-low yield	Max use exceeds production capacity by 38%, problems with solids carryover
	City of Pattonsburg	4	3-low yield	NR
DeKalb	City of Osborn	2	NR	NR

NR = Not Reported

Table 5-3 (Continued)
Municipal Groundwater Supply Reliability Issues

County	Location	Number of Active Wells	Recent Well Closures (#-Reason)	Reliability Issues
Gentry	City of Albany	6	NR	One well has high level of ammonia, location of new wells difficult
Harrison	Harrison CO PWSD #2	6	1-NR	Lowered water levels, should not construct additional wells until levels stabilize, supplemented by the City of Bethany
Holt	City of Craig	2	NR	Requires more wells, build a larger lime softening plant, or purchase water
	City of Maitland	2	2-nitrate MCLs	City must notify customers of nitrate level, may supply water to the City of Graham
	City of Mound City	2	3-low yield	NR
	City of Oregon	2	1-collapsed wall screen	NR
Nodaway	City of Barnard	2	NR	Treatment plant does not meet design standards, may purchase water from Nodaway County PWSD #1
	City of Burlington Junction	3	NR	One well not properly sealed-susceptible to contamination, only one well adequate for production, currently building new treatment plant and will supply water to Nodaway County PWSD #1
	City of Clearmont	2	1-NR	Pending connection to Nodaway County PWSD #1, will abandon wells due to low yields
	City of Conception Junction	3	NR	May purchase water from Nodaway County PWSD #1
	City of Graham	1	NR	Will purchase water from Nodaway County PWSD #1 and City of Maitland
	City of Hopkins	3	Several-low yield, screen failure	Requires more wells to meet demands
	City of Ravenwood	2	1-NR	NR
	City of Skidmore	3	3-low yield, screen failure	Water level fluctuates with river, cannot be pumped below screen, may purchase water from Nodaway County PWSD #1
Worth	City of Sheridan	2	3-no yield	Does not meet daily demand, may purchase water from Nodaway County PWSD #1

NR = Not Reported

5.4 Regional Water Quality

5.4.1 Surface Water Sources Quality

Since surface water is essential to the population's water needs, water quality monitoring to ensure an adherence to drinking water standards is important (Brookshire, 1997). Generally, surface water in Missouri is of good quality, and the constituents are within the regulated limits (Vandike, 1995). Several operating facilities experience poor water quality during drought when water supplies are limited. Quality problems in raw water can also arise from underlying geologic formations and surrounding land use. Soil type also plays a role in water quality. Soils with large portions of clay or silt are impenetrable for water and prone to erosion. With these soil conditions, flooding is more probable and turbidity is higher in rivers and streams (Brookshire, 1997). Since a large portion of the study area possesses these soil conditions and the region is susceptible to meteorological extremes such as droughts and floods, raw water quality issues can arise.

Water quality issues identified in the Public Water Supply (PWS) Violations Database (MDNR, 2009) are presented by county in Table 5-4. Table 5-4 also outlines treatment processes used at each facility. The level and complexity of treatment is indicative of the quality of raw water, water that is of good quality does not require as much treatment. A majority of surface water treatment systems in northwest Missouri require several steps of treatment to provide clean drinking water.

MDNR water system inspection reports issued from 2005 through 2009 for facilities in the 12-county region were reviewed. Issues noted on the quality of treatment in the inspection reports included:

- Contact time was not met with some of the chemicals.
- Chlorination process was not long enough.
- Unknown chemical doses.
- Additional filter capacity needed.
- High percent water loss.
- Maintenance logs incomplete.
- Time of chlorination not calculated.
- Need to perform regular disinfectant residual monitoring.
- Maximum contaminant level exceeded for a few constituents.
- Maximum contaminate level for disinfection byproducts exceeded.
- Samples should be taken on a regular basis and conducted to represent the water quality of a body of water.

Table 5-4
Municipal Surface Water Supply Quality Issues

	Water Quality Issues[1]										Treatment Processes[2]										
	Carbon	Chlorine Dioxide	Chlorite	Coliform	Free residual chlorine	Nitrate-Nitrite	Total Haloacetic Acids	Total Trihalomethanes	Turbidity	Activated Carbon	Chlorination	Chlorine Dioxide	Coagulation	Filtration	Flocculation	Fluoridation	Hypochlorination	Permanganate	pH Adjustment	Sedimentation	Sludge Treatment
Caldwell County	X	X	X	X			X	X	X	X	X	X	X	X	X	X			X	X	
Clinton County				X		X	X	X		X	X	X	X	X	X	X		X	X	X	
Daviess County							X	X		X	X		X	X			X			X	X
DeKalb County	X		X	X	X		X	X			X	X		X	X			X	X	X	
Gentry County		X	X	X	X		X	X			X	X	X	X	X				X	X	X
Harrison County	X					X	X				X	X	X	X	X	X			X	X	
Nodaway County	X			X		X		X		X		X		X	X		X		X	X	X

[1]PWS Violation Database 1999-2009

[2]2008 Census of Missouri Public Water Systems

5.4.2 Groundwater Sources Quality

Groundwater quality is largely dependent on the aquifer type it is derived from. A brief description of the general quality concerns for each geologic formation is presented below:

- **Pennsylvanian- Age Bedrock Aquifer**. The quality of water obtained from these formations is usually marginal at best. Deeper units generally contain progressively more mineralized groundwater. The shallow bedrock zones generally have total dissolved solids that range from 800 milligrams per liter (mg/L) to about 2,000 mg/L. The water can also contain excessive sulfate, chloride, iron and manganese (Miller and Vandike, 1997).

- **Pleistocene (Glacial Till and Preglacial Valley Fill) Aquifer.** The water quality of the shallow glacial deposits is better than the underlying bedrock deposits (Miller and Vandike, 1997), but is not of good chemical quality (Vandike, 2010).Total dissolved solids range between 400 and 1,500 mg/L. Groundwater in the deep, buried preglacial channels generally tends to be of poorer quality than the shallow glacial sediments due to the poor recharge potential and local leakage of water from adjacent bedrock formations. Due to the chemical content, well screens typically become encrusted after a few years of use and reduce production. Many small facilities cannot afford the remedial treatments, such as acidification, to maintain pumping capacity (Vandike, 2010).

- **Recent Alluvium**. The chemistry of the groundwater in the alluvial deposits along the major rivers and tributaries of northwest Missouri is similar to the chemistry of water from the alluvium of the Missouri river. However, iron and manganese levels tend to be even higher in the alluvium of the Missouri River tributaries, ranging between 0.4 mg/L to 18.0 mg/L for iron, and 0.3 mg/L to 1.8 mg/L for manganese. Total dissolved solids range from a low of 230 mg/L to a high of approximately 850 mg/L (Miller and Vandike, 1997).

- **Missouri River Alluvium.** Groundwater quality in the alluvium of the Missouri River is typical of alluvial aquifers. At greater distances from the river, it is a moderately mineralized calcium bicarbonate type. Iron concentrations average as high as 6.0 mg/L and manganese averages about 3.0 mg/L. Closer to the river the total iron and manganese content will be much lower (Miller and Vandike, 1997).

Groundwater contamination potential is high in large diameter, shallow wells in alluvial or glacial drift due to the proximity to the surface. Pesticides were detected in several domestic wells throughout Nodaway, Gentry, Daviess, Clinton, and Caldwell counties during the 1997 assessment of groundwater resources. Shallow, large diameter wells also showed traces of nitrate and nitrate contamination during the 1997 assessment (Brookshire, 1997).

As shown in Table 5-5, a majority of municipal well facilities have water quality issues. Several facilities reported elevated levels of sulfates and chlorides and the presence of hard water. Other contamination was noted on an individual basis, including the fuel oxygenate methyl tertiary butyl ether (MTBE), ammonia, and nitrate (Hills, 2007). A majority of wells in northwest Missouri require periodic acidification to maintain pumping capacity. Table 5-5 also outlines treatment processes used at each facility. The level and complexity of treatment is indicative of the quality of raw water. Water that is of good quality does not require as much treatment.

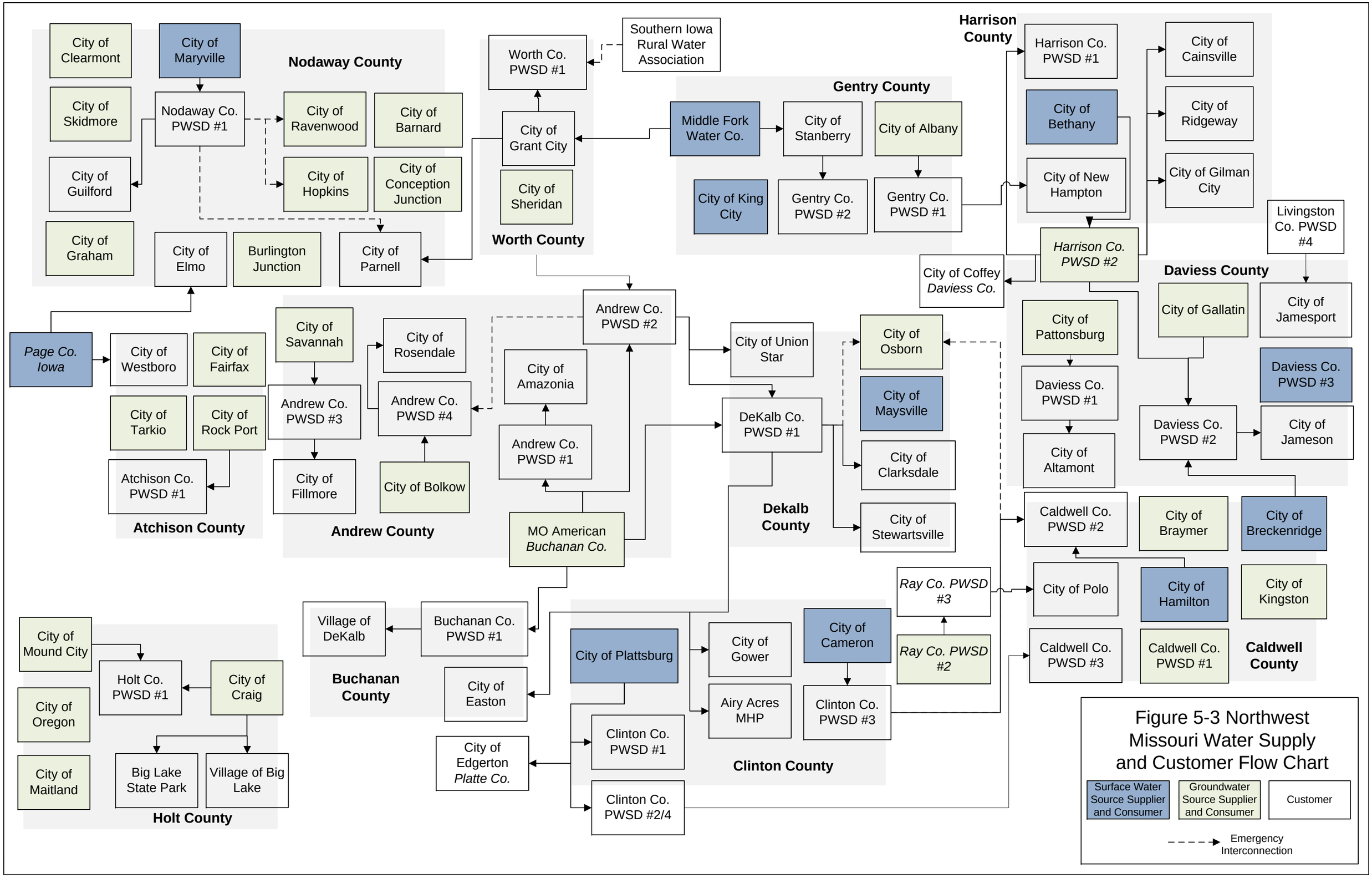
Table 5-5
Municipal Groundwater Supply Quality Issues

	Water Quality Issues																Treatment Processes[3]									
	Ammonia[1]	Carbon[2]	Chlorides[1]	Chlorite[2]	Coliform[2]	Hard Water[1]	Iron[1]	Manganese[1]	MTBE Contamination[1]	Nitrates[1]	Residual Chlorine[2]	Sulfates[2]	Total Haloacertic Acid[2]	Total Triahalomethanes[2]	Turbidity[2]	Routine Acidification	Aeration	Coagulation	Filtration	Flocculation	Fluoridation	Disinfection	Polyphosphate Inhibitor	Lime-soda Ash	Permanganate	pH Adjustment	Rapid Mix Sedimentation
Andrew County		X			X	X	X	X					X			X		X	X			X			X	X	X
Atchison County			X		X	X	X					X						X	X			X		X		X	X
Buchanan County						X	X											X	X	X	X	X		X			X
Caldwell County		X	X	X	X								X	X	X		X	X	X	X		X			X	X	X
Daviess County					X	X	X									X	X		X		X	X		X			X
DeKalb County					X					X									X			X			X		
Gentry County	X				X	X	X											X	X	X		X					X
Harrison County					X									X			X		X			X	X				X
Holt County	X				X	X	X			X				X			X	X	X	X	X	X		X		X	X
Nodaway County					X		X	X	X	X	X					X	X	X	X			X		X	X	X	X
Worth County	X				X						X						X	X	X			X			X	X	

[1]Hills, 2007

[2]PWS Violation Database 1999-2009

[3]2008 Census of Missouri Public Water Systems


City of Clearmont
City of Maryville
Nodaway County
City of Skidmore
Nodaway Co. PWSD #1
City of Ravenwood
City of Barnard
City of Guilford
City of Hopkins
City of Conception Junction
City of Graham
City of Elmo
Burlington Junction
City of Parnell
Worth Co. PWSD #1
Southern Iowa Rural Water Association
City of Grant City
City of Sheridan
Worth County
Gentry County
Middle Fork Water Co.
City of Stanberry
City of Albany
City of King City
Gentry Co. PWSD #2
Gentry Co. PWSD #1
Harrison County
Harrison Co. PWSD #1
City of Cainsville
City of Bethany
City of Ridgeway
City of New Hampton
City of Gilman City
Harrison Co. PWSD #2
Livingston Co. PWSD #4
City of Coffey Daviess Co.
Daviess County
City of Gallatin
City of Jamesport
City of Pattonsburg
Daviess Co. PWSD #3
Daviess Co. PWSD #1
Daviess Co. PWSD #2
City of Jameson
City of Altamont
Page Co. Iowa
City of Westboro
City of Fairfax
City of Savannah
City of Rosendale
Andrew Co. PWSD #2
City of Union Star
City of Osborn
City of Maysville
City of Tarkio
City of Rock Port
Andrew Co. PWSD #3
Andrew Co. PWSD #4
City of Amazonia
DeKalb Co. PWSD #1
City of Clarksdale
City of Stewartsville
Andrew Co. PWSD #1
Atchison Co. PWSD #1
City of Fillmore
City of Bolkow
Atchison County
Andrew County
MO American Buchanan Co.
Dekalb County
Caldwell Co. PWSD #2
City of Braymer
City of Breckenridge
Ray Co. PWSD #3
City of Polo
City of Hamilton
City of Kingston
Ray Co. PWSD #2
Caldwell Co. PWSD #3
Caldwell Co. PWSD #1
Caldwell County
Village of DeKalb
Buchanan Co. PWSD #1
Buchanan County
City of Mound City
Holt Co. PWSD #1
City of Craig
City of Oregon
City of Maitland
Big Lake State Park
Village of Big Lake
Holt County
City of Plattsburg
City of Gower
City of Cameron
City of Easton
Airy Acres MHP
Clinton Co. PWSD #3
City of Edgerton Platte Co.
Clinton Co. PWSD #1
Clinton Co. PWSD #2/4
Clinton County
Figure 5-3 Northwest Missouri Water Supply and Customer Flow Chart
Surface Water Source Supplier and Consumer
Groundwater Source Supplier and Consumer
Customer
Emergency Interconnection

5.5 Drinking Water Sources by County

The following subsections provide a summary on the availability, reliability, and quality of groundwater sources by county. Site-specific information was obtained from evaluation reports (Hills, 2007; Hills, 2009) and confirmed by information from the most recent system inspection reports conducted by MDNR. Please refer to Figure 5-1 for the locations of existing surface water and groundwater drinking water sources in relation to glacial deposits, alluvium deposits, and major rivers. As discussed in Section 5.2, 5.3, and 5.4, alluvium and glacial deposits are important players in the availability, reliability, and quality of water sources.

Figure 5-3 is a schematic that shows connections between drinking water suppliers and their customers. In the figure, surface water sources are shown as blue squares and groundwater sources are shown as green squares. The dotted line represents an emergency interconnection. These connections can be used as an emergency supply or a future permanent supply. Note that several sources do not have connections to other entities. This means the source only serves the city in which it is located. The schematic was created with information from the Phase I report and system evaluations conducted for both groundwater and surface water systems by William Hills (MDNR, 2007; Hills, 2007; Hills, 2009).

Table 5-6 outlines current drinking water treatment and source facilities in the northwest region of Missouri. The table includes information on the source type (groundwater or surface water) and geologic formation. Recall that the most reliable sources of groundwater are derived from the Missouri River alluvium, other alluvium deposits, and thick glacial deposited in preglacial valleys and channels.

In Table 5-6, the firm capacity presented for surface water sources summarizes RESOP studies conducted by MDNR as part of a supply study for the state of Missouri. The study analyzed the ability of the surface water sources to meet current demands under drought conditions. Analyses were conducted using rainfall data from the drought of record from 1951-1959 (Edwards et al. 2005). Treatment capacity and average daily use data in Table 5-6 were compiled in the Phase I report (MDNR, 2007). Values indicated with an asterisk were confirmed by consensus with MDNR staff, Water Partnership staff and presented in the Phase II report (CDM/Bartlett and West, 2009).

