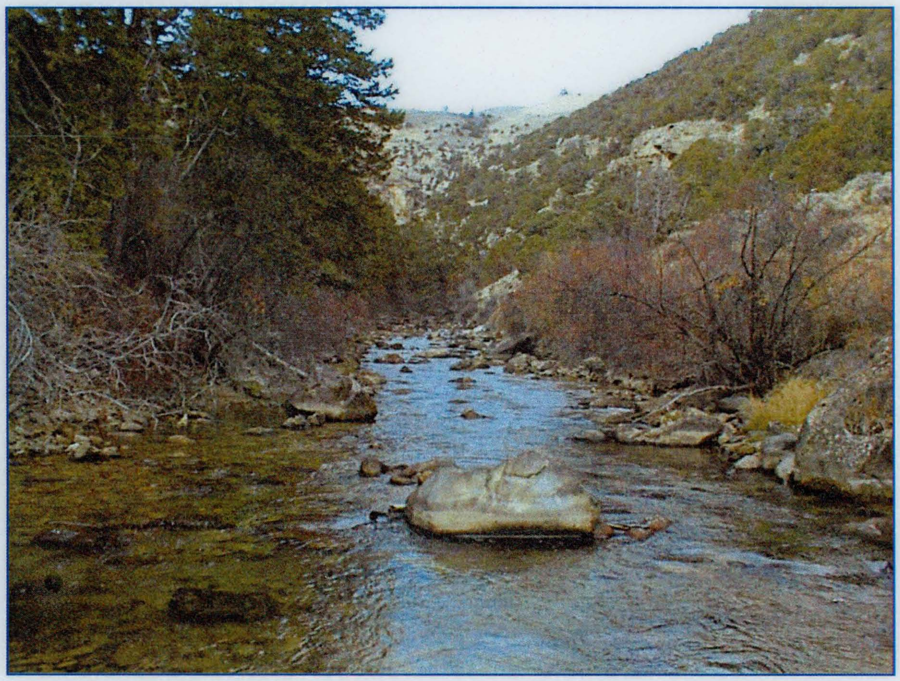
FINAL REPORT

POPO AGIE RIVER WATERSHED STUDY, LEVEL I



Prepared for:

Wyoming Water Development Commission
6920 Yellowtail Road
Cheyenne, WY 82002

Prepared by:

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772 Whalers Way, Suite 200
Fort Collins, CO 80525
(ACE Project No. WYWDC17)

July 9, 2003

ANDERSON CONSULTING ENGINEERS, INC.
Civil • Water Resources • Environmental

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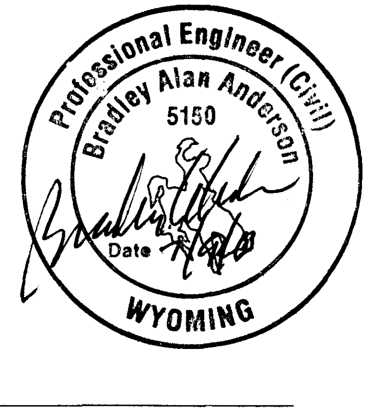

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Chapter 1

INTRODUCTION

1.1 General

On May 30, 2001 Anderson Consulting Engineers, Inc. (ACE) entered into a contract with the Wyoming Water Development Commission (WWDC) to provide professional services for the Popo Agie River Watershed Level I Study. ACE was retained to evaluate and describe the Popo Agie River watershed and specifically develop a watershed management plan. Problems and problem areas within the watershed are to be identified and practical economic solutions proposed. This report documents the results of all tasks associated with this effort.

1.2 Project History

The City of Lander is located near the eastern slope of the Wind River Range in west central Wyoming and is considered by a growing number of people as a highly desirable place to live. Since 1990, Lander and the adjacent rural areas have sustained sufficient growth to alert community leaders to the needs for planning and consideration of the area's existing resources. By 1995, the Lander population had increased to approximately 7,370 with an additional rural population of approximately 2,650, bringing the total population for the planning area to about 10,020.

Historically, the Lander Valley's economy was dominated by the Atlantic City Iron Mine; its closure in 1983 eliminated 500 jobs and began an economic downturn that resulted in a population reduction of almost 25 percent by 1990. Since 1990, however; the region and its amenities have been *discovered*. The 1993 publication, "100 Best Small Towns in America" by N. Crampton, is attributed by some as the initiation of an influx of residents. According to informal statistics, approximately 18 percent of Lander's population in 1994 had arrived in the previous three years and inquiries to the Chamber of Commerce increased by 600 percent.

In response to foreseen pressures on the area's natural resources, the Lander Valley 2020 Committee was formed by the community and the PACD and held their first meeting in 1994. Approximately 200 people attended that meeting and discussed their concerns for the region and its future. In the group's second meeting on May 20, 1995, water quality and planning were identified as the issues of most concern. The Lander 2020 Water Planning Committee (LWPC) and its Steering Committee were formed to inventory and investigate water resources-related issues in the area. The Steering Committee consists of twenty volunteers representing a cross section of the community. Its members include representatives of local community governments (City of Lander, Town of Hudson, and Fremont County), federal agencies (USFS and BLM), the Wind River Reservation, ranchers, outdoor enthusiasts, and others. The LWPC Steering Committee was established to develop the watershed plan by building agreement among citizens with diverse viewpoints. It receives technical assistance from United States Fish and Wildlife Service (USFWS), the Natural Resources Conservation Service (NRCS), the United States Environmental Protection Agency (USEPA) and other interested entities. ***(Please note that the NRCS was formerly referred to as the Soil Conservation Service, or SCS. Within this document, all references to this agency will be by its current name, NRCS).***

In 1999, following four years of research, the LWPC published the "Lander 2020 Water Planning Report". That document summarizes the planning area's demographics, surface and groundwater quality and quantity, aquifer sensitivity and vulnerability, important aquatic life, habitat quality, and riparian area conditions. The item presented in the 2020 Report that is especially pertinent to this Level I watershed study was the recommendation for further study and state assistance. Specifically, the report stated, "…the committee believes that comprehensive and integrated water planning by all agencies, groups, and interests is critical. Such coordination would achieve the following:

- Coordinate and network with all individuals, groups and agencies engaged in water studies and water planning initiatives.
- Help local planners and stakeholders identify, assess, and monitor water resources and potential problems.
- Acquire and publish information about the Popo Agie watershed and its water resources.
- Promote the standard, uniform use of EPA-approved practices for measuring water quantity and quality to yield scientifically sound data.
- Help acquire regional resources (financial and human) for water resource protection, mitigation, and restoration of impaired water bodied in Popo Agie watershed.
- Help deliver regional resources and planning tools to support locally determined needs, goals and objectives.

The Lander 2020 Water Planning Committee suggests that an agency whose public charge is to develop a watershed assessment be asked to fulfill these functions. In the Lander Valley, the Popo Agie Conservation District (PACD) is a likely candidate." This recommendation culminated in the application for a Level I study on behalf of the PACD as the project sponsor.

1.3 General Description of the Study Area

The Popo Agie River watershed is located on the eastern slope of the Wind River Range in Fremont County, Wyoming (Figure 1.1). The Popo Agie River watershed can be subdivided into three principal subbasins: the North Popo Agie River, the Middle Popo Agie River, and the Little Popo Agie River. The topography of the basin varies greatly, ranging from the rugged alpine peaks of the Popo Agie Wilderness surpassing 13,000 feet in elevation, to the gently rolling lowlands near Riverton, Wyoming where the elevation is less than 5,000 feet.

The City of Lander is the economic and population center of the Popo Agie River Basin. Historically, mining activities dominated the local economy. Today, the economic growth has been dominated more by tourism and agricultural activities.