Table 5-6
Water Availability and Status of Active Drinking Water Sources in Northwest Missouri

Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg. Daily Use[2] (MGD)
Andrew County					
City of Bolckow	Bolckow MO1010084	Groundwater-Alluvium	NR	0.144	0.05
City of Savannah	Savannah MO1010724	Groundwater-Missouri River Alluvium	NR	1.5	0.55
Atchison County					
City of Fairfax	Fairfax MO1010265	Groundwater-Alluvium	NR	0.288	0.093[3]
City of Rock Port	Rock Port MO1010696	Groundwater-Missouri River Alluvium	NR	0.75	0.280[3]
City of Tarkio	Tarkio MO1010786	Groundwater-Alluvium	NR	0.75	0.161[3]
Buchanan County					
Missouri-American Water Company	MO AM Water MO1010714	Groundwater-Missouri River Alluvium	NR	30.0	15.0
Caldwell County					
City of Braymer	Braymer MO1010098	Groundwater-Alluvium	NR	0.201	0.08
City of Breckenridge-Breckenridge Lake	Breckenridge MO1010099	Surface Water Groundwater-Glacial Deposits	0.052	0.151	0.048
Caldwell County PWSD #1	Caldwell County PWSD #1 MO1024078	Groundwater-Alluvium	NR	0.068	0.03[3]
City of Hamilton-Hamilton Lake	Hamilton MO1010342	Surface Water	0.19	0.648	0.185[3]
City of Kingston	Kingston MO1010426	Groundwater-Alluvium	NR	0.072	0.033[3]
Clinton County					
City of Cameron-Grindstone Reservoir & Cameron Reservoirs	Cameron MO1010131	Surface Water	1.4	2.88	1.592[3]
City of Plattsburg-Smithville Lake	Plattsburg MO1010648	Surface Water	NR	1.453	0.923[3]

[1] MDNR RESOP Studies (MDNR, 2010)

[2] Phase 1 Report (MDNR, 2007)

[3] Confirmed by Phase II Report (CDM/Bartlett and West, 2009)
NR = Not Reported

Table 5-6 (Continued)
Water Availability and Status of Active Drinking Water Sources in Northwest Missouri

Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg. Daily Use[2] (MGD)
Daviess County					
City of Gallatin	Gallatin MO1010299	Groundwater-Glacial Deposits	NR	0.400	0.377[3]
Daviess County PWSD #3-Lake Viking	Daviess County PWSD #3 MO1036130	Surface Water	2.46	0.2	0.058[3]
City of Pattonsburg	Pattonsburg MO1010632	Groundwater-Alluvium and Glacial Deposits	NR	0.432	0.250[3]
DeKalb County					
City of Maysville-Willowbrook Lake	Maysville MO1010510	Surface Water	0.45	0.576	0.115[3]
City of Osborn	Osborn MO1010609	Groundwater-Glacial Deposits	NR	0.086	0.030
Gentry County					
City of Albany	Albany MO101006	Groundwater-Alluvium and Glacial Deposits	NR	1.0	0.430[3]
City of King City-King City Reservoir	King City MO1010425	Surface Water	0.133	0.3	0.100[3]
City of Stanberry-Middle Fork Grand River Reservoir	Middle Fork Water County MO1070639	Surface Water	0.381	1.0	0.335
Harrison County					
City of Bethany-Harrison County Lake and Bethany Lakes	Bethany MO1010068	Surface Water	0.816	1.0	0.325[3]
Harrison County PWSD #2	Harrison County PWSD #2 MO1024242	Groundwater-Alluvium, Glacial, and Pennsylvanian Deposits	NR	0.40	0.45[3]
Holt County					
City of Craig	Craig MO1010191	Groundwater-Missouri River Alluvium	NR	0.2	0.074[3]
City of Maitland	Maitland MO1010489	Groundwater-Alluvium	NR	0.1	0.025
City of Mound City	Mound City MO1010548	Groundwater-Missouri River Alluvium	NR	0.72	0.170[3]
City of Oregon	Oregon MO1010605	Groundwater-Alluvium	NR	0.432	0.175[3]

[1] MDNR RESOP Studies (MDNR, 2010)
[2] Phase 1 Report (MDNR, 2007)
[3] Confirmed by Phase II Report (CDM/Bartlett and West, 2009)
NR = Not Reported

Table 5-6 (Continued)
Water Availability and Status of Active Drinking Water Sources in Northwest Missouri

Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg. Daily Use[2] (MGD)
Nodaway County					
City of Barnard	Barnard MO1010046	Groundwater-Alluvium	NR	0.05	0.022
City of Burlington Junction	Burlington Junction MO1010117	Groundwater-Alluvium	NR	0.13	0.045
City of Clearmont	Clearmont MO1010173	Groundwater-Alluvium	NR	0.05	0.017
City of Conception Junction	Conception Junction MO1010182	Groundwater-Alluvium	NR	0.05	0.015
City of Graham	Graham MO1010319	Groundwater-Alluvium	NR	0.064	0.018
City of Hopkins	Hopkins MO1010378	Groundwater-Alluvium	NR	0.144	0.041
City of Maryville-Mozingo Lake	Maryville MO1010508	Surface Water	2.9	5.0	2.8
City of Ravenwood	Ravenwood MO1010673	Groundwater-Alluvium	NR	0.1	0.035
City of Skidmore	Skidmore MO1010744	Groundwater-Alluvium	NR	0.173	0.02
Worth County					
City of Sheridan	Sheridan MO1010739	Groundwater-Alluvium	NR	0.043	0.024[3]

[1]MDNR RESOP Studies (MDNR, 2010)

[2]Phase I Report (MDNR, 2007)

*Cofirmed by Phase II Report (CDM/Bartlett & West, 2009)

[1] MDNR RESOP Studies (MDNR, 2010)
[2] Phase 1 Report (MDNR, 2007)
[3] Confirmed by Phase II Report (CDM/Bartlett and West, 2009)
NR = Not Reported

5.5.1 Andrew County

Water Potential based on Geologic Formations

Andrew County is adjacent to five other Missouri counties and shares a small part of its border with Kansas. Andrew County contains limited glacial deposits in the far north and south part of the county. The southwest corner of Andrew County contains Missouri River alluvium. Approximately 8,000 acres (3 percent of county land area) was designated capable of supporting high yield wells based on these geologic formations during the 1957 survey of water possibilities (Fuller et al. 1957d). Samples taken from water wells during the 1957 study yielded water high in sulfates, chloride, and total dissolved solids (TDS). Test wells drilled into glacial deposits produced water that was high in iron. Some samples also contained excessive nitrates, presumably from agricultural contamination.

Current Surface Water Suppliers

Andrew County does not have any surface water sources that provide drinking water for the area (MDNR, 2007). This county previously operated a surface water source in the City of Savannah and had access to the Smithville Reservoir (Gehrt, 2010).

Current Groundwater Suppliers

Two cities have operational groundwater treatment facilities in Andrew County: the City of Savannah and the City of Bolckow. Facilities in both cities produce water that is hard and high in iron and manganese concentrations. Wells are periodically acidified to maintain pumping capacity. The treatment facility currently in use in the City of Savannah was built in 2009 and is currently operating at half capacity (Hills, 2010). The City operates three wells, the first of which was built over 50 years ago and is still a viable source of water. All three wells are located in Missouri River alluvium.

The City of Rosendale and the City of Fillmore closed their groundwater treatment facilities due to low water yields from the wells. The City of Rosendale groundwater treatment facility had utilized four groundwater wells drilled into alluvium deposits, until the low yield of the wells forced their closure. In addition to producing low yields, these wells were prone to inundation from surface flooding. The City of Rosendale now purchases water from the Andrew County PWSD #4 (Hills, 2010). The City of Fillmore also closed its facilities due to low production from its two alluvium wells. The City of Fillmore now obtains water from Andrew County PWSD #3 (Hills, 2010)

5.5.2 Atchison County

Water Potential based on Geologic Formations

Atchison County is located in the northwestern corner of the state. The county contains ample alluvial deposits within the Missouri River and Tarkio River floodplain. Approximately one-third of the county contains quaternary alluvium with the potential for high groundwater yields. Estimates of groundwater well production in the Missouri River alluvium exceed 1,200 gpm, while estimates in the Tarkio River alluvium range from 50 to 75 gpm (Heim et al. 1960b). The remaining part of the county consists of shallow glacial and alluvium aquifers.

Reported water quality results from a 1960 study on the groundwater resources of Atchison County by the Missouri Geological Survey and Water Resources indicated that groundwater from this area contained high levels of iron, but was generally of good quality (Heim et al. 1960b).

Current Surface Water Suppliers

Atchison does not have any surface water sources that provide drinking water (MDNR, 2007).

Current Groundwater Suppliers

There are three groundwater sources in Atchison County, including wells in the City of Fairfax, the City of Rock Port, and the City of Tarkio. Water from this county is generally hard and high in manganese. Tarkio has reported water high in sulfates and chlorides and has recently closed five wells due to reduced capacity. The City of Fairfax and the City of Tarkio are located near thick alluvium deposits and have the capacity to be expanded for local use (Hills, 2007).

In April 2007, Atchison County PWSD #1 voted to expand their boundaries to service the entire county (MDNR, 2007), which helped future overall regional water planning. In addition, the Atchison Wholesale Water Commission began the design for a water treatment plant in the summer of 2009, with construction expected by 2012. The Atchison County PWSD #1 is served by groundwater wells in the City of Rock Port.

5.5.3 Buchanan County

Water Potential based on Geologic Formations

Buchanan County is adjacent to three Missouri counties and the State of Kansas. The northern part of the county contains a large store of shallow glacial deposits and a thin strip of deep glacial deposits. The area most favorable for large-yield well development lies in the quaternary alluvium along the Missouri River on the western border of the country. Based on these formations, the 1957 study indicated that Buchanan County contains 40,000 acres with the potential for large-yield well development (Fuller et al. 1957c).

Samples taken from water wells during the 1957 study yielded water high in chloride and TDS. Test wells drilled into glacial deposits produced water of low mineral content, but high TDS (Fuller et al. 1957c).

Current Surface Water Suppliers

Buchanan County does not contain an active surface water treatment facility (MDNR, 2007). Dearborn Reservoir, located near the City of Dearborn, was formerly the primary source of water for the City. The Reservoir was supplemented by water from Bee Creek. The City of Dearborn began purchasing water from the City of Kansas City in 2001. RESOP analysis found that the Reservoir could not independently meet current demands during the drought of record. However, with additional supply from Bee Creek, current demands could be met (MDNR, 2010).

Current Groundwater Suppliers

The Missouri-American groundwater treatment facility is located in the City of St. Joseph in Buchanan County (Hills, 2007). The facility is served by nine gravel-walled wells and one collector well, all located in Andrew County, that produce water that is hard and high in iron. Wells at the facility are very reliable and produce water from the Missouri River alluvium.

5.5.4 Caldwell County

Water Potential based on Geologic Formations

Caldwell County contains an alluvium aquifer that runs through the center of the county from east to west. A small pocket of shallow glacial drift lies in the lower southeast corner of the county. No reports were available on the water quality or groundwater potential of the county based on geological formations.

Current Surface Water Suppliers

Two surface water sources are currently available in Caldwell County, including in the City of Hamilton, and the City of Breckenridge. A potential future water supply reservoir is planned on Otter Creek.

Hamilton Reservoir in the City of Hamilton has a firm capacity of 0.19 MGD (MDNR, 2010) and is the primary source for the City of Hamilton and Caldwell County PWSD #2. Water quality and quantity from the City-owned reservoir is severely cut during periods of extended drought (Edwards et al. 2005) and does not meet demands. According to RESOP analysis, the Reservoir cannot meet current demands during the drought of record (MDNR, 2010). The reduced water quantity during these periods makes treatment more difficult (Hills, 2009). Additional needs could be met by diverting water from Marrowbone Creek (MDNR, 2010). Supplemental supply from Marrowbone Creek could increase the firm yield from Hamilton Reservoir to 0.27 MGD (MDNR, 2010).

Breckenridge Lake in the City of Breckenridge is a shallow lake fed by water from a well drilled into glacial deposits (Hills, 2010). The facility produces water at negligible rates with a firm capacity of 0.052 MGD (MDNR, 2010), and is not considered reliable (Hills, 2009). RESOP analysis concluded that the lake is not capable of meeting current demands during the drought of record (MDNR, 2010). The City may look to the Livingston County PWSD #4 for supplemental supply.

Otter Creek is the most recently commissioned surface water source in the northwest Missouri region. Although the project has local and federal support, the project will require additional fiscal assistance. When complete, Otter Creek Reservoir will provide 1.24 MGD for drinking water purposes (McIntosh, 2010b).

Current Groundwater Suppliers

Four cities in Caldwell County have active groundwater treatment facilities. This includes alluvium wells in the City of Braymer and the City of Kingston and glacial wells in the City of Breckenridge and Caldwell County PWSD #1. All facilities use acidification for periodic maintenance and produce water that is hard and high in manganese. The City of Breckenridge uses groundwater to fill the Breckenridge Lake, as discussed previously.

The City of Polo no longer produces finished water from a groundwater supply. Although the capacity of the alluvium wells is viable, the City of Polo has experienced treatment difficulties and is currently in the process of plugging and abandoning their remaining wells. The City now purchases water from Ray County PWSD #3. The City does not provide any additional treatment (Hills, 2010).

5.5.5 Clinton County

Water Potential based on Geologic Formations

Clinton County consists primarily of sparse alluvial deposits. A store of shallow glacial deposits exists in the southwest corner of the county near Smithville Lake and also in the northern part of the county. No reports were available on the water quality or groundwater potential of the county based on geologic formations.

Current Surface Water Suppliers

Clinton County has the largest available surface water supply in the region with reservoirs in the City of Cameron and near the City of Plattsburg (MDNR, 2007).

Two reservoirs in the City of Cameron and the Grindstone reservoir serve as surface water supply to the City of Cameron. The City of Cameron Reservoir #1 has silted in and no longer provides water (Hills, 2010). Grindstone Reservoir and the City of Cameron Reservoirs #2 and #3 are reliable even during dry periods (Hills, 2009). According to RESOP analysis, the lakes are at risk of not meeting current demands during the drought of record without additional sources (MDNR, 2010). Cameron Reservoir #3 and Grindstone Reservoir provide a firm capacity of 0.4 and 1.0 MGD, respectively. The reservoirs provide 1.4 MGD to Clinton and Caldwell Counties for drinking water treatment (MDNR, 2007).

The City of Plattsburg is allocated 10 MGD from Smithville Lake (Gehrt, 2010). This source is fairly reliable, but there has historically been some problems meeting treatment standards (Hills, 2009). Smithville Lake also provides 30 MGD and 7.1 MGD of raw water to the City of Kansas City, Missouri and the City of Smithville, respectively, both outside the study area (Lemley, 2010).

Current Groundwater Suppliers

There are no municipal wells in operation or planned for in Clinton County.

5.5.6 Daviess County

Water Potential based on Geologic Formations

Underlying geologic formation in Daviess County consists of alluvium and glacial deposits. The largest alluvium aquifer is associated with the Grand River Valley, stretching from the northwest corner to the southeast corner of the county. A majority of wells that produced groundwater at the time of a 1957 study on the water potential of Daviess County were in this alluvium strip. The study estimated that 25,000 acres of the county is capable of supporting large-yield wells (Fuller et al. 1957b).

Samples taken from bedrock and glacial wells during the 1957 study consistently yielded water of poor quality. Samples were high in nitrates, chloride, iron, manganese, and TDS (Fuller et al. 1957b).

Current Surface Water Suppliers

Daviess County has two surface water sources. The privately owned Lake Viking provides a firm yield of 2.46 MGD (MDNR, 2010). Lake Viking serves the population in the immediate Lake Viking area and is reliable even during dry periods (Hills, 2009). RESOP analysis confirmed that the Lake can meet current demands during a modeled drought of record (MDNR, 2010). Lake Viking is used primarily for recreational purposes and may not be marketed for additional water supply (McIntosh, 2010a).

The small lake in the City of Jamesport called the Jamesport Community Lake is no longer in service. This lake did not meet its designated source capacity during periods of drought (Hills, 2009). RESOP analysis found that water levels in the lake would be extremely low during the drought of record (MDNR, 2010). The City of Jamesport now purchases water from Livingston County PWSD #4 (Hills, 2010).

Current Groundwater Suppliers

Five groundwater treatment facilities are located in Daviess County; although two are no longer in operation and two are operated by other counties.

Facilities in the City of Gallatin and the City of Pattonsburg serve Daviess County. Both facilities operate wells drilled into alluvium deposits and the City of Pattonsburg also uses water derived from glacial deposits. Water is generally hard and high in iron. Both facilities use acidification to treat groundwater. Four municipal wells have been closed in these facilities due to low groundwater yields. The maximum treatment capacity of the plant in the City of Gallatin is currently exceeded on a daily basis. The City is in the design phase of building a new treatment plant to meet demands (Johnson, 2010).

Harrison County PWSD #2 and Livingston County PWSD #4 are located in Daviess County, but are operated by their perspective counties. Please refer to Section 5.5.9 for details on the Harrison County facility. Livingston County is not included in this study. Facilities in the City of Coffey and the City of Jameson are no longer in operation and purchase water for treatment.

5.5.7 DeKalb County

Water Potential based on Geologic Formations

Several wells drilled for the 1957 study in DeKalb County produced water. These wells were all located in the large store of glacial deposits that lies under much of the county. A strip of deep glacial deposits stretches from the northeast to southwest corner of the county. According to the study, approximately 9,000 acres of the county are located in an area suitable for large yield wells (Fuller et al. 1957a).

Samples taken from water, oil, and glacial wells during the 1957 study consistently yielded water high in iron, sulfate, and TDS. Several samples from the water and oil wells produced elevated levels of chloride (Fuller et al. 1957a).

Current Surface Water Suppliers

The Willowbrook Lake system serves as a surface water supply for the City of Maysville. South, West, and Willowbrook Lakes have a cumulative firm capacity of 0.45 MGD (MDNR, 2010). The Lake system is owned by the City of Mayville. The storage capacity will continue to decrease over time (Hills, 2009). However, RESOP analysis has determined that Willowbrook Lake is independently capable of meeting current demands during the drought of record (MDNR, 2010).

Current Groundwater Suppliers

One city in DeKalb County has a groundwater treatment facility (Hills, 2007). The City of Osborn produces water from glacial wells that have high levels of nitrates. Two wells have been taken out of operation due to the nitrate level. Nitrates in the groundwater from operational wells have steadily increased since construction of the wells, but do not currently exceed the MCL. DeKalb County PWSD #1 and the City of Cameron (from Clinton County PWSD #3) are currently interconnected with the City of Osborn for emergency use (Williams, 2010).

5.5.8 Gentry County

Water Potential based on Geologic Formations

According to a 1956 study on the water possibilities from the glacial drift of Gentry County, approximately 20,000 acres of the county are suitable for high-yield, municipal wells (Fuller et al. 1956c). This is due in part to the alluvium formation and glacial deposits that occupy much of the county. A strip of thick glacial deposits runs through the center of the county from east to west.

Samples taken from glacial wells during the 1956 study revealed groundwater high in sulfates, iron, and TDS. Several samples also had high manganese content (Fuller et al. 1956c).

Current Surface Water Suppliers

This county has several small surface water sources. King City has four small reservoirs that provide a firm capacity of 0.133 MGD (MDNR, 2010). The South Lake was built during the drought of the 1980's and is located south of the three smaller North Lakes that make up the original water supply. The reservoirs can meet current demands during the drought of record according to RESOP analysis (MDNR, 2010).

There are no current treatment problems with this source, but it will not be able to produce beyond its current firm capacity (Hills, 2009).

The Middle Fork Water Company obtains supply from a lake located on Linn Creek, a tributary to Middle Fork Grand River near the City of Stanberry. The lake is reliable during drought and can sustain a firm capacity of 0.381 MGD (MDNR, 2010). According to RESOP analysis, the lake can meet current demands during the drought of record (MDNR, 2010). However, treatment problems have occurred in the past during times of drought due to the low availability of treatable water (Hills, 2009).

Current Groundwater Suppliers

Gentry County contains one operational municipal groundwater treatment facility in the City of Albany. Six wells drilled in both alluvium and glacial deposits produce hard water that requires routine acidification and treatment for iron. One of the six wells has elevated ammonia levels (Hills, 2007).

5.5.9 Harrison County

Water Potential based on Geologic Formations

Harrison County contains only sparse alluvium deposits and so groundwater is primarily obtained from glacial deposits or bedrock (Fuller et al. 1956a). Bedrock water is highly mineralized and requires extensive treatment. Results from a 1956 study on Harrison County indicate that approximately 17,000 acres of Harrison County are suitable for large yield wells. Operational non-municipal, large yield wells exist in the western part of Harrison County in the glacial aquifer. However at the time of the study, MDNR recommended that no additional wells be located in the aquifer until water levels are stable (Fuller et al. 1956a).

Samples taken from bedrock and glacial wells during the 1956 study consistently yielded water high in sulfate and TDS. Several samples from bedrock wells produced elevated levels of chloride, while all glacial drift samples had high iron concentrations (Fuller et al. 1956a).

Current Surface Water Suppliers

The City of Bethany and Harrison County Reservoir System includes the Harrison County Lake C-1 (West Big Fork Lake) and the City of Bethany North and South Lakes (MDNR, 2010). Harrison County Lake C-1 was planned for flood prevention and water supply through the Natural Resources Conservation Service (NRCS) small watershed program (PL-566) and began providing water to the City of Bethany and Harrison County PWSD #2 in 1999. The City of Bethany Lakes are the primary source of water for the City of Bethany. Water is transferred from both the Harrison County Lake C-1 and the City of Bethany New Reservoir to the City of Bethany Old Reservoir. The treatment plant receives water from the Old Reservoir (MDNR, 2010). This source is reliable and provides additional water to Harrison Co. PWSD #2 (Hills, 2009). According to RESOP analysis, Harrison County Lake C-1 meets current demands during the drought of record and provides a firm capacity of 0.59 MGD. With use of the recreation allocation of the Harrison County Lake, the firm capacity would

increase to 1.32 MGD. New and Old Bethany Lakes produce a firm capacity of 0.175 and 0.051, respectively (MDNR, 2010).

Eagleville Lake and Rockhouse Lake are two Harrison County sources that are in the process of deactivation. Eagleville Lake currently serves Harrison Co. PWSD #1. The lake was constructed from the East Fork Big Creek PL-566 watershed project. The lake was constructed to be very shallow (Edwards et al. 2005) and water is drawn from the sediment pool (MDNR, 2010). This source is nearly silted in and is very unreliable during drought and according to RESOP analysis, Eagleville Lake does not meet current demands during the drought of record (MDNR, 2010). Water quality and treatment problems at this facility have caused MDNR to ask Harrison County PWSD #1 to take the lake out of production (Hills, 2009). Eagleville Lake is currently supplemented by Harrison Co. PWSD #2 (Hills, 2010).

Rockhouse Lake is located near the City of Ridgeway and was built as part of the NRCS Panther Creek (PL-566) watershed project (MDNR, 2010). According to RESOP analysis, the lake is capable of meeting current demands during the drought of record (MDNR, 2010). However, the City of Ridgeway is in the process of purchasing water from Harrison County PWSD #2 (McIntosh, 2010c).

Current Groundwater Suppliers

Harrison County PWSD #2 is served by one groundwater treatment facility that is located in the adjacent Daviess County and drilled into alluvium, glacial, and bedrock deposits. The Harrison County PWSD #2 produces water high in iron and manganese. The facility requires routine acidification. Water levels have steadily decreased since construction of the wells (Hills, 2007). Water supply to Harrison County PWSD #2 is supplemented by the City of Bethany.

Two additional wells are currently under construction in the northwest part of Daviess County just north of the City of Coffey. These wells will provide an additional 750 gpm. These two wells are part of a phased effort to increase the source capacity of Harrison County PWSD#2. Two additional wells are proposed for the next phase of the project scheduled for completion by 2012. These wells should provide an additional 250 gpm and will more fully utilize water treatment plant capacity (Shafer et al. 2010).

5.5.10 Holt County

Water Potential based on Geologic Formations

Holt County contains ample alluvium deposits within the Missouri River and Nodaway River floodplain. The Missouri River floodplain alone encompasses nearly one-fourth of the area in the county and contains 133 feet maximum depth of alluvium. During the 1960 study on groundwater potential in Holt County, six existing groundwater wells in the Missouri River alluvium produced yields from 70 to 1200 gpm. One well in the Nodaway floodplain was 45 feet deep and yielded 150 gpm. Smaller rivers and streams have limited stores of alluvium and may produce small quantities of water (Heim et al. 1960a).

The glacial drift valley is not as complex in Holt County as neighboring counties and only produces moderate yields of water. Water possibilities in the southern part of the county are limited due to the thin layer of glacial materials overlying the bedrock. Well sampling conducted during the 1960 study showed that only wells drilled in bedrock produced water and that this water was of marginal quality. Seven of eight wells had TDS levels that exceeded levels suitable for human consumption (Heim et al. 1960a).

Samples taken from glacial and alluvium wells during the 1960 study consistently yielded water of relatively good quality. Samples were high in iron and TDS (Heim et al. 1960a).

Current Surface Water Suppliers

Holt County does not have any surface water sources being used for drinking water treatment (MDNR, 2007).

Current Groundwater Suppliers

Four cities in Holt County operate municipal groundwater treatment facilities including the City of Craig, the City of Maitland, the City of Mound City, and the City of Oregon. Water produced in Holt County is generally of good quality.

Wells in the Cities of Craig and Mound City are located in the Missouri River alluvium. Despite expansion of the treatment plant in the City of Craig, the City needs to drill more wells, expand the lime softening treatment plant, or purchase water from a different plant to meet capacity needs (Hills, 2007). Wells in the City of Mound City are less than 10 years old (Hills, 2010).

Wells in the Cities of Maitland and Oregon of are drilled in other alluvium deposits. Groundwater from these wells requires aeration, filtration, and chlorination (Hills, 2007). The City of Maitland produces water high in nitrates and two wells have been abandoned due to the high nitrate levels. The well field for the City of Maitland is located in the Nodaway River alluvium (Hills, 2007) and could be a future water supply to the City of Graham in Nodaway County.

5.5.11 Nodaway County

Water Potential based on Geologic Formations

Nodaway County contains three large stores of alluvium in the floodplains of the One Hundred and Two River, the Nodaway River, and the Platte River. Estimates of well production from these sources can be made based on the thickness of alluvium (Heim et al. 1959).

- **One Hundred and Two River**. Alluvium ranges in thickness from 27 to 115 feet and may yield an estimated 2 to 500 gpm.
- **Nodaway River**. Alluvium ranged from 27 to 31 feet in thickness and production estimates ranged from 0 to 20 gpm.

- **Platte River** Alluvium ranged in thickness from 25 to 45 feet and would produce an estimated 3 to 150 gpm.

Glacial deposits in Nodaway County are variable. The most favorable geologic material for groundwater supply development is located in the deeper parts of this system in the center and southern parts of the county. A major east-west valley of deep water-bearing material is located along the Nodaway-Andrew county line (Heim et al. 1959).

Samples taken from glacial and bedrock wells during the 1959 study yielded water high in sulfate and TDS. Test wells drilled into bedrock produced water with high chloride levels (Heim et al. 1959).

Current Surface Water Suppliers

Nodaway County has one surface water source located in the City of Maryville, called the Mozingo Reservoir. The reservoir was planned and constructed as a watershed lake through the NRCS small watershed program (PL-566) in cooperation with the City of Maryville. Without utilization of the recreation pool, Mozingo can provide a firm capacity of 2.9 MGD (MDNR, 2010). If the recreation pool was deauthorized and allocated to water supply, Mozingo could provide a firm capacity of 4.0 MGD (MDNR, 2010). This reservoir is under contract with the City to provide 0.3 MGD to the Nodaway County PWSD #1 (Crane, 2010) and meets demands during times of drought (MDNR, 2010). RESOP analysis confirmed that the reservoir will meet current demands during the drought of record (MDNR, 2010).

Prior to lake construction, the City of Maryville obtained water from the One Hundred and Two River. The lake is configured to obtain water from the river as supplement (MDNR, 2010). Although the source is considered reliable, treatment problems may arise from the short life expectancy of the membrane (Hills, 2009).

Current Groundwater Water Suppliers

Eight cities in Nodaway County currently operate treatment facilities for groundwater obtained from alluvium deposits. This includes facilities in the City of Barnard, the City of Burlington Junction, the City of Conception Junction, the City of Clearmont, the City of Graham, the City of Hopkins, the City of Ravenwood and the City of Skidmore.

The City of Burlington Junction is currently building a new treatment plant that will allow the City to supply water to Nodaway County PWSD #1 (Crane, 2010). The City of Graham currently operates one well, but there are several private, high-producing wells in the area. The City plans to take part in a buy/sell hookup with Nodaway County PWSD #1 and the City of Maitland in Holt County. The City of Hopkins operates wells in the One Hundred and Two alluvium. The water is high in iron and manganese. Recent updates to the facility include an aeration and filtration system. The City of Ravenwood is served by two shallow, low-production wells. Water must be treated for high iron and manganese levels (Hills, 2007).

Nodaway County PWSD #1 has an emergency interconnect with the City of Ravenwood, the City of Hopkins, and the City of Parnell (Williams, 2010) and is also considering forming a buy/sell connection with the City of Graham and Andrew County (Crane, 2010). Nodaway County PWSD #1 does not have an independent source of water.

Two groundwater facilities have been taken out of production in the City of Collins Corner and the City of Parnell (MDNR, 2010). The City of Clearmont is currently connecting to Nodaway County PWSD #1 and will abandon its source when the connection is complete (Pfost, 2010). Four other facilities are also considering closure. The City of Barnard, The City of Conception Junction, the City of Skidmore, and the City of Sheridan (Worth County) are considering the abandonment of their wells and may also purchase water from Nodaway County PWSD #1. These cities have experienced low yields and treatment issues. The treatment plant in the City of Barnard does not meet current design standards and require renovation. The City of Skidmore has wells in the Nodaway alluvium, but water levels have experienced extreme fluctuations. The groundwater frequently has high levels of iron and manganese and is chlorinated for disinfection (Hills, 2007).

5.5.12 Worth County

Water Potential based on Geologic Formations

The results of a 1956 study on the water possibilities from the glacial deposits of Worth County indicate that approximately 9,000 acres of the county are suitable for the construction of large yield wells (Fuller et al. 1956b). Alluvium deposits in Worth County are highly variable.

Wells drilled into glacial deposit sampled during the 1965 study produced water with low levels of chloride, sulfate, and TDS. Samples did however have high iron concentrations (Fuller et al. 1956b).

Current Surface Water Suppliers

Worth County does not have any surface water sources being used for drinking water (MDNR, 2009).

Current Groundwater Water Suppliers

The City of Sheridan operates a groundwater treatment facility in Worth County. The City has experienced difficulties with ammonia levels. Three wells have been abandoned due to low production and the City is considering the purchase of water from Nodaway County PWSD #1. The current source capacity is exceeded on a daily basis (Hills, 2007).

Worth County PWSD #1 obtains water from the City of Grant City. Grant City purchases water from Middle Fork Water Company. The facility could be permanently supplied by the Southern Iowa Rural Association, but is contractually obligated to Grant City (Hills, 2010).

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Section 6
Moving Forward-Issue Statements on Drinking Water Sources in Northwest Missouri

Locating a reliable supply of water is important as it ultimately impacts the growth and sustainability of a community. Communities with limited water supply may experience adverse impacts to property taxes and real estate values as community members leave to seek more reliable water sources.

The northwest region of Missouri may effectively meet challenges posed by limited economic and environmental resources by utilizing the most reliable water sources on a regional scale. When assessing if a community would benefit from purchasing water from a regional wholesale supplier the following issues should be evaluated. These issues are summarized below on a regional basis, and by county in the issue statements included in Appendix B. The issue statements are part of the outreach program designed to assist local governments in assessing the benefit of joining the GNWWWC.

- What is the availability of additional water sources?

  Historically, communities in the study area have not used rivers as drinking water sources due to the unreliability of flow. Groundwater availability is dependent upon proximity to the Missouri River and other thick alluvium and glacial deposits. Communities should look at past well drilling reports and assess the number of test holes and drilling attempts required to find a sustained-yield well. If historical records show that finding high-yield wells was difficult in the past, locating additional groundwater resources now will also be challenging. Well logs may also provide insight to the geologic stratum and availability of water-bearing material. See Section 5.2.

- Is the current source of drinking water reliable?

  Reliability is based upon the source type and location. Surface water sources in the study area generally yield limited quantities of water during dry periods. Many current surface water sources have reported silting problems which directly relate to the cost to treat water and final water quality. Groundwater sources derived from thick glacial and alluvium deposits, like those associated with the Missouri River, are generally very reliable. See Section 5.3.

- What is the quality of current water sources?

  Generally, surface water in Missouri is of good quality and constituents are within the regulated limits. However, water quality is impacted by drought when supplies are limited. Quality is also impacted by the silting rate of surface water bodies.

Groundwater quality in the study area is dependent on the aquifer type. Water from glacial deposits is of good quality in shallow deposits due to the frequent recharge. Water from alluvium deposits is generally high in mineral content and contains moderate amounts of total suspended solids. The quality of raw water is important as it impacts the economic and environmental costs of treatment, and ultimately the cost to the consumer. See Section 5.4.

- What are the costs for the supplier and customer?

  Joining the GNWWWC will impact the cost to suppliers and customers. To quantify how the water costs will change, facility managers must be sure that they are comparing the GNWWWC wholesale rate to the current water rate adjusted for depreciation. Many distributors do not account for depreciation when calculating water rates and thus do not currently recover all costs caused by that utility. Although the costs to the supplier may be higher initially, long-term savings from reduced operations will need to be considered. See Section 3.

- What is the lifespan of treatment and distribution infrastructure?

  A majority of the infrastructure associated with the treatment and distribution of drinking water is aging and will require replacement within the next few years. According to the GNWWWC, many drinking water facilities have already surpassed their useful life and should be replaced or abandoned (GNWWWC, 2009a). A community that has reached this point should assess the costs of replacing infrastructure and how that compares to long-term costs of joining the GNWWWC. Facilities that provide treatment should also consider the savings from no longer providing the infrastructure replacement and ongoing maintenance associated with water treatment.

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Appendix A

Public Drinking Water Wells
Northwestern Missouri

Public Drinking Water Wells Northwestern Missouri

1:210,000

1 in = 12 miles

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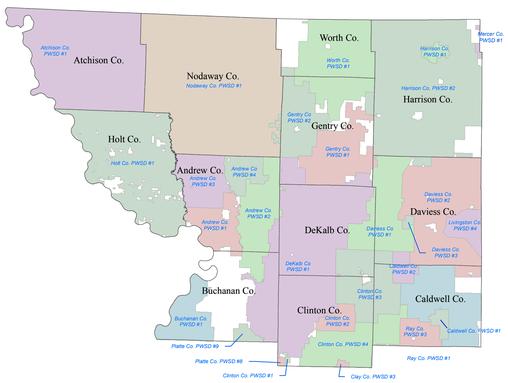
Map Projection
Universal Transverse Mercator, Zone 15



NW Water Districts

Public Drinking Water Wells
Type and Status of Well

- Community Well, Abandoned
- Community Well, Active
- Non-Community Well, Active
- Community Well, Inactive
- Non-Community Well, Inactive
- Non-Public Well, Inactive
- Community Well, Emergency
- Community Well, Proposed

Glacial Deposits
Deposit Thickness

- 10 - 100 ft
- >100 ft

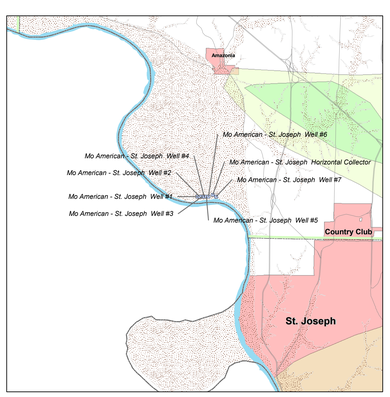
Aluvium

- Hydrology
- Urban Areas
- Major Roads

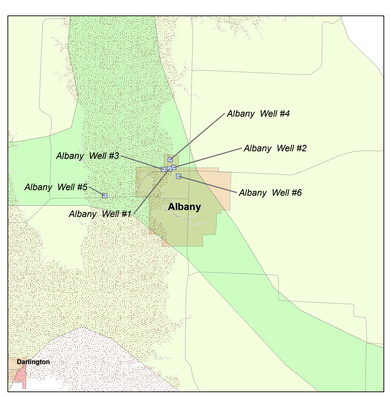
Digital compilation and cartography by David Erickson
Missouri Department of Natural Resources, Water Resources Center
October 2009

Missouri Department of Natural Resources

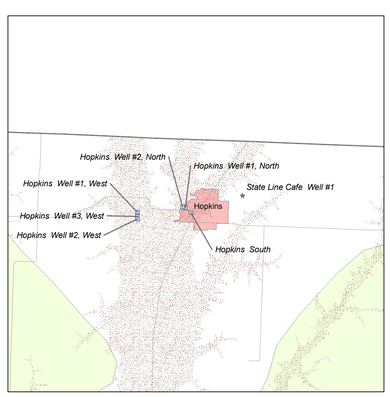
Saint Joseph Area



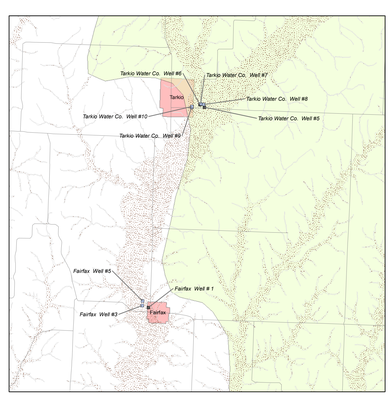
Albany Area



Hopkins Area



Tarkio Area



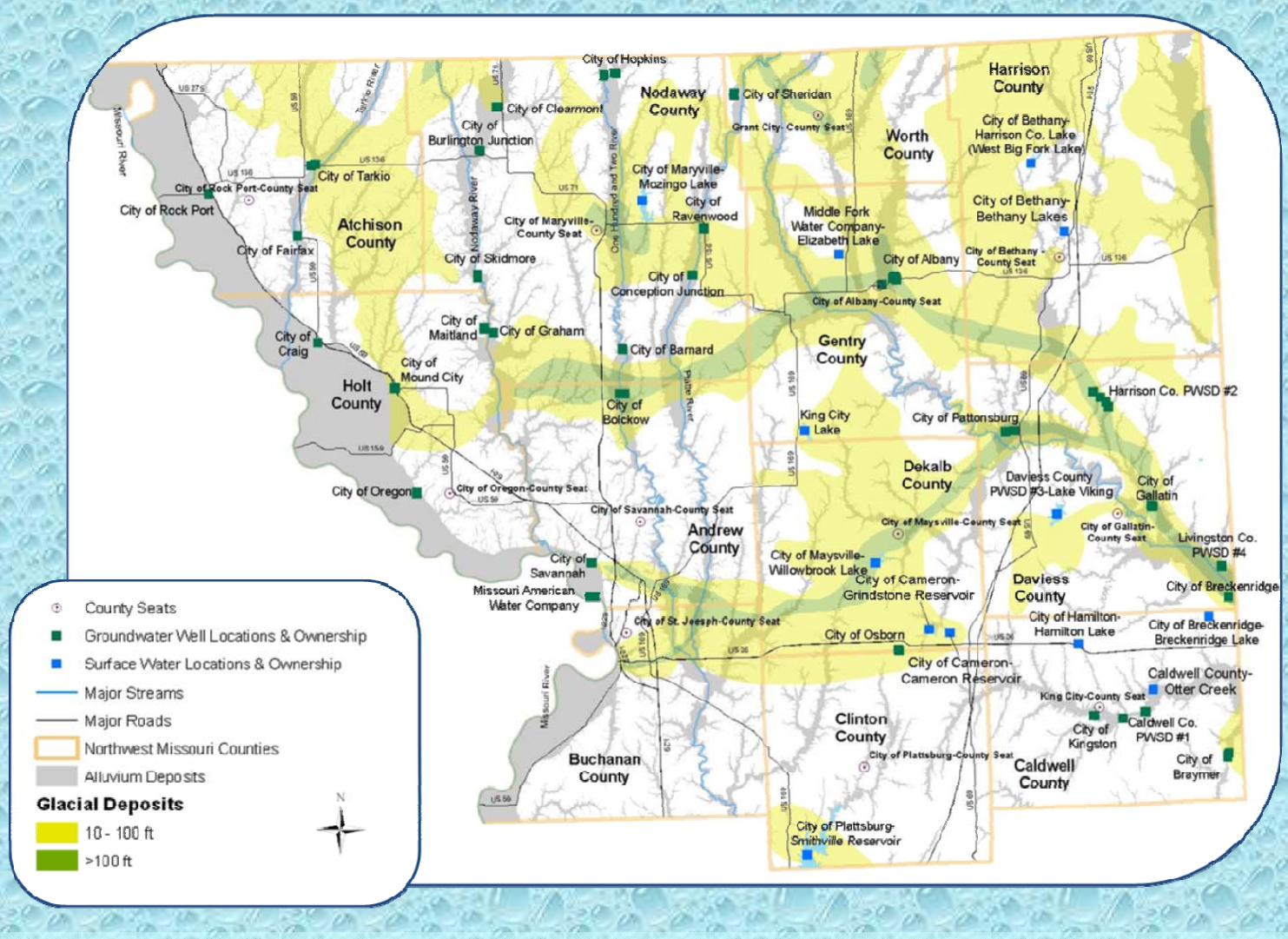
Appendix B

Issue Statements

Water Supply Study

Limitations for Drinking Water Supply in Northwest Missouri

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.