The majority of the basin is federally managed public land (Figure 1.2). The largest portion of these lands is managed by the United States Forest Service as the Shoshone National Forest that includes the Popo Agie Wilderness Area. In addition, portions of public lands are managed by the Bureau of Land Management (BLM). Downstream of the Town of Hudson, the basin lies within the boundary of the Wind River Indian Reservation.

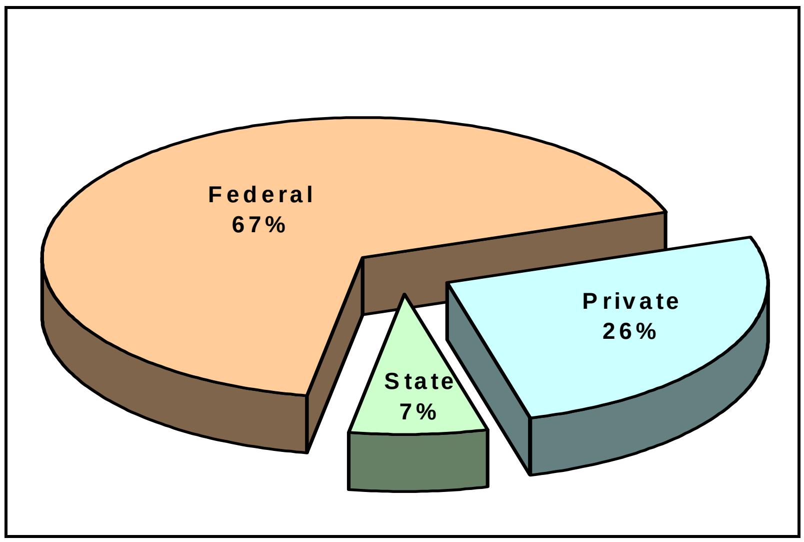


Figure 1.2 Distribution of Land Ownership in the Popo Agie River Watershed.

1.4 Key Issues

It is the goal and objective of the sponsor and the WWDC to generate a watershed management plan (the Plan) that is not only technically sound, but also one that is practical and economically feasible. The formulation of the Plan will also include development of a database to facilitate the planning process and the evaluation/implementation of watershed improvements. In order to accomplish this task, the PACD, the Steering Committee, WWDC, and the consultant identified and addressed several key issues.

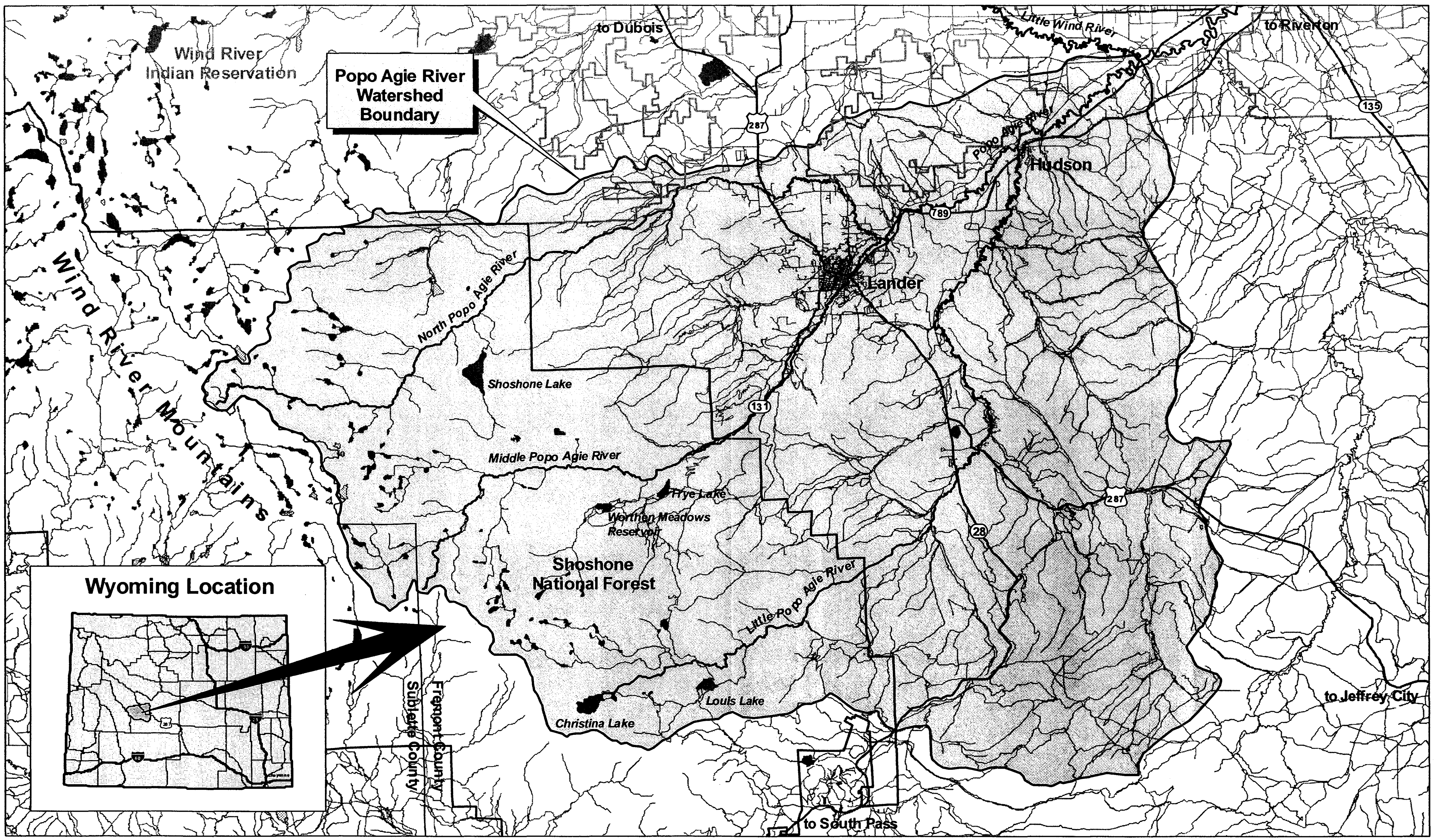


Figure 1.1 Location Map

1.4.1 Surface Water Availability and Timing

One of the principal issues associated with this project involves the quantity and timing of surface water runoff. The three principal streams possess typical snowmelt hydrographs. During the winter months, streams are supported by groundwater flow from alluvial materials and are typically at their lowest. Spring snowmelt beginning in May and peaks during the month of June before receding to low-flow conditions during the summer and fall months.

Diversions from the rivers and streams within the watershed include municipal, industrial and irrigation diversions. The City of Lander diverts surface water from an intake structure located on the Middle Popo Agie River near the mouth of Sinks Canyon. An infiltration gallery also exists which diverts water from the Middle Popo Agie River between the surface water intake structure and the City of Lander. In addition, there are several irrigation canals/companies operating within the basin. These irrigation entities all divert flow from the tributaries during the irrigation season (Figure 1.3). The timing associated with these diversions typically coincides with periods of limited runoff within the drainages. A portion of the water diverted for municipal and irrigation purposes returns back to the streams as return flow or effluent. However, given the limited runoff during the summer months as well as the diversions and the location of the return flows, certain stream reaches may be severely depleted, consequently degrading habitat for aquatic biota. According to the USFWS, flows ranging from 25 to 50 cfs are desirable to sustain conditions beneficial to aquatic life (Lander 2020, 1999). Flows on the Middle Popo Agie River near Lander have been measured as low as 5 cfs; this magnitude of flow has been reported to exemplify the need for maintenance of flows during the low-flow period**.**

Figure 1.3 Consolidated Ditch Diversion: Example Structure Located on the North Popo Agie River.