DRINKING WATER SOURCE AVAILABILITY

- The 12-county area of northwest Missouri is served by 19 active surface water sources and 81 active groundwater wells. Since 2007, four surface water sources have closed and more than 43 wells have been taken out of production.
- Historically, communities in northwest Missouri have not used rivers as drinking water sources due to the unreliability of flow.
- Groundwater availability is dependent upon proximity to the Missouri River and other thick alluvium and glacial deposits.

DRINKING WATER SOURCE RELIABILITY

- According to the Missouri Drought Response Plan, a majority of the region is vulnerable to severe drought. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs.
- Surface water sources in the northwest region of Missouri generally yield limited quantities of water during dry periods. Many current surface water sources have reported silting problems which directly relate to the cost to treat water and final water quality.
- Groundwater sources derived from thick glacial and alluvium deposits, like those associated with the Missouri River, are generally very reliable.

DRINKING WATER SOURCE QUALITY

- Generally, surface water in Missouri is of good quality and constituents are within the regulated limits. However, water quality is impacted by drought when supplies are limited. Quality is also impacted by the silting rate of surface water bodies.
- Groundwater quality is dependent on the aquifer type. Water from glacial deposits is of good quality in shallow deposits due to the frequent recharge. Water from alluvium deposits is generally high in mineral content and contains moderate amounts of total suspended solids. All groundwater wells in the region require treatment prior to distribution for drinking water.

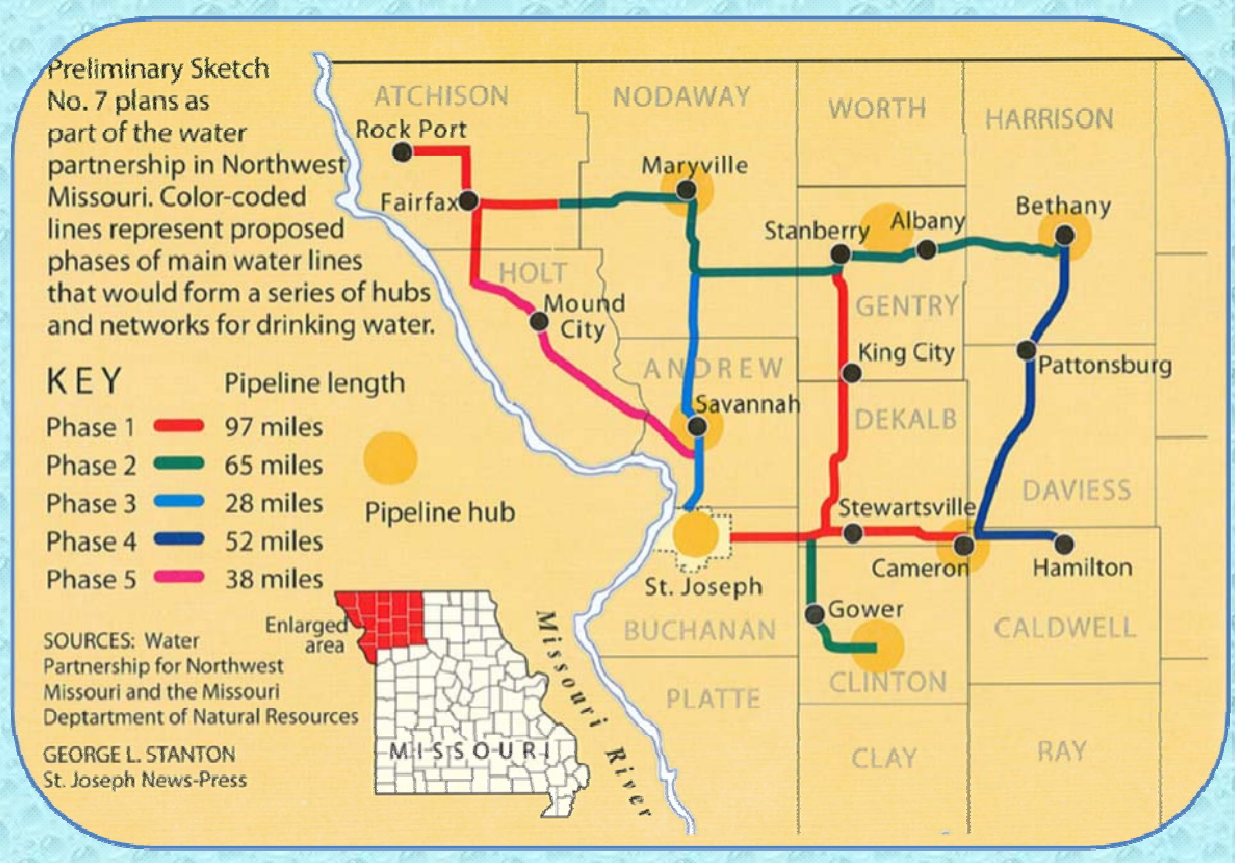
Water Supply Study

Should We Join the Great Northwest Wholesale Water Commission?

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.

FORMATION & PURPOSE OF GNWWWC

- Initiated in 2003 with the formation of the Water Partnership for Northwest Missouri that included representatives from the twelve county area.
- The Water Partnership found that challenges to drinking water supply were due to lack of a reliable source of raw water and deteriorating water treatment infrastructure and developed Sketch Number 7, a plan for a regional water transmission system.
- In late 2008, the Water Partnership voted to form the Great Northwest Wholesale Water Commission under Chapter 393 of the Missouri Revised State Statues.
- The GNWWWC is a public utility with authority to construct and own infrastructure, issue debt on behalf of its members, receive grant proceeds and other public assistance, and purchase and sell water from retail water systems.
- The GNWWWC met for the first time on July 16, 2009 in the City of Savannah, Missouri with eight water providers. As of February 2010, 22 cities and water districts have joined the GNWWWC.



COST OF WATER

- A modified cash-needs approach can be used to provide a comparison between the costs associated with treating and supplying finished water, and the cost of purchasing wholesale water from the GNWWWC.
- Joining the GNWWWC will impact the cost to water systems. To quantify how the water costs will change, facility managers must be sure that they are comparing the GNWWWC wholesale rate to the current cost of producing water adjusted for depreciation.

CURRENT & FUTURE REGULATORY ISSUES

- **Stage 1 and Stage 2 Disinfectants/Disinfection By-Product Rules.** Sets maximum residual disinfectant levels for chlorine, chloramine and chlorine dioxide and tightens the maximum contaminant levels (MCLs) for disinfection by-products. Regulated throughout entire system.
- **Long-Term 2 Enhanced Surface Water Treatment Rule**. Requires monitoring for Cryptosporidium (or for small systems, E. coli) to determine treatment requirements according to a bin category system.
- **Groundwater Rule.** Requires specific inspections to ensure that treatment technology achieves inactivation or removal of viruses.
- **Lead and Copper Rule Short-Term Revisions.** Provides modifications to general monitoring procedures.
- **Revised Total Coliform Rule**. Requires special assessments of water systems, investigation and correction of sanitary defects, and increased monitoring for high-risk small systems with unacceptable compliance history or significant non-compliance

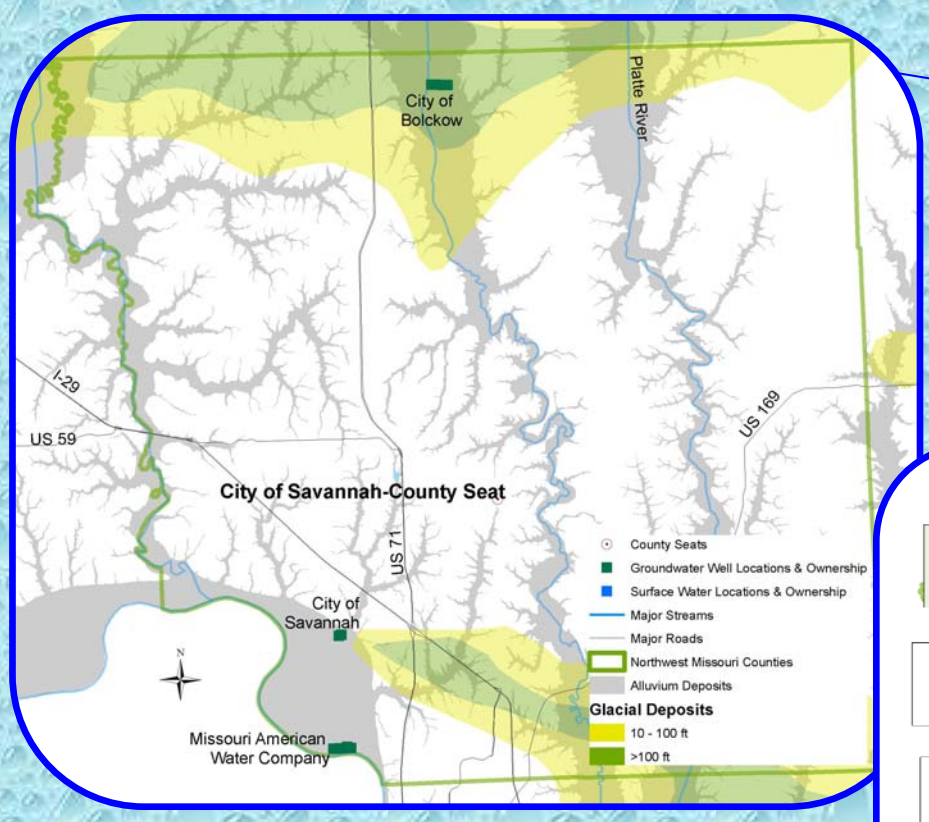
MOVING FORWARD-ASSESSMENT FOR JOINING GNWWWC

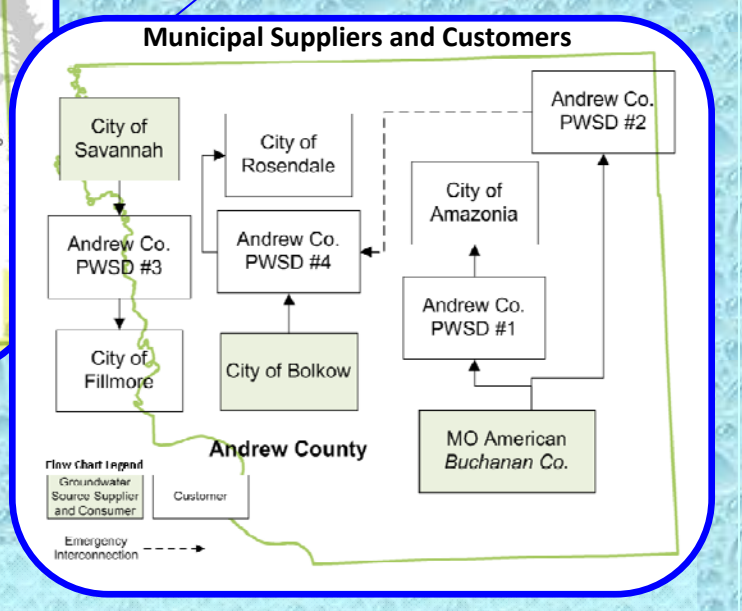
- Is your current water source reliable?
- What is the availability of additional resources to encourage community growth and sustainability?
- What is the quality of current water sources?
- What are the current costs to the supplier and the customer? How do we compare to purchase of water from a regional wholesale supply?
- What are the current costs to the supplier and the customer?
- How do we compare to purchase of water from a regional wholesale supply?

Water Supply Summary

Andrew County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.





AVAILABILITY

- Limited glacial deposits in far north and south part of the County which may yield low to moderate quantities of groundwater. The southwest corner contains Missouri River alluvium which may support large-yield wells.

RELIABILITY

- According to the Missouri Drought Response Plan, a majority of the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs. Areas along the Missouri River are not considered vulnerable to drought.
- Andrew County does not currently contain any surface water drinking sources.
- The City of Bolckow is located in alluvium deposits and has recently closed several wells to due low groundwater yield.
- The City of Savannah operates three wells in the Missouri River alluvium, the first of which was built over 50 years ago and is still a viable source of water. The treatment facility was recently constructed and is currently operating at half capacity.
- The City of Rosendale and the City of Fillmore closed their groundwater treatment facilities due to low water yields from the wells.

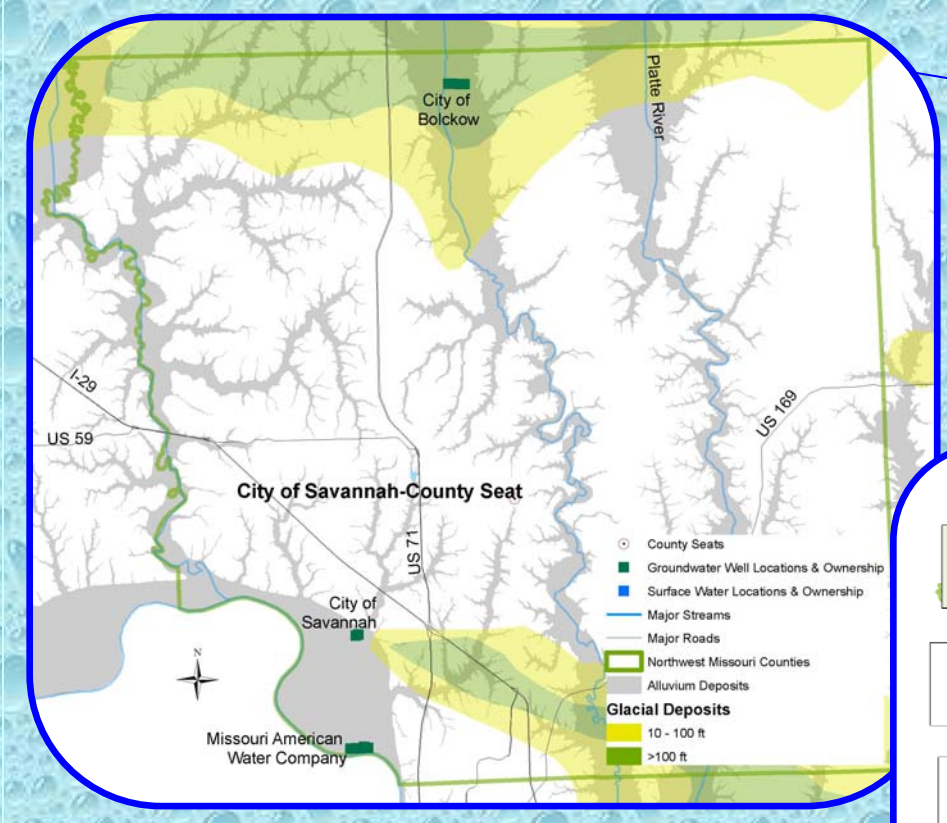
QUALITY

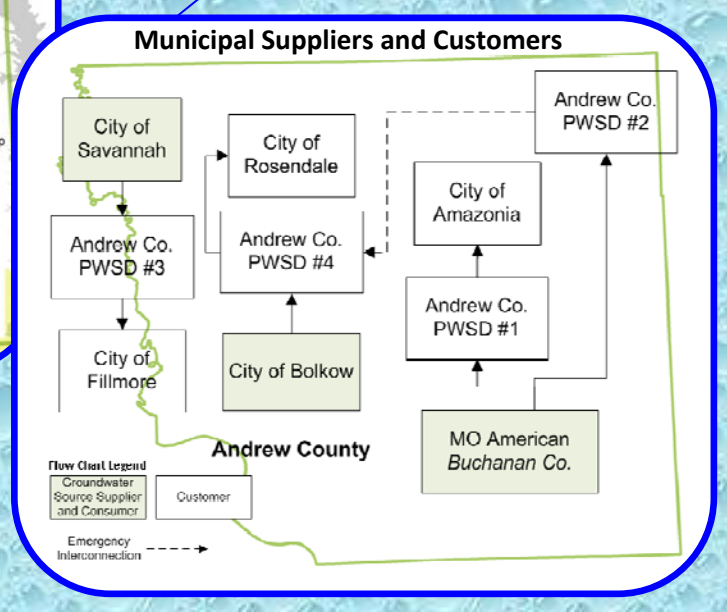
- Groundwater is high in sulfates, chloride, and total dissolved solids. Test wells drilled into glacial deposits produced water high in iron. Some samples also contained excessive nitrates, presumably from agricultural contamination.
- Current groundwater facilities produce water that is hard and high in iron and manganese concentrations.

Water Supply Summary

Andrew County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.





WATER STATISTICS

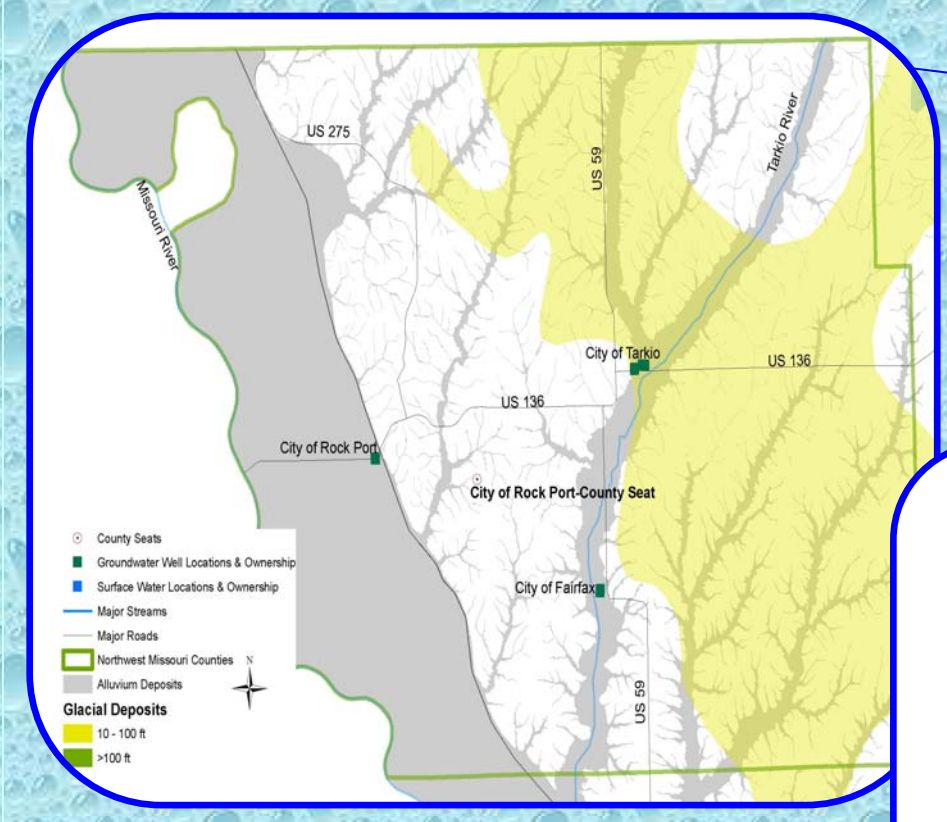
Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2] (MGD)
City of Bolckow	Bolckow MO1010084	Groundwater-Alluvium	NR	0.144	0.05
City of Savannah	Savannah MO1010724	Groundwater-Missouri River Alluvium	NR	1.5	0.55

1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
NR Not Reported

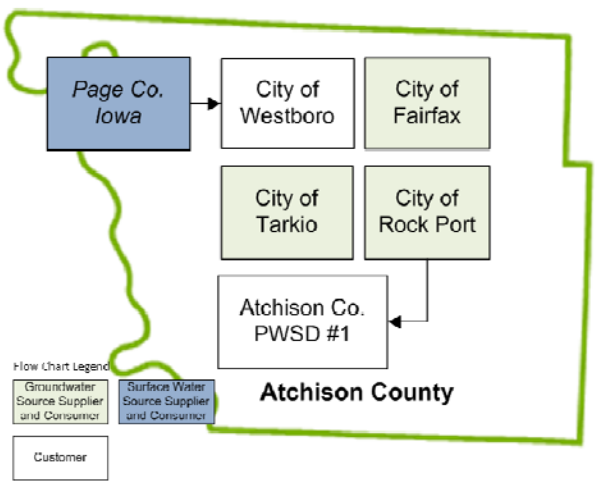
Water Supply Summary

Atchison County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.



Municipal Suppliers and Customers



AVAILABILITY

- Contains ample alluvial deposits within the Missouri River and Tarkio River floodplain. Approximately one-third of the County contains quaternary alluvium with the potential for high groundwater yields.

RELIABILITY

- According to the Missouri Drought Response Plan, a majority of the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs. Areas along the Missouri River are not considered vulnerable to drought.
- The City of Fairfax and the City of Tarkio are located near thick alluvium deposits, the City of Rock Port uses wells drilled into the Missouri River alluvium.

QUALITY

- Groundwater from this area contained high levels of iron and manganese, but is generally of good quality.
- Current groundwater facilities have reported water with high sulfates and chlorides.

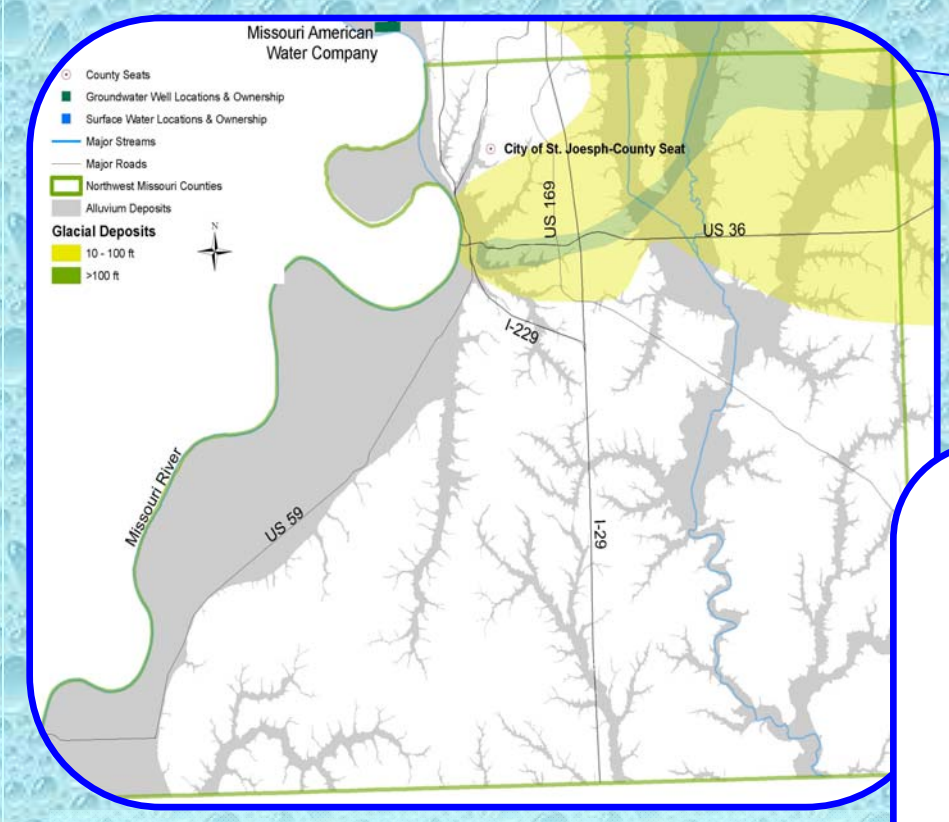
WATER STATISTICS

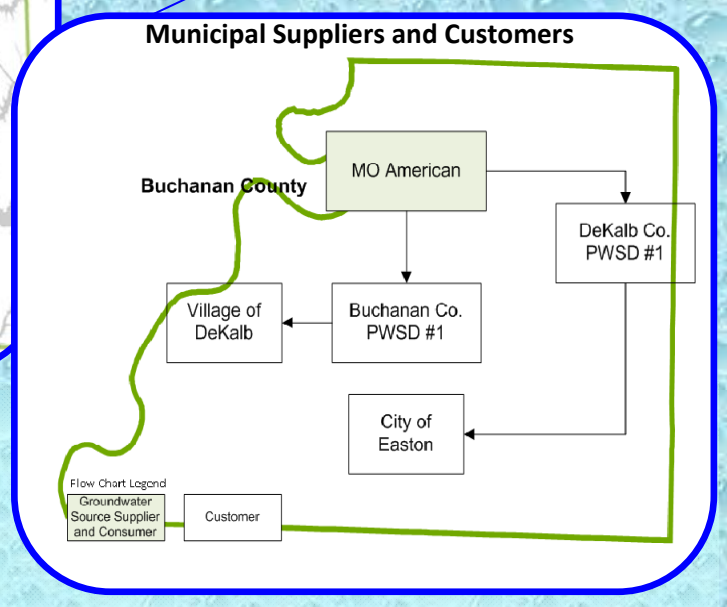
Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2,3] (MGD)
City of Fairfax	Fairfax MO1010265	Groundwater-Alluvium	NR	0.288	0.093
City of Rock Port	Rock Port MO1010696	Groundwater-Missouri River Alluvium	NR	0.75	0.280
City of Tarkio	Tarkio MO1010786	Groundwater-Alluvium	NR	0.75	0.161

1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
3 Confirmed by Phase II Report (CDM/Bartlett & West, 2009)
NR Not Reported

Water Supply Summary

Buchanan County, MO





AVAILABILITY

- Contains a large store of shallow glacial deposits and a thin strip of deep glacial deposits with low-moderate potential yields of water. The area most favorable for large-yield well development lies in the quaternary alluvium along the Missouri River on the eastern border of the country.

RELIABILITY

- According to the Missouri Drought Response Plan, a majority of the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs. Areas along the Missouri River are not considered vulnerable to drought.
- The Missouri-American groundwater treatment facility located in the City of St. Joseph. The facility is served by nine gravel-walled wells and one collector located in Andrew County. The wells are very reliable and produce water from the Missouri River alluvium.

QUALITY

- Groundwater is high in chloride and total dissolved solids. Test wells drilled into glacial deposits produced water of low mineral content, but high TDS.
- Current groundwater facilities have reported hard water that has elevated levels of iron.

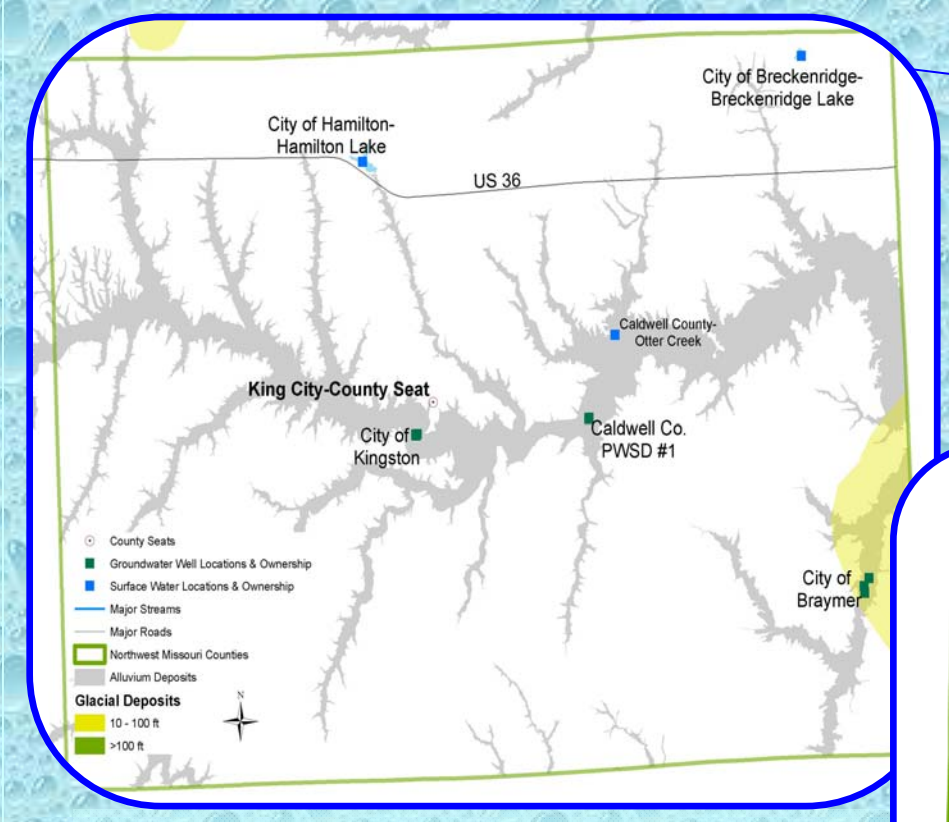
WATER STATISTICS

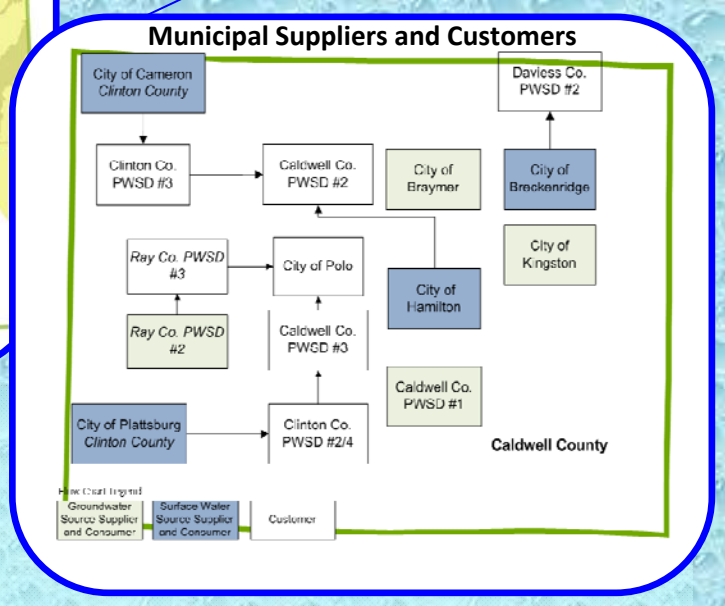
Location- Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2] (MGD)
Missouri-American Water Company	MO AM Water MO1010714	Groundwater-Missouri River Alluvium	NR	30.0	15.0

1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
NR Not Reported

Water Supply Summary

Caldwell County, MO





AVAILABILITY

- Contains an alluvium aquifer that runs through the center of the County with the potential for moderate-yield wells. A small pocket of shallow glacial drift lies in the lower southeast corner of the County that may produce low yields of water with limited recharge potential.

RELIABILITY

- According to the Missouri Drought Response Plan, the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs.
- This county is served by three surface water sources in the City of Hamilton, City of Breckenridge, and by Otter Creek.
- Hamilton Lake experiences decreased water quality and quantity during periods of extended drought, which makes treatment more difficult. Additional needs could be met by diverting water from Marrowbone Creek.
- Breckenridge Lake is fed by water from a well drilled into glacial deposits. The facility produces water at negligible rates and is not considered reliable and is at risk of not meeting current demands during drought.
- Otter Creek is the most recently commissioned surface water source in the NW Missouri region. Although the project has local and federal support, it requires additional fiscal assistance. When Complete, Otter Creek will provide 1.24 MGD for drinking water purposes.
- Four cities in Caldwell County operate groundwater treatment facilities in alluvium deposits.
- The City of Polo no longer produces groundwater. Although the capacity of the alluvium wells is viable, treatment challenges caused the facility to close. The City of Polo now purchases water.

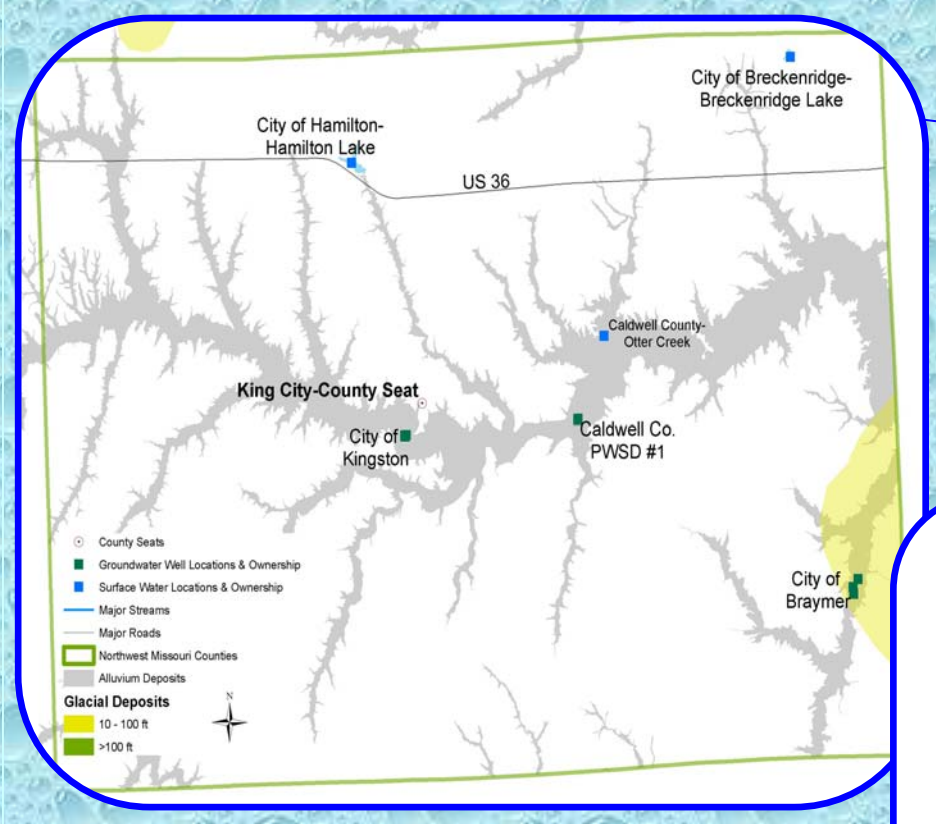
QUALITY

- All groundwater facilities use acidification for periodic maintenance and produce water that is hard and high in manganese.
- The quality of water from surface water sources is reduced during periods of drought.

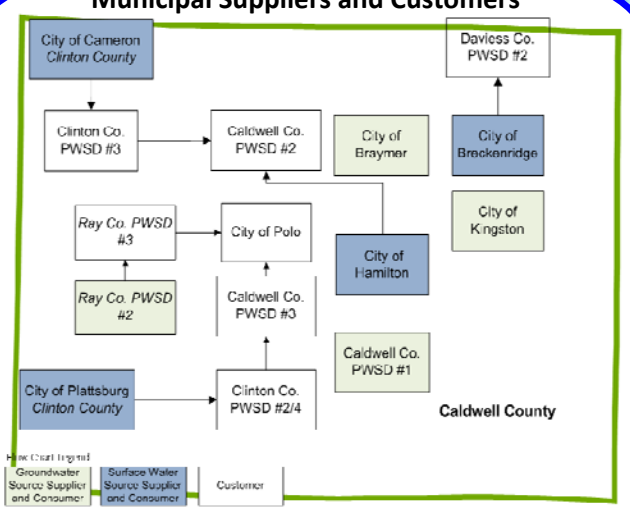
Water Supply Summary

Caldwell County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.