1.4.2 Flooding and Flood Control

Flooding has been a long-term problem in the Popo Agie River watershed; particularly on the Middle Popo Agie River. Major floods, recorded in 1963 and 1995, both promulgated modifications to the channel to improve the river's conveyance capacity and reduce impacts associated with flooding. Prior to 1964, flooding sources included the Middle Popo Agie River, Dickinson Creek, Squaw Creek, and Baldwin Creek. The 1963 event on the Middle Popo Agie

River was estimated to be approximately 4,180 cfs, which exceeded the 500-year flood event. Following that event, major channel modifications were made which included increasing the conveyance capacity of the channel through Lander to 3,800 cfs. Modifications included channel widening and levee construction. In 1975, a flood warning system was installed that provides from 1 to 2 hours notice in the event of a flood.

Flooding again in 1995 promulgated another wave of flood mitigation measures. By 1997, several flood protection projects were completed by landowners and the City of Lander. These efforts were reported to be uncoordinated and were completed without a comprehensive flood protection plan; consequently, flood problems appear to have been transferred to locations downstream. Figure 1.4 shows a location where flooding occurs frequently within the City of Lander.

Figure 1.4 Flood Prone Area of Middle Popo Agie River at 2nd Street.

Flooding also is reported on the Little Popo Agie River near the Town of Hudson. This location is situated at the confluence with the Middle Popo Agie River where backwater from the Middle Popo Agie River may exacerbate flooding on the Little Popo Agie River and Hudson Draw.

The NRCS has recently completed a flood study of the Middle Popo Agie River in the reach affecting the City of Lander. Their study includes evaluation of various alternatives designed to reduce or eliminate future flooding.

It is commonly accepted within the community that improvements must be identified to reduce the magnitude of the flooding event, and/or convey the flood event through the watershed thereby reducing potential damages due to flooding. These improvements must be formulated to avoid exacerbating the potential for flood damages in downstream reaches. In addition, the improvements must be integrated with the results of previous and ongoing studies such as those completed by FEMA, the community and the NRCS.

1.4.3 Water Quality

Water quality of surface water resources in the basin was previously identified by the Steering Committee as another key issue. The Popo Agie River is subjected to several sources of contamination, including both point source and non-point sources. According to the Wyoming Department of Environmental Quality, most stream segments in the study area are classified as

Class II waters. The exceptions to this statement are those stream segments found within the Popo Agie Wilderness Area which are classified as high quality, Class I waters. The stream classifications govern the water quality standards prescribed by the State for each segment, anti-degradation rulings, and dictate provisions of discharge permits within the basins.

Point sources of contamination are easily identifiable because they are represented by discrete, definable, locations of discharge. That is, there is usually a pipe outfall to a surface water body. Within the Popo Agie Watershed, point sources of contaminants include several industrial sites permitted through the United States Environmental Protection Agency's (USEPA) National Pollutant Discharge Elimination System (NPDES) and administered by the Wyoming Department of Environmental Quality. NPDES permit sites in the watershed include the City of Lander's wastewater treatment plant (Figure 1.5) and several oil "treators" where water separated from pumped oil is discharged.

Figure 1.5 City of Lander Wastewater Treatment Lagoons.

Non-point source contamination is more difficult to delineate and to quantify. There are typically no identifiable locations, or "points", where contaminants are delivered to a surface water body. Even though they may not be as visible or discernable as point sources, they may be just as detrimental (if not more) to water quality. Within the Popo Agie River watershed, potential sources of non-point source contamination include runoff from agricultural lands (range lands and irrigated acreage), septic systems and leach fields, runoff from urban areas (streets, parking lots, etc.), treatment of noxious weeds, and urban land use such as application of fertilizers and herbicides to lawns and landscapes.

Presently, the PACD is conducting an assessment of the watershed using the Wyoming Department of Environmental Quality Beneficial Use Reconnaissance Program (BURP)/ Bioassessment protocol. This protocol is designed to address assessment issues relative to the State's 305b reporting process and includes an assessment of water quality. Data and information available from this ongoing PACD study are to be integrated into the database developed during this work effort.

1.4.4 Channel Stability

Surface water stream channels throughout the watershed have been directly and indirectly affected by man's activities in many ways. An example of direct impacts includes channelization of the Middle Popo Agie River within the city of Lander to mitigate flooding issues. Portions of the Little Popo Agie River have also been straightened in an effort to reduce flooding. By straightening the channel and eliminating natural meander patterns, flood flows are conveyed more efficiently through a reach; however, accelerated velocities and steepened channel slopes may lead to both lateral migration and vertical degradation.

Other land use practices that can exacerbate channel stability problems include agricultural activities occurring immediately adjacent to the stream channel with no riparian buffer zone (Figure 1.6). Conditions such as this were recently mitigated during the completion of the Squaw Creek/Baldwin Creek Water Quality Improvement Project that was sponsored by the Popo Agie Conservation District. These creeks had been identified as the single largest contributors of sediment to the Popo Agie River. This project utilized monies obtained through the USEPA's 319 water quality grant program and administered by WDEQ Water Quality Division, to restore degraded portions of the two creeks, thereby reducing the overall sediment contribution to the Popo Agie River. Through the implementation of Best Management Practices (BMP's), such as creation of riparian buffers and streambank stabilization measures, the project has become a nationally recognized success. Figure 1.7 displays a portion of Baldwin Creek enhanced by these efforts.

Figure 1.6 Stream Bank Erosion on Little Popo Agie River.

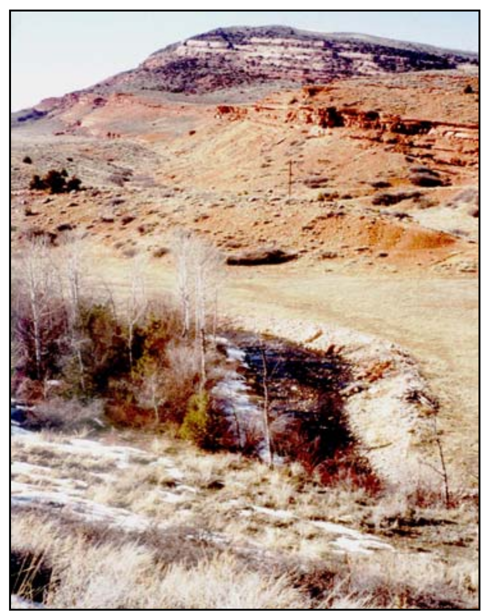


Figure 1.7 Baldwin Creek Stabilization Project.

1.4.5 Water Rights, Major Water Users and Conservation

The major water users in the Popo Agie River Watershed are associated with agricultural, industrial and municipal use. The Lander 2020 Report implies that the three major tributaries are over-appropriated, i.e., there are more water rights for the water flowing in the rivers than water to satisfy the rights, especially during the summer months. Assuming that this condition exists, the alternatives to provide for flow regulation within the watershed may be limited to conservation and/or construction of storage reservoirs to capture flood flows. It should be noted that construction of storage reservoirs must also adhere to the provisions and stipulations itemized in the Yellowstone River Compact.

With respect to agricultural use, the majority of the water is earmarked for irrigation. The ditch companies provide water to irrigators who use it primarily for irrigation of grass hay and alfalfa by simple flood irrigation techniques. Current trends in irrigation management are toward the use of gated-pipe systems. Although more efficient than other flood irrigation methods, application efficiencies are still much lower than other methods (i.e., sprinkler systems). Only a limited number of sprinkler systems exist within the watershed.

Ditch seepage losses are reportedly very high. Previous studies of several ditches, completed by the NRCS (NRCS, 1983, 1986a, 1986b, 1986c) and the GEI (1986), have indicated that seepage may represent significant portions of the irrigation diversions. The information available in these studies, as well as data gathered during the completion of this work effort, has been integrated into the project database to provide insight to potential water losses and opportunities for conservation that may provide water available for flow regulation.

With respect to the municipal water use, several studies have been completed which document the water supplies and future demands associated with the City of Lander. Lander's adjudicated water rights from the Middle Popo Agie River total approximately 13 cfs. Consequently, conservation measures associated with the municipal diversion offer limited potential with respect to water available for flow regulation.

Whether conservation is realized within the agricultural or municipal communities is largely dependent upon the identification of financial incentives provided to water users to conserve water. These incentives will likely be required to reap the benefits associated with providing additional water for flow regulation within the watershed.

1.4.6 Consensus

One of the more critical issues that must be addressed during and after the preparation of the watershed management plan is the need for a clear and concise consensus among the parties involved. The Lander Valley 2020 Steering Committee consists of twenty individuals representing a cross section of the community. Consequently, the group represents several diverse opinions with respect to its natural resources and development of a watershed management plan. Unless the Steering Committee, the Popo Agie Conservation District, and the community can arrive at a consensus with respect to the needs and direction for the basin's watershed, development of a plan may be futile. Communication and development of a community outreach program will be instrumental in moving forward with a watershed management plan.

1.4.7 Formation of a District

Implementation of a watershed management plan and irrigation system rehabilitation plan will require funding from several sources. To be eligible for funding from the WWDC, a district must be formed that has the capability to incur debt and assess its users. This issue should be addressed during the planning process to facilitate the progression of this project into a Level II study and ultimately to construction in Level III.

1.5 Project Purpose and Objectives

In view of the previous discussions, the purpose and objectives associated with the development of a watershed management and irrigation plan are itemized below.

- Facilitate consensus building among the Steering Committee, Popo Agie Conservation District, community and the Wyoming Water Development Commission.
- Facilitate public participation.
- Conduct an in-depth evaluation and description of the Popo Agie River watershed, including quantity, quality and availability of surface water sources.
- Identify water supply needs for fisheries, wildlife, municipalities and irrigation.
- Identify flood prone areas in addition to the City of Lander.
- Conduct an irrigation system inventory and develop a rehabilitation plan.
- Conduct a geomorphic investigation of the primary channels within the watershed and identify potential mitigation measures to improve impaired channel reaches.

- Develop a watershed management plan that identifies problem areas within the watershed and propose practical economic solutions.

- Evaluate alternative sources of funding.

The primary goal of the study is to combine a wealth of previously obtained information with the newly obtained data from this study to form a comprehensive Watershed Management Plan and Irrigation System Rehabilitation Plan. In summary, the Popo Agie River Watershed study represents a unique opportunity for the State and the community of Lander to plan for, and take control of the future of their watershed.

PROJECT MEETINGS

Chapter 2

2.1 Introduction

The Popo Agie River Watershed Study was completed in conjunction with a series of meetings held for the purpose of sharing information. The meetings were orchestrated by the Popo Agie Conservation District and typically included "around the table" discussions with representatives of the PACD Board, the LWPC Steering Committee, Anderson Consulting Engineers (ACE) and the Wyoming Water Development Commission (WWDC), followed by a public presentation and discussion. The objectives of the meetings were to:

- Obtain direction from the PACD Board and Steering Committee pertaining to the project;
- Obtain information and opinions of the public regarding their perspective on the watershed planning process;
- Provide guidance to the PACD with respect to setting of goals and formation of an entity capable of completing watershed improvement projects; and
- Keep the public and the PACD informed of initial results and project progress.

The meetings were well attended, indicating a high level of interest by the public in the process. The PACD advertised the meetings in the local paper and invited interested parties personally through a direct mailing process. In general, the meetings were considered a success and were characterized by a high degree of interaction between participants (Figure 2.1).

Figure 2.1 Public Meeting Attendees.

2.2 Initial Work Session

A work session was conducted on July 12, 2001 shortly after initiation of the project. The purpose of the meeting was to enable ACE, WWDC, and the PACD to get acquainted, to discuss the project and schedule, and to initiate the process of consensus building by the PACD. At the meeting, project goals and objectives were addressed.

Perhaps the most important issue discussed at this meeting was the need of the PACD to form a district capable of managing debt associated with potential implementation of watershed and irrigation improvement projects. The WWDC presented district formation options for the PACD to consider, including creation of a watershed improvement district or irrigation district(s).

2.3 Public Meetings

Four meetings were held following the initial work sessions:

1.	Project Scoping Meeting	August 20, 2001	Lander Senior Center
2.	Steering Committee Meeting	November 26, 2001	Central Wyoming College
3.	Project Update Meeting	May 20, 2002	Pronghorn Lodge
4.	Results Presentation	November 6, 2002	Pronghorn Lodge
5.	Report Presentation	May 12, 2003	Pronghorn Lodge

At each of the meetings, ACE representatives made presentations summarizing the status of the project and the next steps to be accomplished. The project GIS was demonstrated throughout the process to keep the public and the PACD up to date on the information which would ultimately be incorporated within it. Following each meeting, discussions and question and answer sessions were held (Figure 2.2).

Figure 2.2 Popo Agie River Watershed Study Results Presentation.

2.4 Reporting

The Draft Final Report for the Popo Agie River Watershed Study, Level I investigation was presented to the public on May 12, 2003. Written comments received during the 30-day comment period were reviewed and modifications to the report were made where appropriate. Copies of those comments are included in Appendix A.

During the course of this study, a considerable volume of additional information and backup data were collected. This information was collated and provided to the PACD in a two-volume project notebook. Included in these volumes are copies of the various Technical Memoranda that provide greater detail on selected tasks.

2.5 Field Trips and "Tailgate Talks"

In addition to the public meetings, ACE staff met with PACD representatives on several occasions during the completion of the study. In conjunction with the field investigations, ACE and WWDC staff met with PACD representatives frequently in an effort to coordinate field activities, determine appropriate contacts for further information, and plan future efforts. This technique for data collection emphasizes the philosophy that local ranchers, irrigators, and residents generally have the best knowledge of the watershed. Through the interviewing process, the project team incorporates this knowledge and experience directly into the study. These informal interviews, often held spontaneously while in the field, have become dubbed "tailgate talks" and provide valuable insight into the overall assessment of the watershed

When appropriate, field tours of selected sites and features were held. In fall of 2002, ACE, WWDC, PACD, and NRCS representatives toured potential storage sites in an effort to evaluate feasibility and to discuss storage objectives (Figure 2.3).

Figure 2.3 Representatives of ACE, WWDC and PACD Discuss Storage Opportunities at Worthen Meadows Reservoir.

Chapter 3

WATERSHED INVENTORY

3.1 Introduction and Purpose

There is a considerable amount of available information pertaining to the Popo Agie River watershed and its resources. This information spans a wide variety of disciplines and includes the basin's hydrology and water quality, land use and ownership, geology and soils, and agricultural practices to name just a few. Each resource area has its own issues and problems relating to growth and increased demands being placed upon it. Development of a watershed management plan can be a daunting process when facing such a variety of issues.

The purpose of the watershed inventory phase of this project was three fold. It was intended to:

1. collect, review, and compile pertinent information regarding the study area;
2. collate this information in a single database; and
3. assess the information to identify problem areas within the watershed.

3.2 Geographic Information System

The results of the data collection efforts were incorporated into a comprehensive Geographic Information System (GIS). A GIS can be thought of as a powerful three-dimensional mapping tool that can be used to evaluate and compare spatial data pertaining to a wide range of topics. Numerous maps can be "stacked" to overlay information; each map (or "theme") incorporates data (or "attributes") pertaining to the theme. For instance, a theme showing location of irrigation ditches could also include numerical data pertaining to each ditch's irrigated acreage, improvements, problems, etc.

The Popo Agie River watershed GIS was developed with the "clearinghouse" approach in mind. The GIS is intended to incorporate not only the spatial data pertaining to the watershed, but also analytical spreadsheets and documents. Figure 3.1 displays this approach graphically. The user can evaluate spatial data with the conventional GIS tools as well as linking to photographs, spreadsheets containing analytical tools and graphical representation of the various data, and the various documents prepared or collected in the course of this investigation.