Municipal Suppliers and Customers



WATER STATISTICS

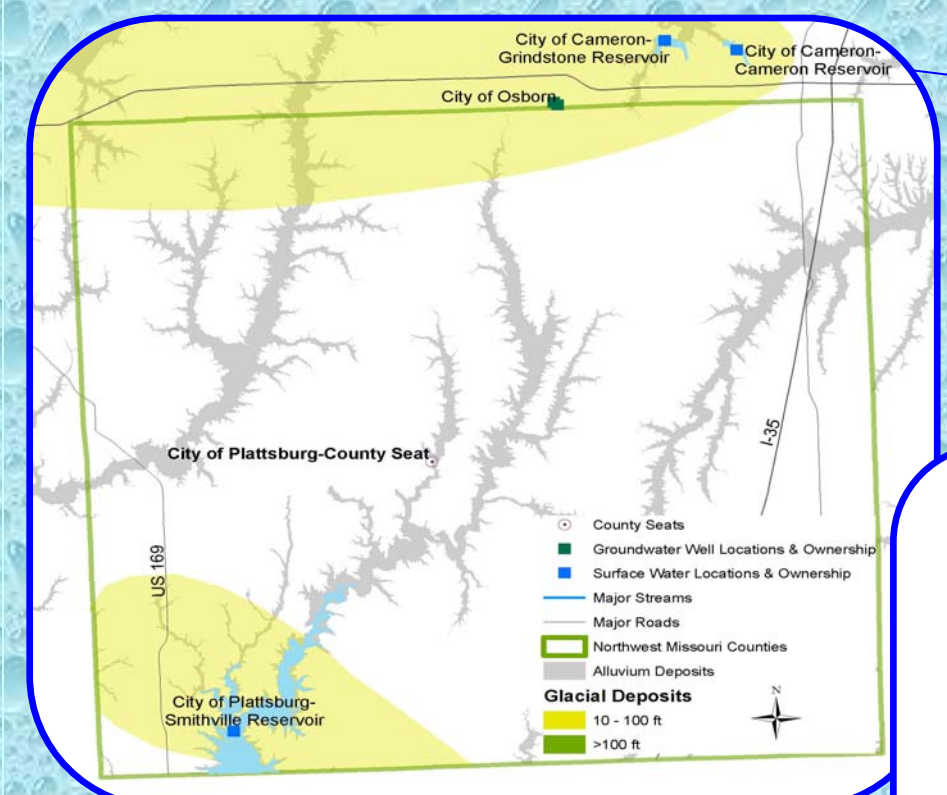
Location- Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2] (MGD)
City of Braymer	Braymer MO1010098	Groundwater-Alluvium	NR	0.201	0.08
City of Breckenridge-Breckenridge Lake	Breckenridge MO1010099	Surface Water Groundwater-Glacial Deposits	0.052	0.151	0.048
Caldwell County PWSD #1	Caldwell County PWSD #1 MO1024078	Groundwater-Alluvium	NR	0.068	0.03[3]
City of Hamilton-Hamilton Lake	Hamilton MO1010342	Surface Water	0.19	0.648	0.185[3]
City of Kingston	Kingston MO1010426	Groundwater-Alluvium	NR	0.072	0.033[3]

1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
3 Confirmed by Phase II Report (CDM/Bartlett & West, 2009)
NR Not Reported

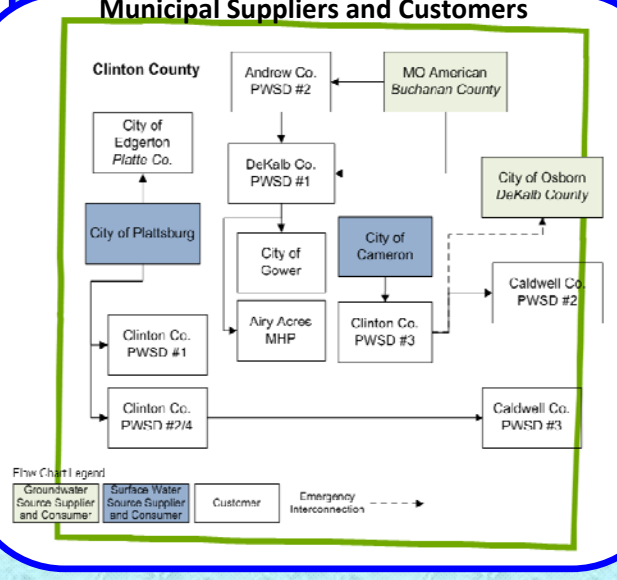
Water Supply Summary

Clinton County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.



Municipal Suppliers and Customers



AVAILABILITY

- Clinton County consists primarily of sparse alluvial deposits. A store of shallow glacial deposits exists in the southwest corner of the County near Smithville Lake and also in the northern part of the county with limited yield and recharge potential.

RELIABILITY

- According to the Missouri Drought Response Plan, the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs.
- Smithville Lake is reliable and allocates 30 MGD to the City of Kansas City and 10 MGD to the City of Plattsburg.
- Two reservoirs in the City of Cameron and the Grindstone reservoir serve as surface water supply to the City of Cameron. The City of Cameron Reservoir #1 has silted in and no longer provides water. Grindstone and the City of Cameron Reservoirs #2 and #3 are reliable even during dry periods. However, according to RESOP analysis, these lakes would not meet current demands during the drought of record from 1951-1959.

QUALITY

- Smithville Lake is fairly reliable, but has historically had problems meeting treatment standards.

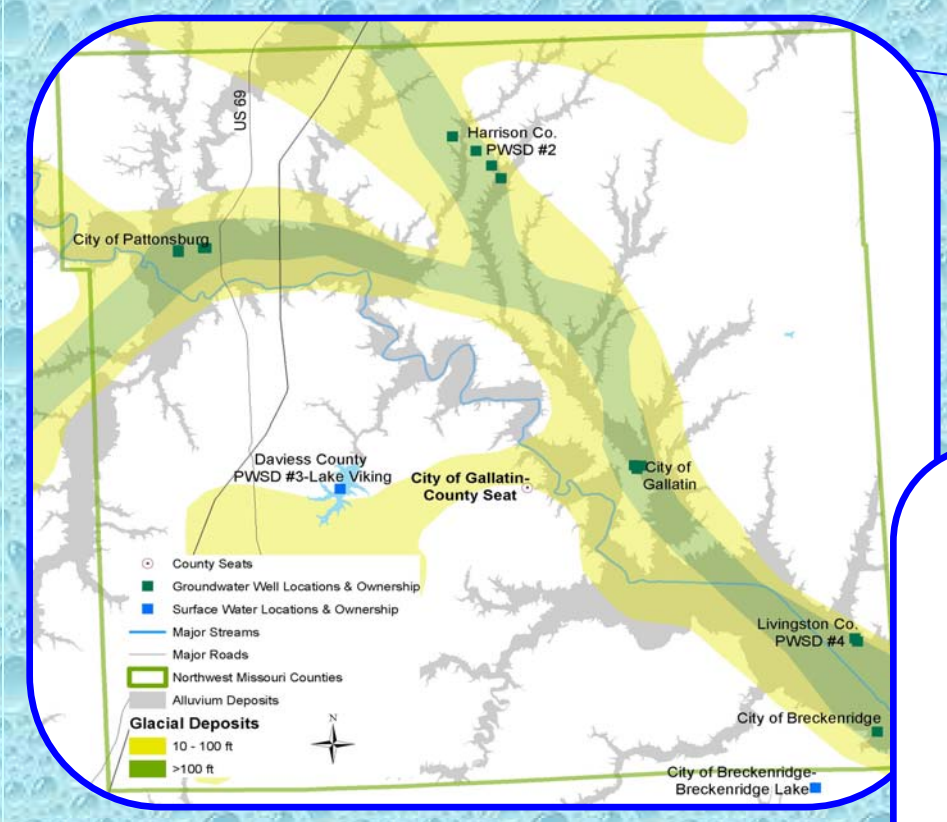
WATER STATISTICS

Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2,3] (MGD)
City of Cameron-Grindstone Reservoir & Cameron Reservoir	Cameron MO1010131	Surface Water	1.4	2.88	1.592
City of Plattsburg-Smithville Lake	Plattsburg MO1010648	Surface Water	NR	1.453	0.923

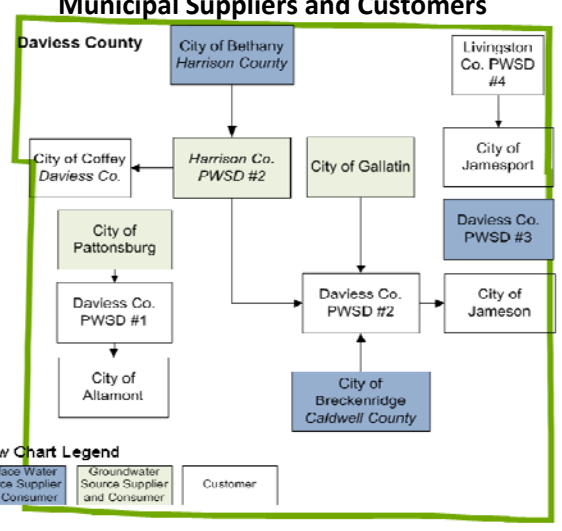
1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
3 Confirmed by Phase II Report (CDM/Bartlett & West, 2009)
NR Not Reported

Water Supply Summary

Daviess County, MO



Municipal Suppliers and Customers



AVAILABILITY

- Contains some alluvium and glacial deposits, with low-moderate potential of water production and well recharge. The largest alluvium aquifer is associated with the Grand River Valley that runs from the northwest corner to the southeast corner of the County.

RELIABILITY

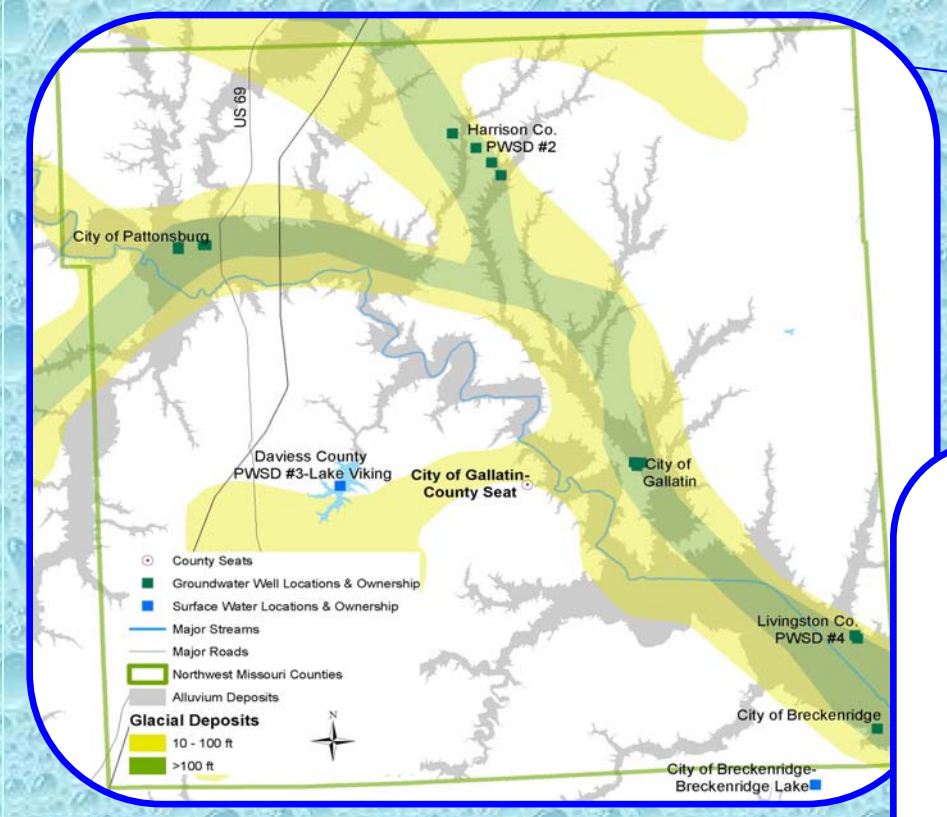
- According to the Missouri Drought Response Plan, the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs.
- Lake Viking is reliable, but is used primarily used for recreational purposes and may not be marketed for additional water supply. Lake Viking serves Davies County PWSD #3 and has a firm capacity of 2.46 MGD.
- Jamesport Community Lake is no longer in service because it could not meet its designated source capacity during periods of drought. The City now purchases water.
- Harrison County PWSD #2 and Livingston County PWSD #4 are located in Daviess County, but are operated by their perspective counties. Harrison County PWSD #2 is currently undergoing construction to expand capacity.
- Four municipal wells have been closed in the City of Gallatin and the City of Pattonsburg due to low groundwater yields. The maximum daily treatment capacity is currently exceeded in the City of Gallatin.
- Facilities in the City of Coffey and the City of Jameson are no longer in operation due to low well production.

QUALITY

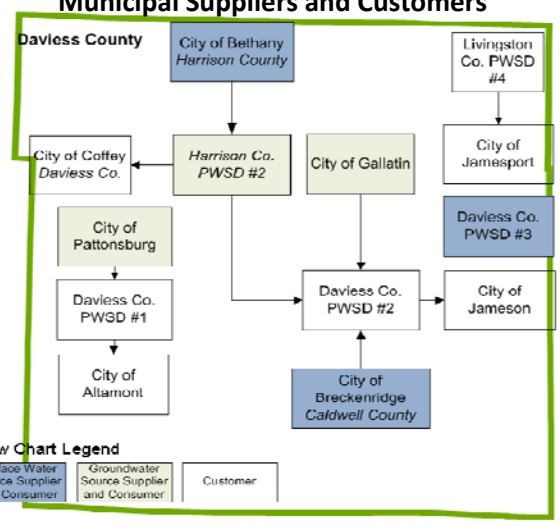
- Groundwater from bedrock and glacial wells is of poor quality. Samples were high in nitrates, chloride, iron, manganese, and total dissolved solids.
- Water from current facilities is generally hard and high in iron. Wells in the area require acidification to maintain pumping capacity.

Water Supply Summary

Daviess County, MO



Municipal Suppliers and Customers



WATER STATISTICS

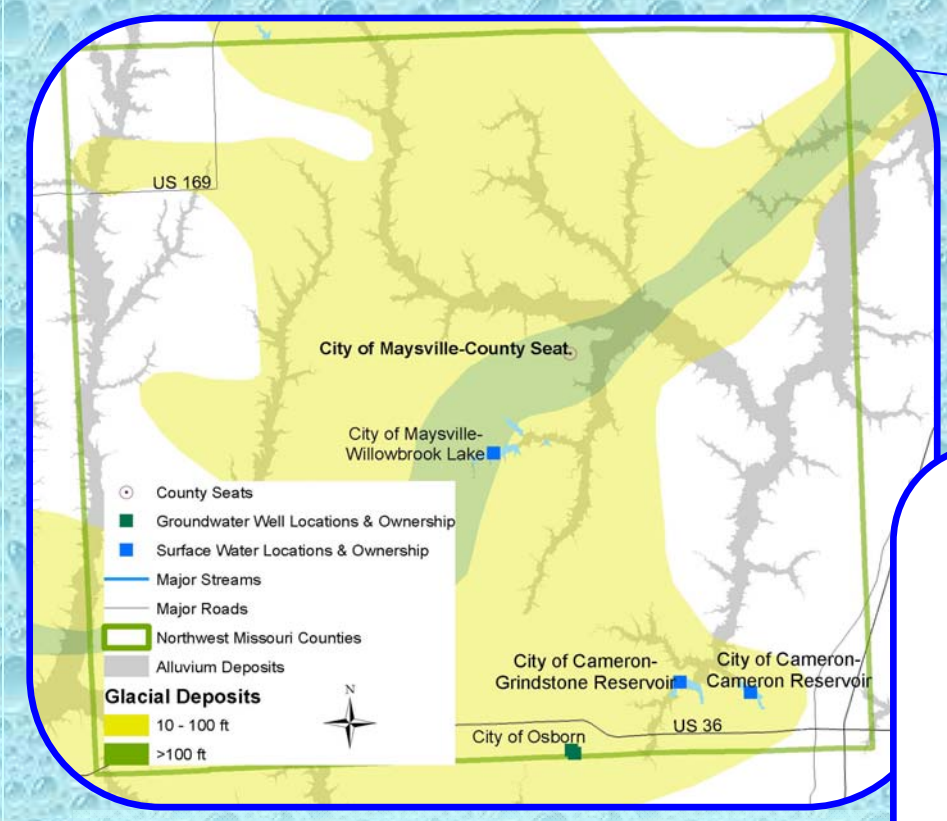
Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2,3] (MGD)
City of Gallatin	Gallatin MO1010299	Groundwater-Glacial Deposits	NR	0.400	0.377
Daviess County PWSD #3-Lake Viking	Daviess County PWSD #3 MO1036130	Surface Water	2.46	0.2	0.058
City of Pattonsburg	Pattonsburg MO1010632	Groundwater-Alluvium and Glacial Deposits	NR	0.432	0.250

1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
3 Confirmed by Phase II Report (CDM/Bartlett & West, 2009)
NR Not Reported

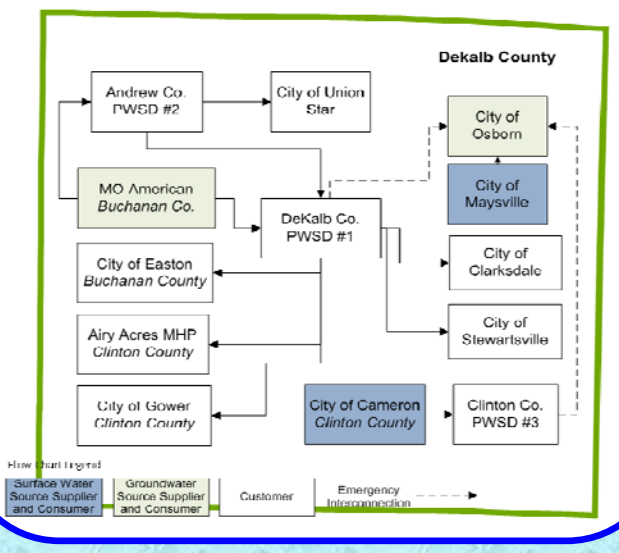
Water Supply Summary

DeKalb County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.



Municipal Suppliers and Customers



AVAILABILITY

- Contains a large store of glacial deposits that lies under much of the County with low yield and recharge potential. A strip of deep glacial deposits stretches from the northeast to southwest corner of the County with moderate yield and recharge potential.

RELIABILITY

- According to the Missouri Drought Response Plan, the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs.
- Willowbrook Lake in the City of Maysville has experienced silting problems that have resulted in reduced storage capacity, but can meet current demands during the drought of record from 1951-1959.

QUALITY

- Samples taken from water, oil, and glacial wells consistently yield water high in iron, sulfate, and total dissolved solids. Several samples from the water and oil wells produced elevated levels of chloride.
- Wells in the county have historically produced high levels of nitrates from glacial wells, and two wells have been taken out of operation due to the nitrate level.

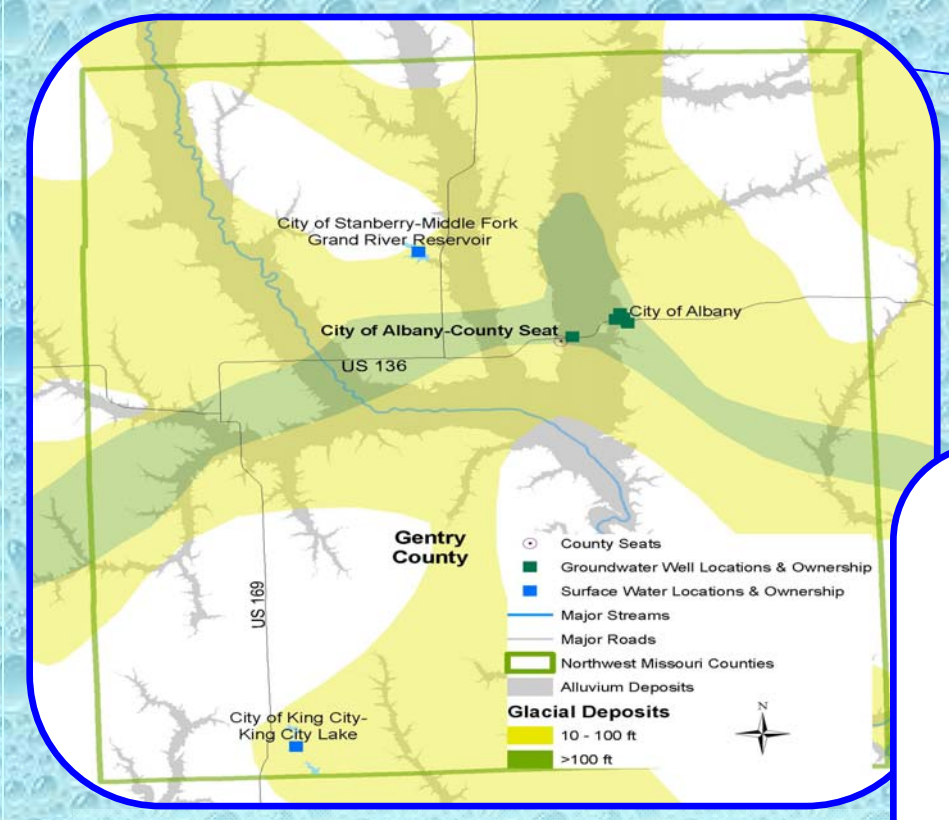
WATER STATISTICS

Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2] (MGD)
City of Maysville-Willowbrook Lake	Maysville MO1010510	Surface Water	0.45	0.576	0.115[3]
City of Osborn	Osborn MO1010609	Groundwater-Glacial Deposits	NR	0.086	0.030

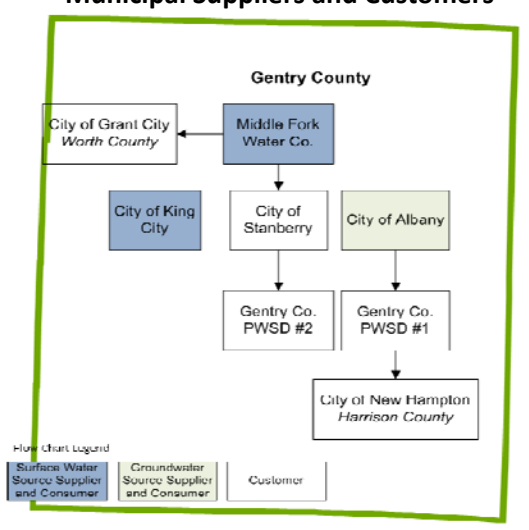
1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
3 Confirmed by Phase II Report (CDM/Bartlett & West, 2009)
NR Not Reported

Water Supply Summary

Gentry County, MO



Municipal Suppliers and Customers



AVAILABILITY

- Contains alluvium and glacial deposits throughout much of the County. A strip of thick glacial deposits with moderate yield and recharge potential runs through the center of the County from east to west.