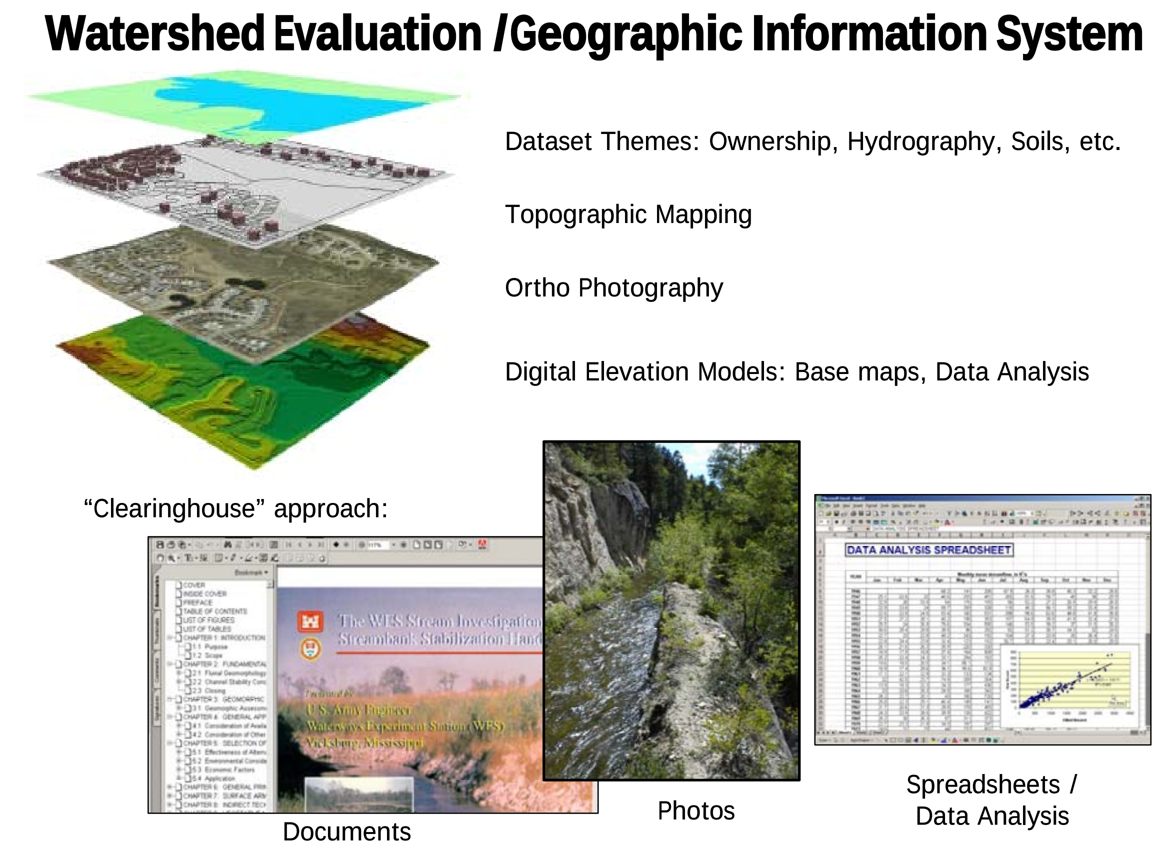


Figure 3.1 Example of the Popo Agie River Watershed Study GIS Structure and "Clearinghouse" Capabilities.

3.2.1 Spatial Data

Spatial data pertaining to the Popo Agie River watershed was collected from a wide range of sources. Agencies providing information included the State of Wyoming, the USDA Forest Service, the USDI Bureau of Land Management, Fremont County, the USDA Natural Resources Conservation Service, and others. A significant amount of the information was also specifically developed during the course of this investigation. Table 3.1 presents a list of the individual themes, maps, and aerial photographs which have been incorporated into the project GIS.

3.2.2 Additional Data

ArcView represents an incredibly powerful mapping and analysis tool for spatial data. However, when a need exists for more rigorous data analysis, its abilities can fall short of other

Table 3.1 Information Incorporated in the Popo Agie River Watershed Study Project GIS.

Land Use/Ownership
- Land Ownership
- National Land Use Classification Grid
- Popo Agie Wilderness Boundary
- USFS Shoshone National Forest Boundary
- Roads
- Recreation
- State Boundary
- County Boundary
- Grazing Allotments

Irrigation
- ACE Irrigation System Inventory
- Conceptual Rehabilitation Plans - 10 ditches
- Ditch Location Map
- Ditch Schematics - 10 ditches
- Irrigated Acreage
- Irrigation Points of Diversion
- Seepage Study
- Water Rights

Environmental
- National Wetlands Inventory
- Noxious Weeds
- Precipitation Isohyetals
- Precipitation PRISM model

Storage
- Existing Reservoir Locations
- Potential Reservoir Locations

Hydrology
- FEMA Floodplain Mappings (FIRMs)
- Gaging Station Locations
- Popo Agie River - Mainstems
- Popo Agie River - Selected Ditches
- Popo Agie River - Tributaries
- Popo Agie River Drainage Basin
- Sub-basin Drainage Area Delineations
- Water Quality Monitoring Locations
- Water Use Model Node Diagram
- Water Use Model Node Locations

Geology / Soils / Geomorphology
- General Soils
- Geomorphic Evaluation - Drainage basins
- Geomorphic Evaluation - Impairments
- Geomorphic Evaluation - Level 1
- Geomorphic Evaluation - Level 2
- Structural Geology
- Surficial Geology

Photos and Maps
- Digital Ortho Photo Quads - Individual
- Digital Ortho Photo Quads - Seamless
- Landsat Imagery
- USGS 1:100,000 Topo
- USGS 1:250,000 Topo
- USGS 1:24,000 Topo - 3D Shaded Relief
- USGS 1:24,000Topo - Standard

Document Links
- Watershed Management Plan
- Ditch Inventory Reports
- Water Use Model Documentation
- Additional documents available in an electronic format

Spreadsheet Links
- Geomorphic Evaluation - Level 1
- Geomorphic Evaluation - Level 2
- Hydrologic Database
- Lander Climate Database
- PACD Water Quality Database
- Reservoir Site Evaluation
- Seepage Study Results
- Water Use Models (6)

Photo Links
- Geomorphic Evaluation Sites
- Irrigation System Inventory Sites
- Seepage Study Sites

Analysis Tools
- Sinuosity Tool
- Channel Slope Tool
- Map Selection Tool

tools. In an effort to provide the PACD with as powerful a tool as possible, links were incorporated into the GIS to other software tools where appropriate. The objective was simply to provide the "right tool for the job". Consequently, the user is capable of linking to a variety of spreadsheets developed in Microsoft Excel which incorporate analytical capabilities not available in ArcView. Likewise, many of the documents prepared or collected during this investigation are linked to the GIS.

3.3 Land Ownership and Use

The majority of land in the Popo Agie River watershed consists of publicly owned federal lands. Land ownership information was obtained from the Fremont County Assessor's Office and incorporated into the project GIS. Figure 3.2 presents a map indicating the various land ownership categories within the watershed. Federally administered public lands comprise approximately 63 percent of the watershed. The upper reaches of the basin lie within the Shoshone National Forest and are administered by the USDA Forest Service. A large portion of the National Forest has been designated as the Popo Agie Wilderness Area. Approximately 195,400 acres (37.4 percent) of the Popo Agie River watershed lie within the Shoshone National Forest and 85,000 of these acres are designated wilderness. In the lowlands of the watershed, the majority of land consists of publicly owned federal lands administered by the USDI Bureau of Land Management. These lands cover approximately 130,400 acres, or 25.6 percent of the watershed. The Wind River Indian Reservation covers approximately 7.0 percent of the watershed and state owned lands comprise approximately 6.5 percent. The remainder of the watershed is either privately owned (approximately 23 percent) or municipal. A pie chart displaying the relative percentage of land ownership within the watershed is presented as Figure 3.3.

Land use was evaluated using data obtained from the National Land Classification Data System (NLCD). The National Land Cover Characterization project was created in 1995. In addition to satellite data, scientists used a variety of supporting information including topography, census data, agricultural statistics, soil characteristics, other land cover maps, and wetlands data to determine and label the land cover type at a resolution of 30 meters. Twenty-one land cover classes were mapped, using consistent procedures for the entire U.S. and a subsequent accuracy assessment was performed.

The portion of the NLCD data set covering the study area was incorporated in the project GIS. Figure 3.4 presents graphically the distribution of these data. The grid data were summarized and the relative percentages computed. Figure 3.5 shows a pie chart of the relative distribution.

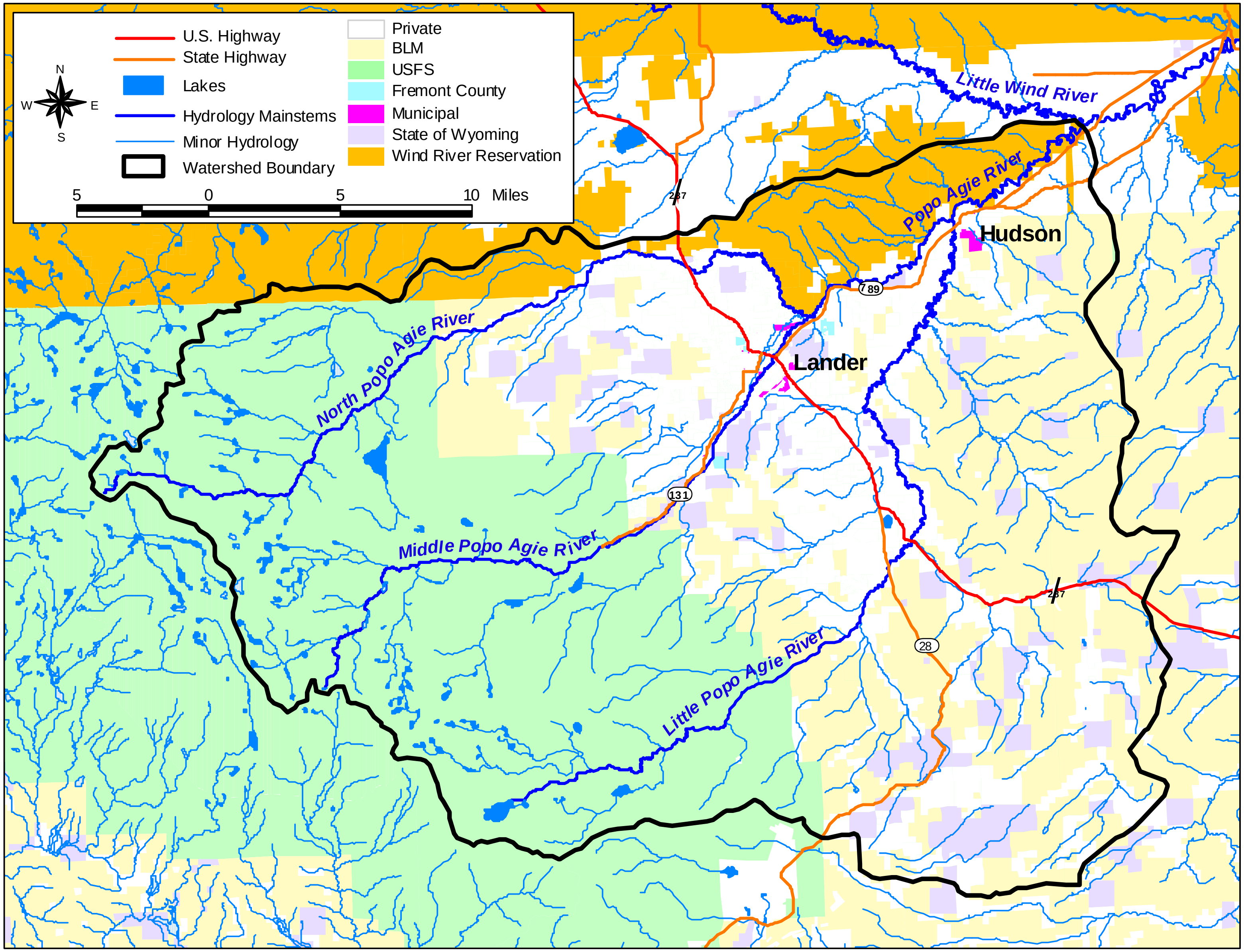


Figure 3.2 Popo Agie River Watershed Land Ownership.

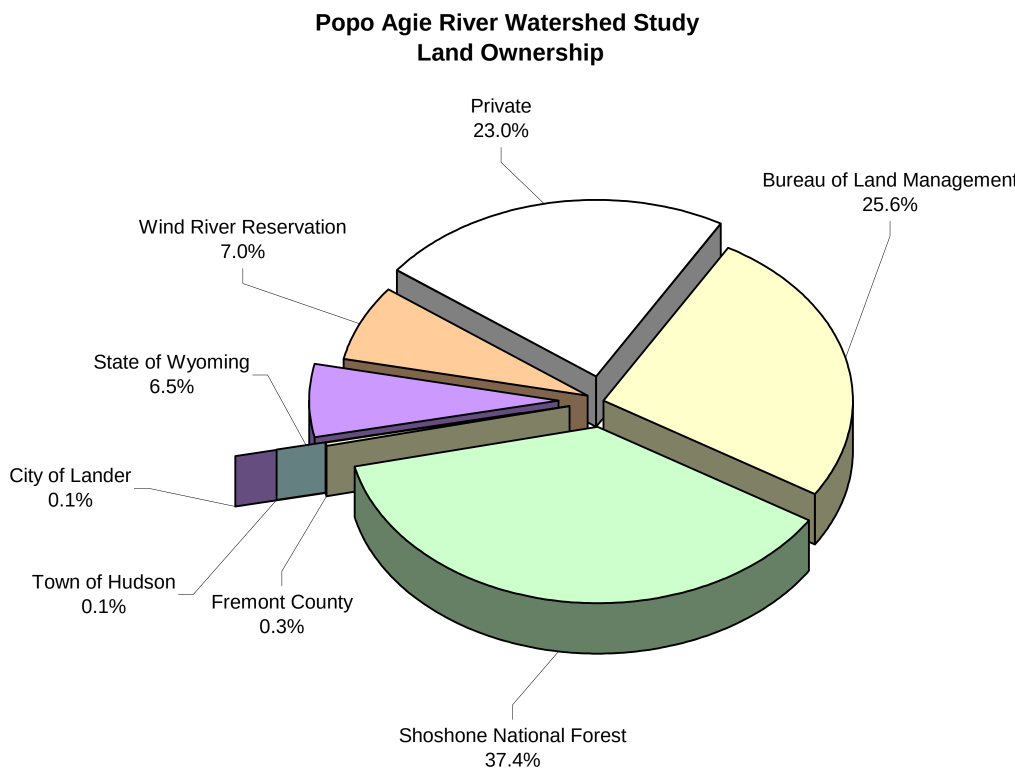


Figure 3.3 Distribution of Popo Agie River Watershed Land Ownership.