RELIABILITY

- According to the Missouri Drought Response Plan, the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs.
- The City of King City has four small reservoirs that can produce a field capacity of 0.133 MGD and can meet current demand during the drought of record.
- Middle Fork Reservoir near the City of Stanberry can meet demands during the drought of record, but has experienced treatment problems during drought in the past.
- Contains six groundwater wells in the City of Albany drilled in both alluvium and glacial deposits.

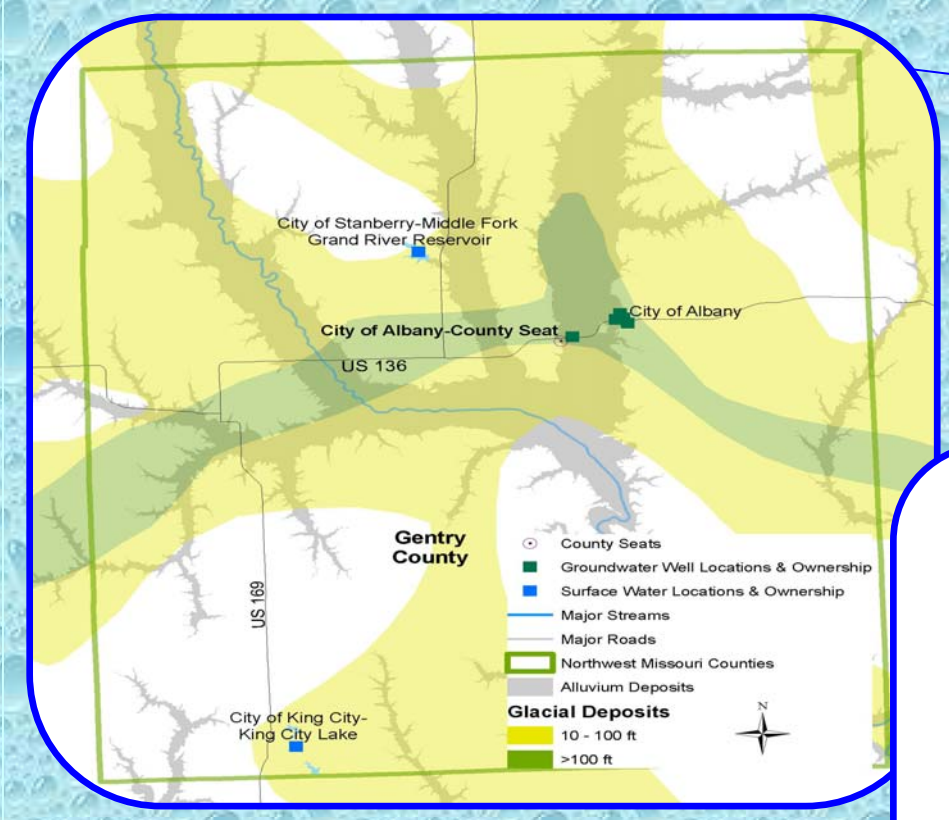
QUALITY

- Groundwater is high in sulfates, iron, and total dissolved solids. Several samples also had high manganese content.
- Current groundwater facilities produce hard water that requires treatment for iron. Periodic problems arise with ammonia levels in groundwater wells.

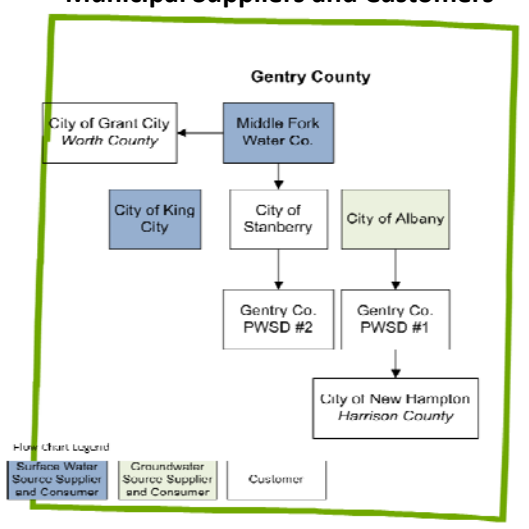
Water Supply Summary

Gentry County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.



Municipal Suppliers and Customers



WATER STATISTICS

Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2] (MGD)
City of Albany	Albany MO101006	Groundwater-Alluvium and Glacial Deposits	NR	1.0	0.430[3]
City of King City-King City Reservoir	King City MO1010425	Surface Water	0.133	0.	0.100[3]
City of Stanberry-Middle Fork Grand River Reservoir	Middle Fork Water County MO1070639	Surface Water	0.381	1.0	0.335

1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
3 Confirmed by Phase II Report (CDM/Bartlett & West, 2009)
NR Not Reported

Water Supply Summary

Harrison County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
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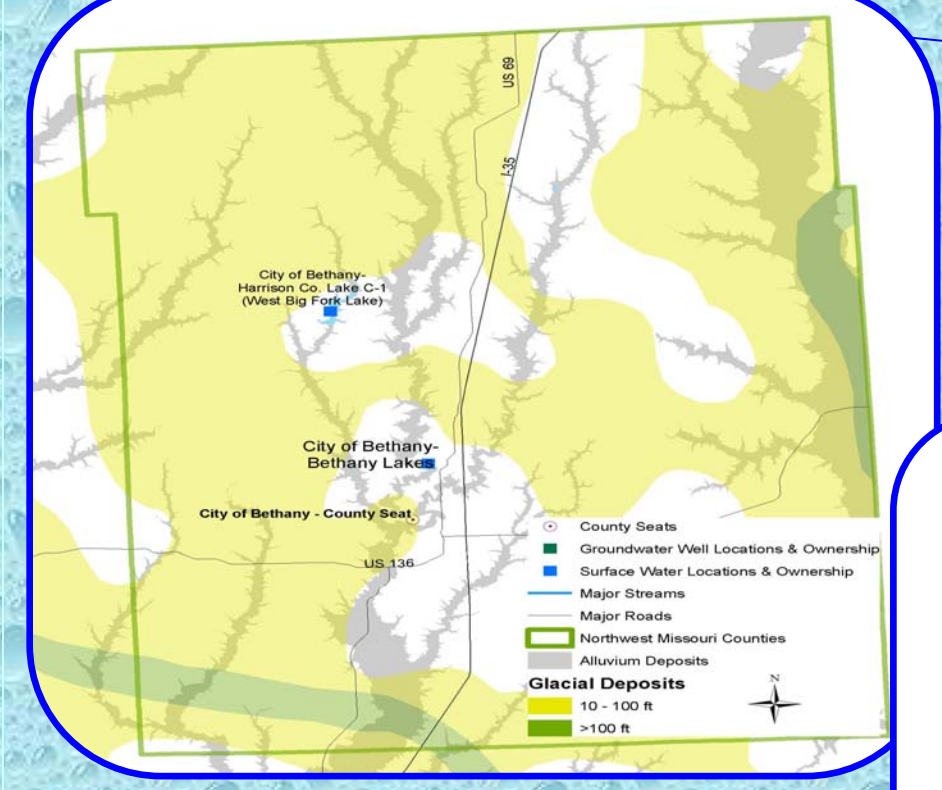
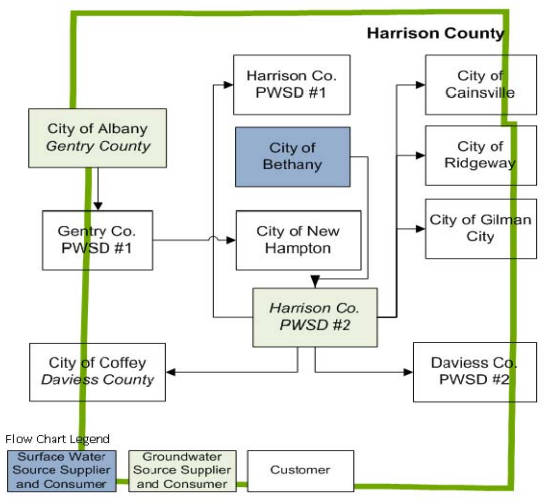


Municipal Suppliers and Customers



AVAILABILITY

- Contains sparse alluvium deposits so groundwater is primarily obtained from glacial deposits or bedrock, with low yield and recharge potential.

RELIABILITY

- According to the Missouri Drought Response Plan, the County is located in a region of severe drought vulnerability. This indicates that surface water sources are inadequate during drought and that groundwater is sufficient only for domestic needs.
- The Harrison County Reservoir System can meet current demands during the time of drought, and could provide additional water with allocation of recreation pools to water supply.
- Harrison County is served by one groundwater treatment facility that is located in the adjacent Daviess County. Two additional wells are currently under construction and will provide an additional 750 gpm. These two wells are part of a phased effort to increase the source capacity of Harrison County PWSD#2.
- Operational non-municipal, large yield wells exist in the western part of Harrison County in the glacial aquifer.

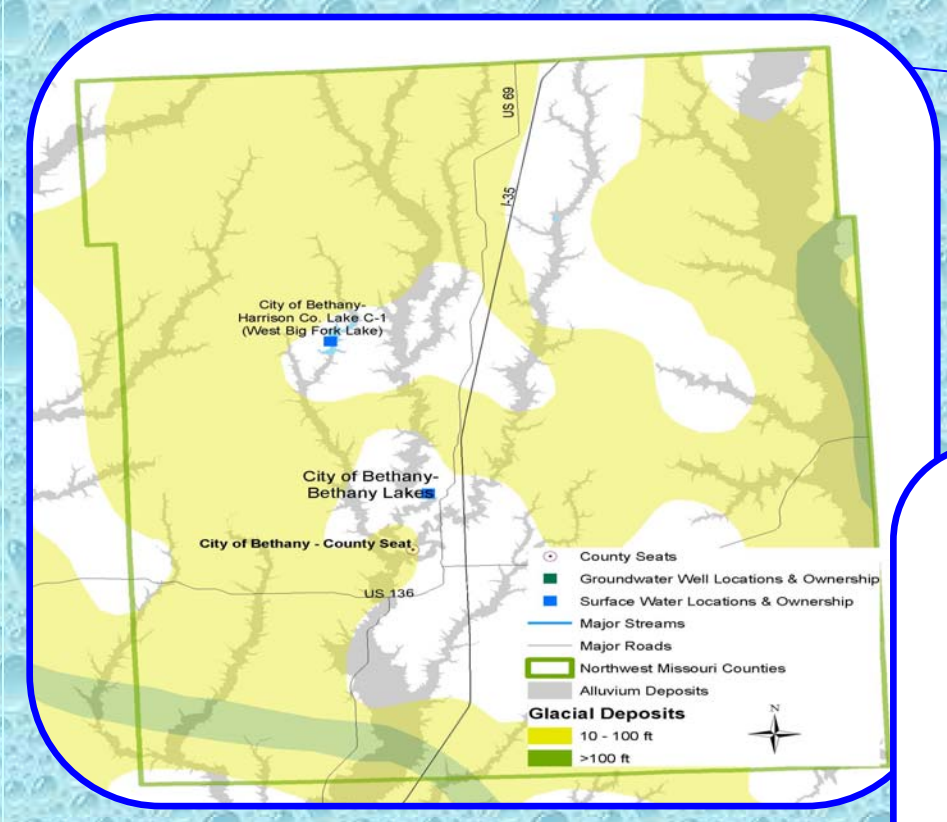
QUALITY

- Samples taken from bedrock and glacial wells consistently yield water high in sulfate and total dissolved solids. Several samples from bedrock wells produced elevated levels of chloride, while all glacial drift samples had high iron concentrations.
- Water that is obtained from glacial deposits or bedrock is generally mineralized and requires extensive treatment.
- Existing groundwater facilities produce water high in iron and manganese.

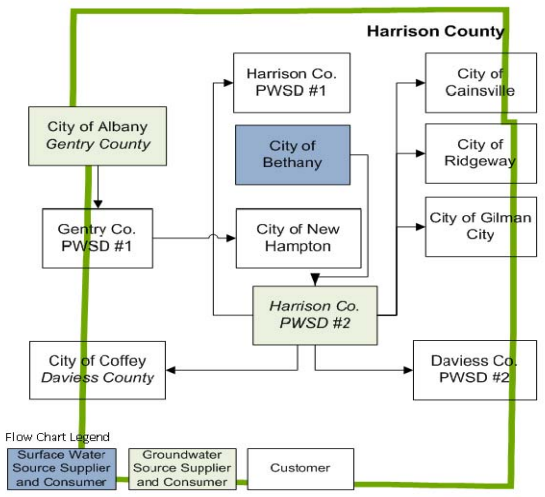
Water Supply Summary

Harrison County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.



Municipal Suppliers and Customers



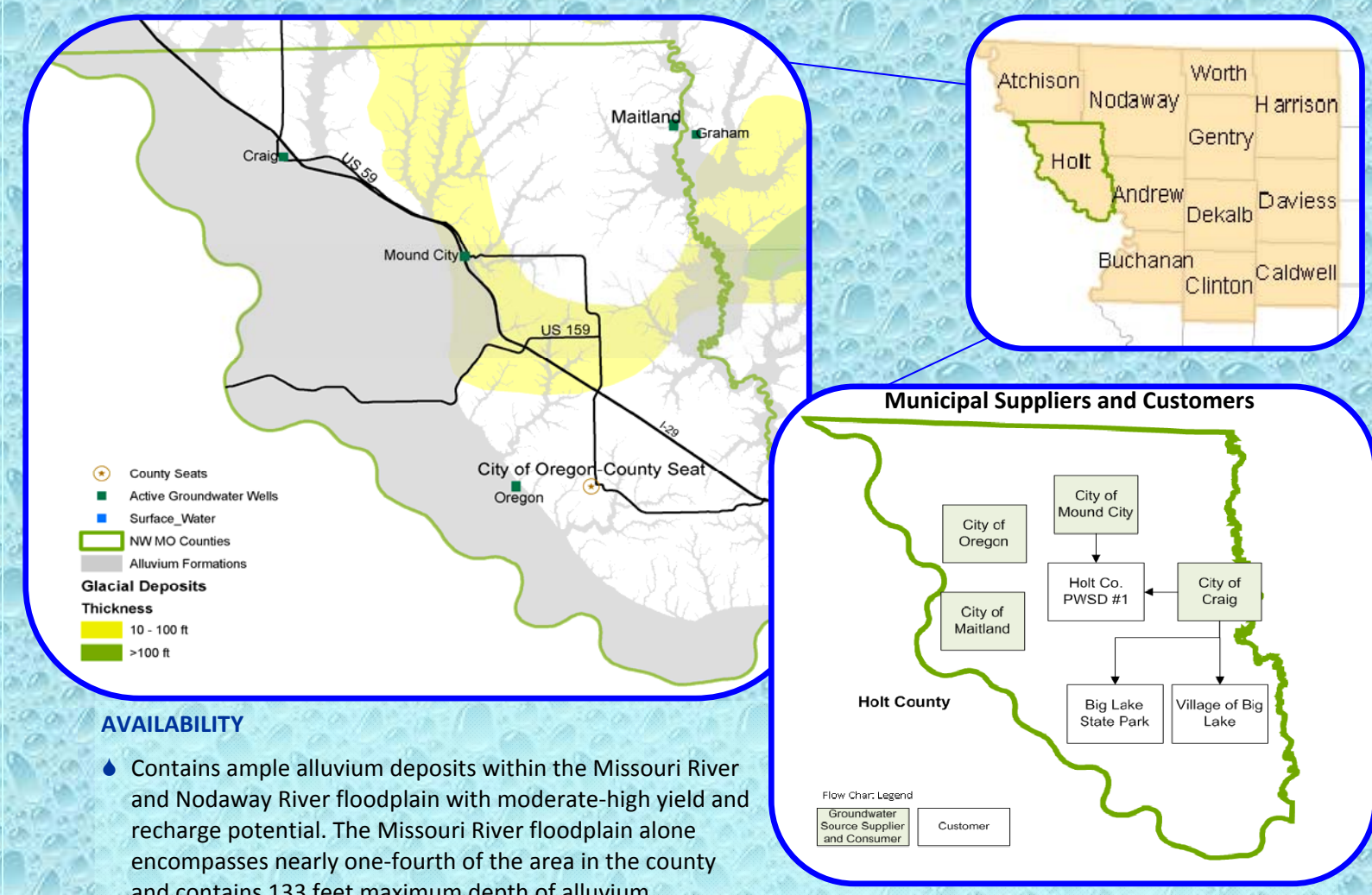
WATER STATISTICS

Location- Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2,3] (MGD)
City of Bethany-Harrison County Lake and Bethany Lakes	Bethany MO1010068	Surface Water	0.816	1.0	0.325
Harrison County PWSD #2	Harrison County PWSD #2 MO1024242	Groundwater-Alluvium, Glacial, and Pennsylvanian Deposits	NR	0.40	0.45

1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
3 Confirmed by Phase II Report (CDM/Bartlett & West, 2009)
NR Not Reported

Water Supply Summary

Holt County, MO



AVAILABILITY

- Contains ample alluvium deposits within the Missouri River and Nodaway River floodplain with moderate-high yield and recharge potential. The Missouri River floodplain alone encompasses nearly one-fourth of the area in the county and contains 133 feet maximum depth of alluvium.
- The glacial drift valley produces moderate yields of water. Water possibilities in the southern part of the County are limited due to the thin layer of glacial materials overlying the bedrock.

RELIABILITY

- According to the Missouri Drought Response Plan, a majority of the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs. Areas along the Missouri River are not considered vulnerable to drought.
- Four cities in Holt County operate municipal groundwater treatment facilities including the City of Craig, the City of Maitland, the City of Mound City, and the City of Oregon.
- The well field for the City of Maitland is located in the Nodaway River alluvium.