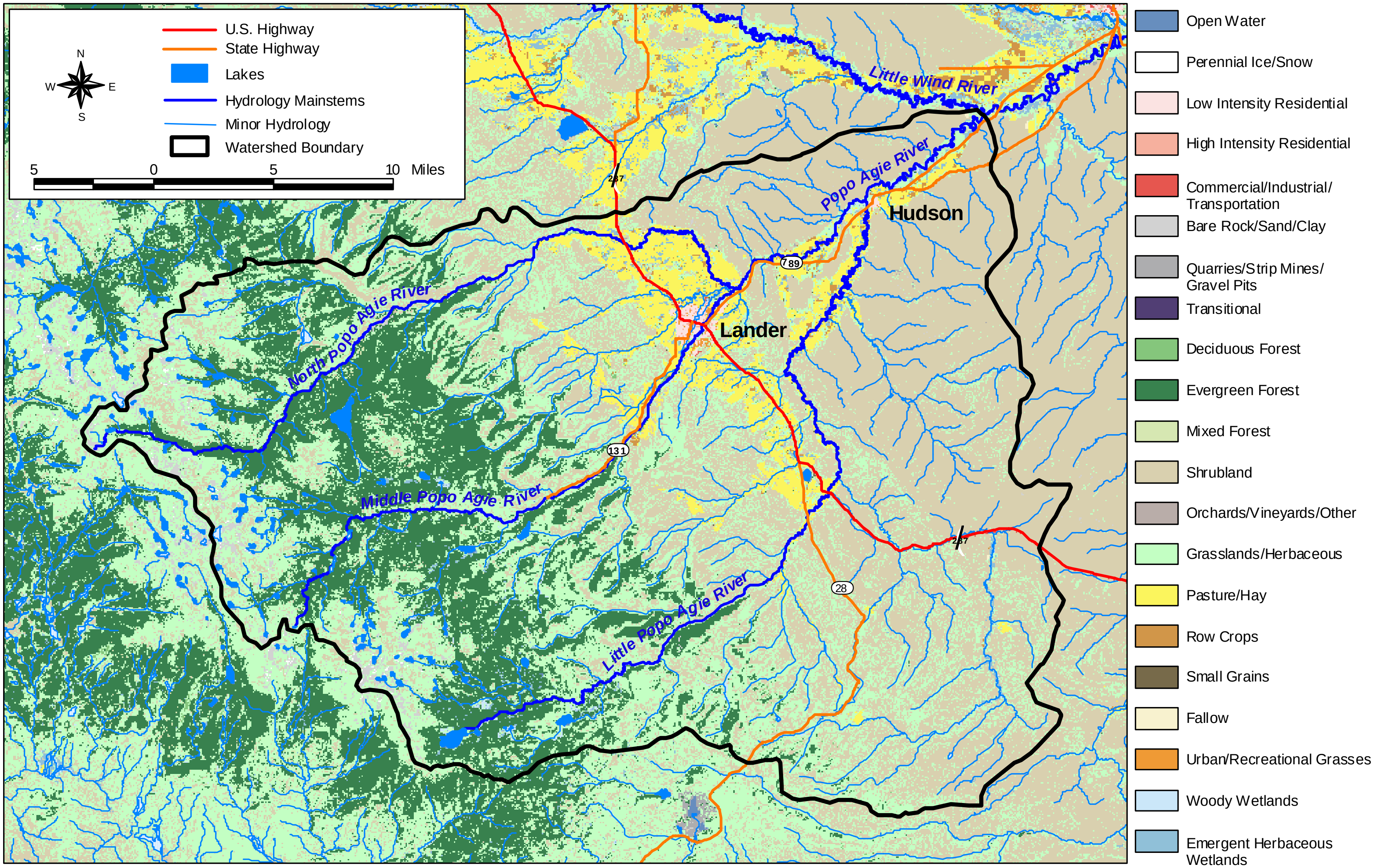
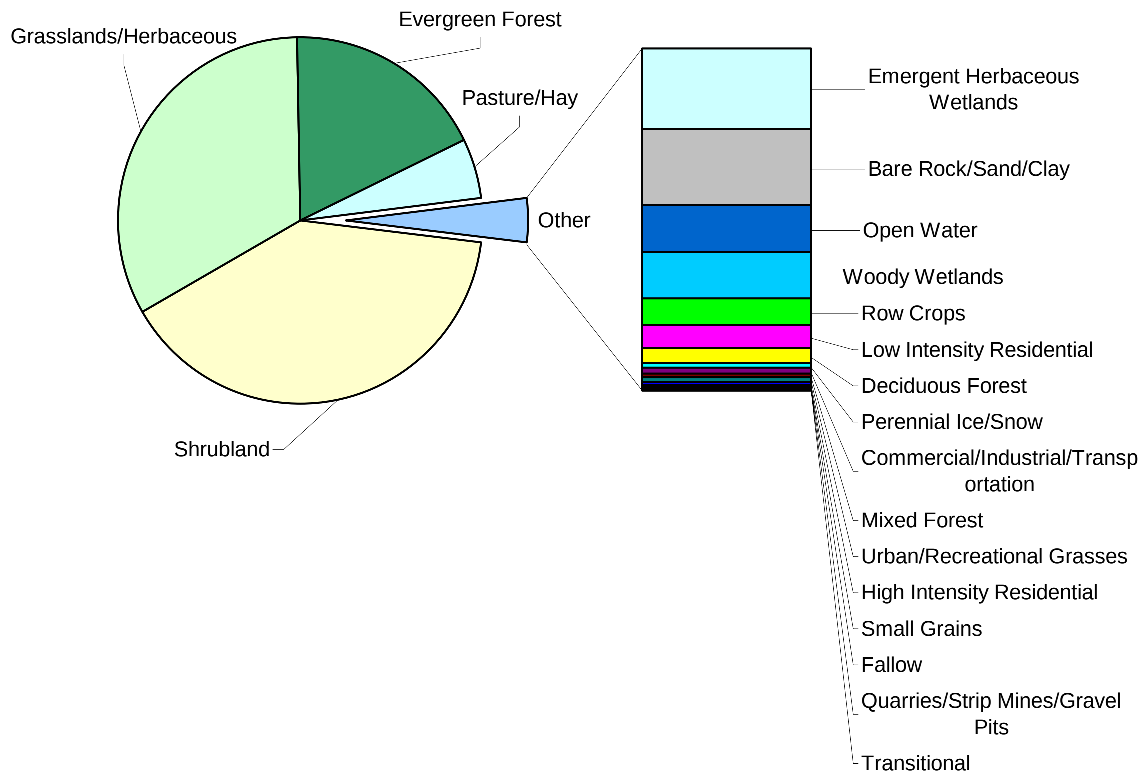


Figure 3.4 NCLD Coverage Within the Popo Agie River Watershed.



NLCD Class	Description	Percent
	Water	
11	Open Water	0.53%
12	Perennial Ice/Snow	0.06%
	Developed	
21	Low Intensity Residential	0.26%
22	High Intensity Residential	0.03%
23	Commercial/Industrial/Transportation	0.06%
	Barren	
31	Bare Rock/Sand/Clay	0.86%
32	Quarries/Strip Mines/Gravel Pits	0.01%
33	Transitional	0.00%
	Forested Upland	
41	Deciduous Forest	0.17%
42	Evergreen Forest	18.30%
43	Mixed Forest	0.05%
	Shrubland	
51	Shrubland	40.01%
71	Grasslands/Herbaceous	33.13%
	Planted/Cultivated	
81	Pasture/Hay	5.23%
82	Row Crops	0.30%
83	Small Grains	0.02%
84	Fallow	0.01%
85	Urban/Recreational Grasses	0.05%
	Wetland	
91	Woody Wetlands	0.52%
92	Emergent Herbaceous Wetlands	0.93%

Figure 3.5 Relative Distribution of NCLD Categories Within the Popo Agie River Watershed.