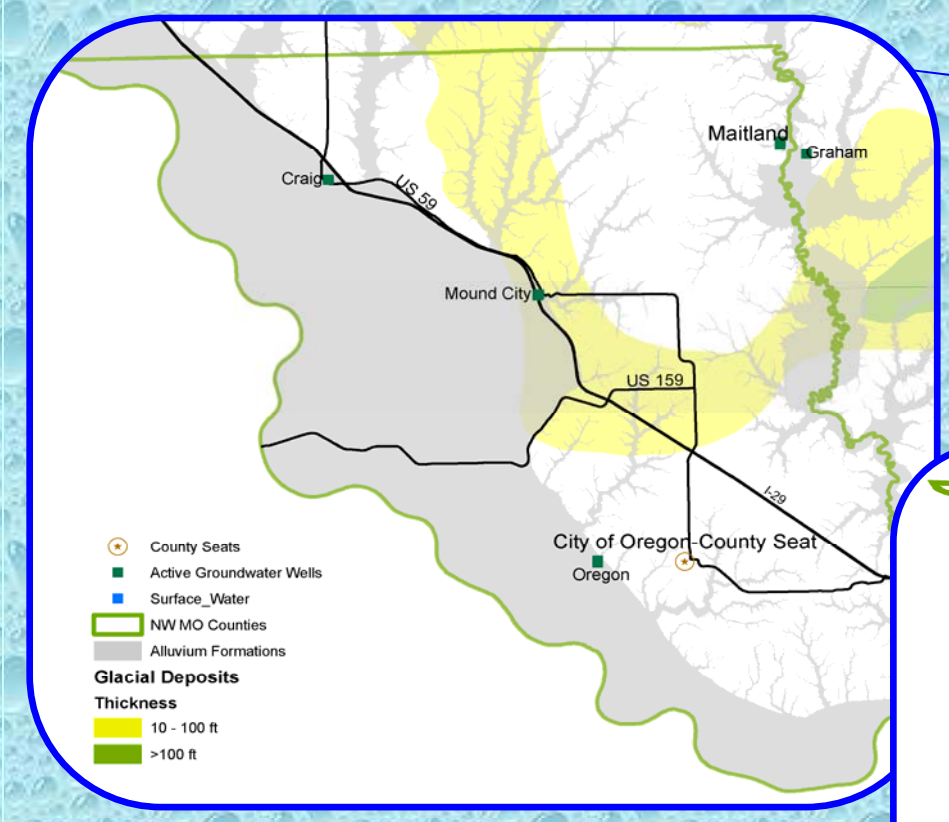
QUALITY

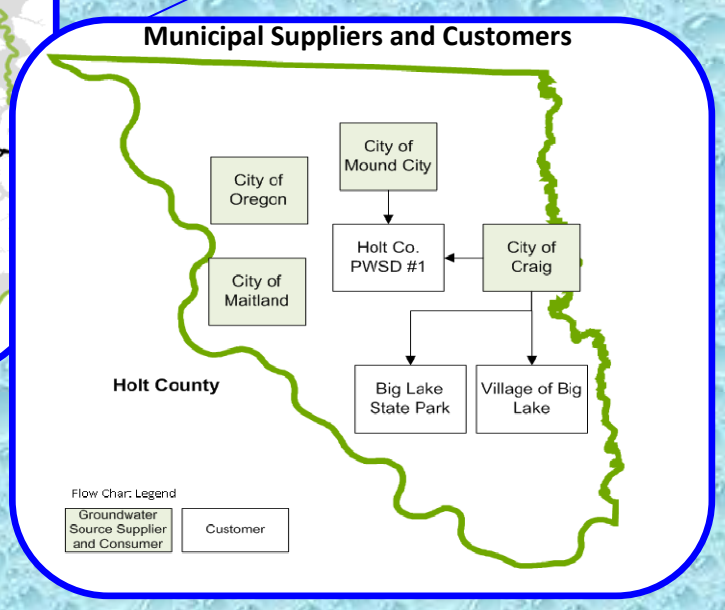
- Samples taken from glacial and alluvium wells yield water of relatively good quality. Samples were high in iron and TDS.
- Water derived from wells drilled into alluvium deposits require aeration, filtration, and chlorination.
- Some wells in the County have been abandoned due to high nitrate levels.

Water Supply Summary

Holt County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.





WATER STATISTICS

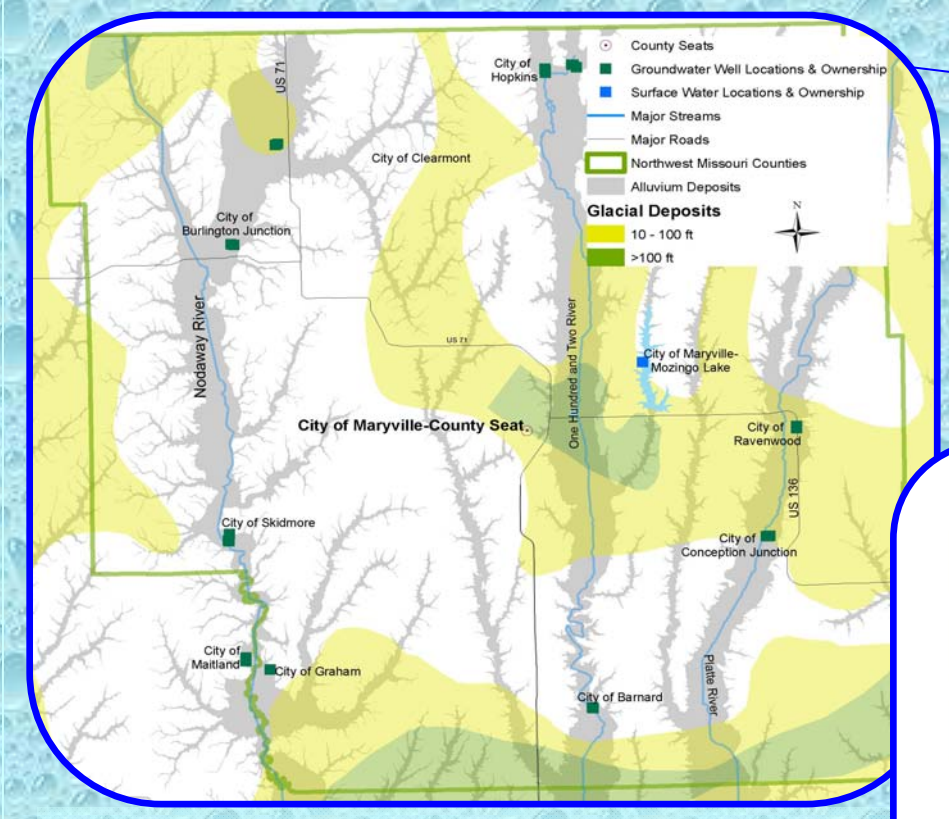
Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2] (MGD)
City of Craig	Craig MO1010191	Groundwater-Missouri River Alluvium	NR	0.2	0.074[3]
City of Maitland	Maitland MO1010489	Groundwater-Alluvium	NR	0.1	0.025
City of Mound City	Mound City MO1010548	Groundwater-Missouri River Alluvium	NR	0.72	0.170[3]
City of Oregon	Oregon MO1010605	Groundwater-Alluvium	NR	0.432	0.175[3]

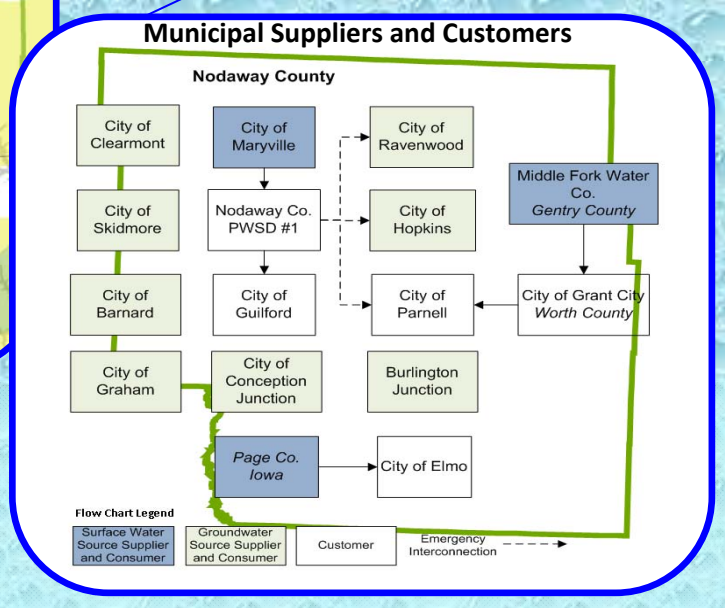
1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
3 Confirmed by Phase II Report (CDM/Bartlett & West, 2009)
NR Not Reported

Water Supply Summary

Nodaway County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.





AVAILABILITY

- Nodaway County contains three large stores of alluvium in the floodplains of the One Hundred and Two River, the Nodaway River, and the Platte River with moderate-high yield and recharge potential.
- The most favorable geologic material for groundwater supply development is located in the deeper parts of this system in the center and southern parts of the County. A major east-west valley of deep water-bearing material is located along the Nodaway-Andrew county line.
- The City of Burlington Junction is currently building a new treatment plant that will allow the City to supply water to Nodaway County PWSD #1.

RELIABILITY

- According to the Missouri Drought Response Plan, the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs.
- The Mozingo Reservoir in City of Maryville is considered reliable and provides water to Nodaway County PWSD #1. Additional supply could be generated from recreation allocation of Mozingo Reservoir, or supplemented by the One Hundred and Two River.
- Eight groundwater well treatment facilities have been closed, four plan to connect with Nodaway County PWSD #1 and abandon individual sources.
- Two groundwater facilities have been taken out of production in the City of Collins Corner and the City of Parnell.
- The City of Clearmont is currently connecting to Nodaway County PWSD #1 and will abandon its source when the connection is complete.

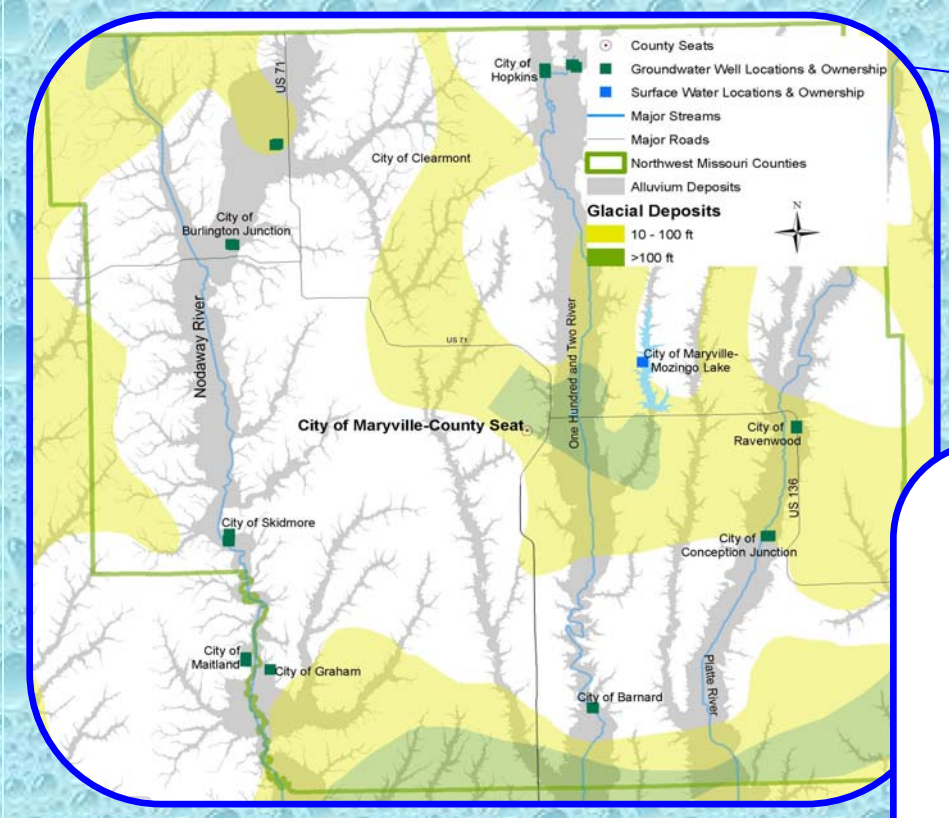
QUALITY

- Samples taken from glacial and bedrock wells yields water high in sulfate and total dissolved solids. Test wells drilled into bedrock produced water with high chloride levels.
- Several existing facilities have experienced high levels of iron and manganese. There have been some instances of Methyl Tertiary Butyl Ether contamination.

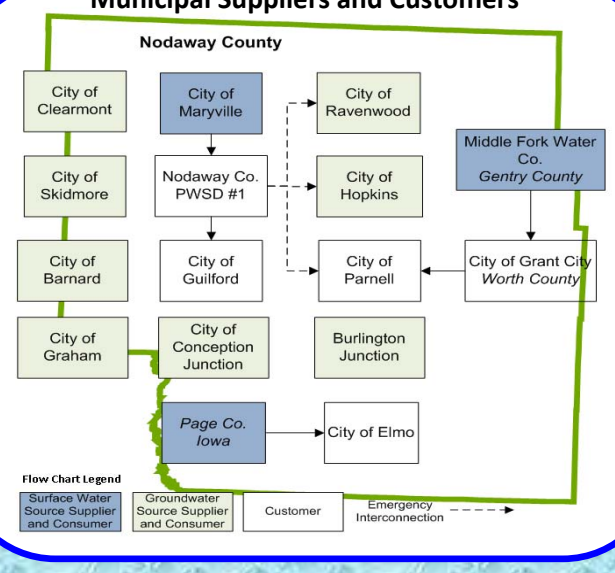
Water Supply Summary

Nodaway County, MO

GREAT NORTHWEST WHOLESALE WATER COMMISSION
The great grid to the future.



Municipal Suppliers and Customers



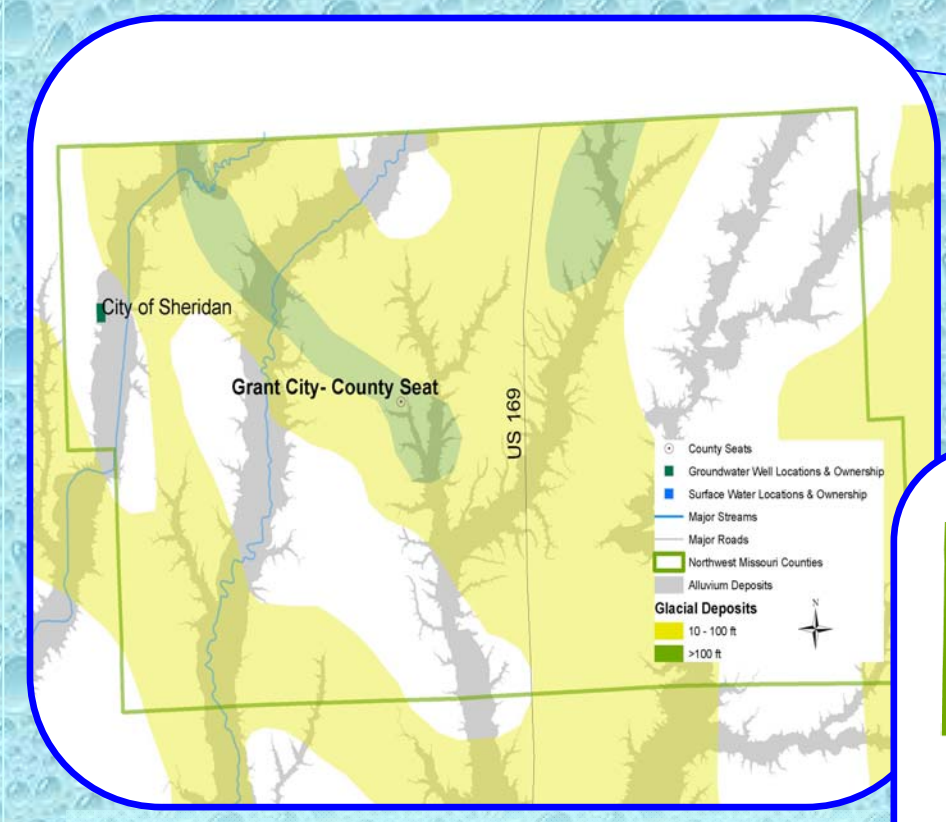
WATER STATISTICS

Location-Lake Name	Source Name and ID[2]	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2] (MGD)
City of Barnard	Barnard MO1010046	Groundwater-Alluvium	NR	0.05	0.022
City of Burlington Junction	Burlington Junction MO1010117	Groundwater-Alluvium	NR	0.13	0.045
City of Clearmont	Clearmont MO1010173	Groundwater-Alluvium	NR	0.05	0.017
City of Conception Junction	Conception Junction MO1010182	Groundwater-Alluvium	NR	0.05	0.015
City of Graham	Graham MO1010319	Groundwater-Alluvium	NR	0.064	0.018
City of Hopkins	Hopkins MO1010378	Groundwater-Alluvium	NR	0.144	0.041
City of Maryville-Mozingo Lake	Maryville MO1010508	Surface Water	2.9	5.0	2.8
City of Ravenwood	Ravenwood MO1010673	Groundwater-Alluvium	NR	0.1	0.035
City of Skidmore	Skidmore MO1010744	Groundwater-Alluvium	NR	0.173	0.02

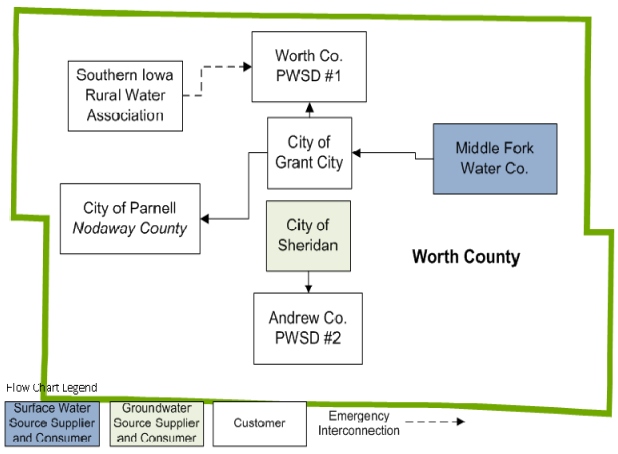
1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
NR Not Reported

Water Supply Summary

Worth County, MO



Municipal Suppliers and Customers



AVAILABILITY

- Alluvium deposits in Worth County are highly variable and may provide moderate-high yields of water depending on aquifer thickness.

RELIABILITY

- According to the Missouri Drought Response Plan, a majority of the County is located in a region of severe drought vulnerability. This indicates that surface water sources are usually inadequate during drought and that groundwater is sufficient only for domestic needs.
- Three groundwater wells have been abandoned due to low production.

QUALITY

- Glacial deposit wells produce water with low levels of chloride, sulfate, and total dissolved solids. Samples had high iron concentrations.
- The City of Sheridan operates a groundwater treatment facility in Worth County drilled from alluvium. The City has experienced difficulties with ammonia levels.

WATER STATISTICS

Location-Lake Name	Source Name and ID	Supply Type	Firm Yield Capacity[1] (MGD)	Treatment Capacity[2] (MGD)	Avg Daily Use[2,3] (MGD)
City of Sheridan	Sheridan MO1010739	Groundwater-Alluvium	NR	0.043	0.024

1 MDNR RESOP Studies (MDNR, 2010)
2 Phase I Report (MDNR, 2007)
3 Confirmed by Phase II Report (CDM/Bartlett & West, 2009)
NR Not Reported