3.4 Climate

The Popo Agie River watershed contains topography ranging in elevation from below 5,000 feet above mean sea level (msl) at the mouth to over 13,000 feet on Wind River Peak, the highest point in the basin. Consequently, climate varies greatly within the study area. The Lander weather station is located at the airport at an elevation of 5,550 feet, msl. Data recorded at this station were obtained from the High Plains Climate Center and used as the basis of a climatic analysis. The data analysis was conducted for the period from 1971 through 2002. Table 3.2 presents a summary of this dataset.

To a large degree, the climate patterns in Lander are controlled by the Wind River Mountains. They tend to block easterly moving Pacific air masses and moisture, creating a semi-arid climate on the leeward, eastern slopes. At the time of this investigation (2001 to 2002), the region was in the midst of a severe drought. Figure 3.6 displays the annual precipitation for the study period. *As indicated on this figure, the area has experienced three consecutive years with precipitation well below the average.*

The mean annual precipitation for the Lander weather station is approximately 13.4 inches. Figure 3.7 shows the average monthly precipitation distribution. This figure and Table 3.2 show that the wettest months are typically April and May when about one third of the annual precipitation arrives. According to the NRCS, the heaviest precipitation in Lander occurs with east winds formed by the convergence of a low pressure system from the south (i.e., over Colorado) and a high pressure system to the north (i.e., over Montana or western Dakotas) forming an upslope condition.

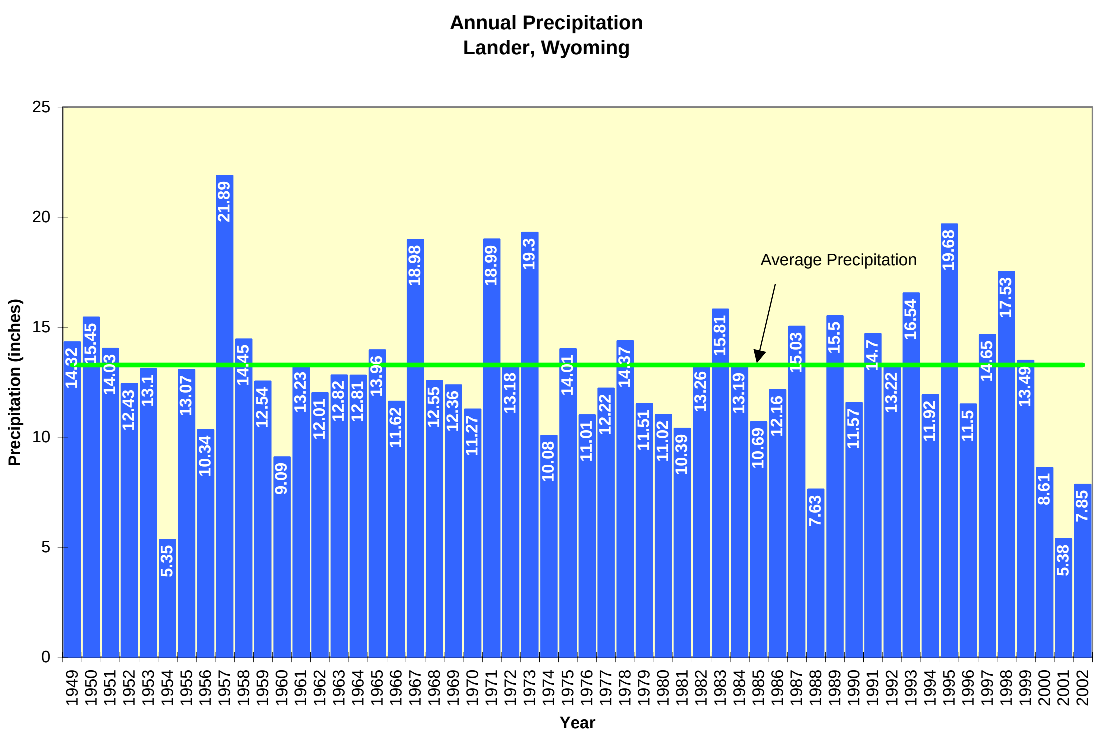


Figure 3.6 Annual Precipitation at Lander, 1971 to 2002.

Table 3.2 Summary of Normal Monthly Climate Statistics at Lander (1971 – 2000).

	Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Monthly Maximum	Mean Max. Temperature (F)	31.9	37.4	47.5	56.5	66.5	78.5	86.3	84.8	73	59.5	41.8	32.6	58
	Highest Mean Max. Temperature (F)	41.9	45.7	56.7	65.2	75.4	88.3	91.4	89	80.2	68	54.8	46	91.4
	Year Highest Occurred	1999	1991	1986	1992	1994	1988	1988	2000	1979	1988	1999	1980	1988
	Lowest Mean Max. Temperature (F)	12.7	20.4	38.1	45.8	59.2	66.7	79.5	80.3	64.7	53.2	25.1	15.6	12.7
	Year Lowest Occurred	1979	1989	1973	1973	1995	1998	1992	1977	1985	1971	2000	1983	1979
Monthly Mean	Mean Temperature (F)	20.3	25.6	35.5	43.9	53.4	63.7	70.9	69.4	58.7	46.4	30.3	21.3	45
	Highest Mean Temperature (F)	29.4	33.9	44.1	50.7	60.5	72.5	75.3	74	64.8	53.6	41.3	34.3	75.3
	Year Highest Occurred	1999	1991	1986	1987	1994	1988	1988	1983	1990	1988	1999	1980	1988
	Lowest Mean Temperature (F)	1.3	10.5	27.2	35	48.6	54.8	64.7	65.7	53.2	41.3	16	6.1	1.3
	Year Lowest Occurred	1979	1989	1973	1973	1983	1998	1993	1974	1985	1971	2000	1983	1979
Monthly Minimum	Mean Min. Temperature (F)	8.7	13.9	23.5	31.3	40.3	48.9	55.4	54.1	44.4	33.2	18.9	9.9	31.9
	Highest Mean Min. Temperature (F)	18.5	22	31.5	36.5	45.5	56.7	59.6	59.1	50.4	39.1	27.8	22.6	59.6
	Year Highest Occurred	1990	1991	1986	1987	1994	1988	1985	1983	1990	1988	1999	1980	1985
	Lowest Mean Min. Temperature (F)	-10.1	0.5	16.3	24.3	35.6	42.8	49.4	49.4	40.1	28.8	6.9	-3.9	-10.1
	Year Lowest Occurred	1979	1989	1973	1973	1975	1998	1993	1974	1971	1984	2000	1978	1979
Monthly Precipitation	Mean Precipitation (in.)	0.52	0.54	1.24	2.07	2.38	1.15	0.84	0.57	1.14	1.37	0.99	0.61	13.42
	Highest Precipitation (in.)	1.1	1.73	3.44	6.44	5.47	4.96	2.5	2.3	4.68	4.9	3.37	2.02	6.44
	Year Highest Occurred	1994	1987	1998	1999	1995	1993	1977	1979	1973	1994	1983	1997	1999
	Lowest Precipitation (in.)	0.02	0.05	0.37	0.21	0.07	0	0.1	0.07	0.01	0	0.03	0.05	0
	Year Lowest Occurred	2000	1979	1989	1992	1994	1971	1996	1985	1992	1988	1999	1981	1971

Figure 3.7 also shows the mean monthly high and low temperatures for Lander. Mean highs range from the mid 80's in July to the low 30's in January and December. Mean lows range from single digits in January and December to the mid-50's in July. Figure 3.8 displays the Isohyetals (lines of equal precipitation) within the watershed. This figure clearly shows the relationship between elevation and precipitation in amounts. The data used to generate this figure were obtained from Wyoming Geographic Information Science Center (WGISC). These data represent the results of the PRISM spatial climate data generated at the Oregon Climate Center, Oregon State University. As indicated in this figure, the mean annual precipitation varies greatly from a minimum of approximately 7 to 9 inches at the watershed mouth to over 21 to 23 inches along the crest of the Wind River mainstems.

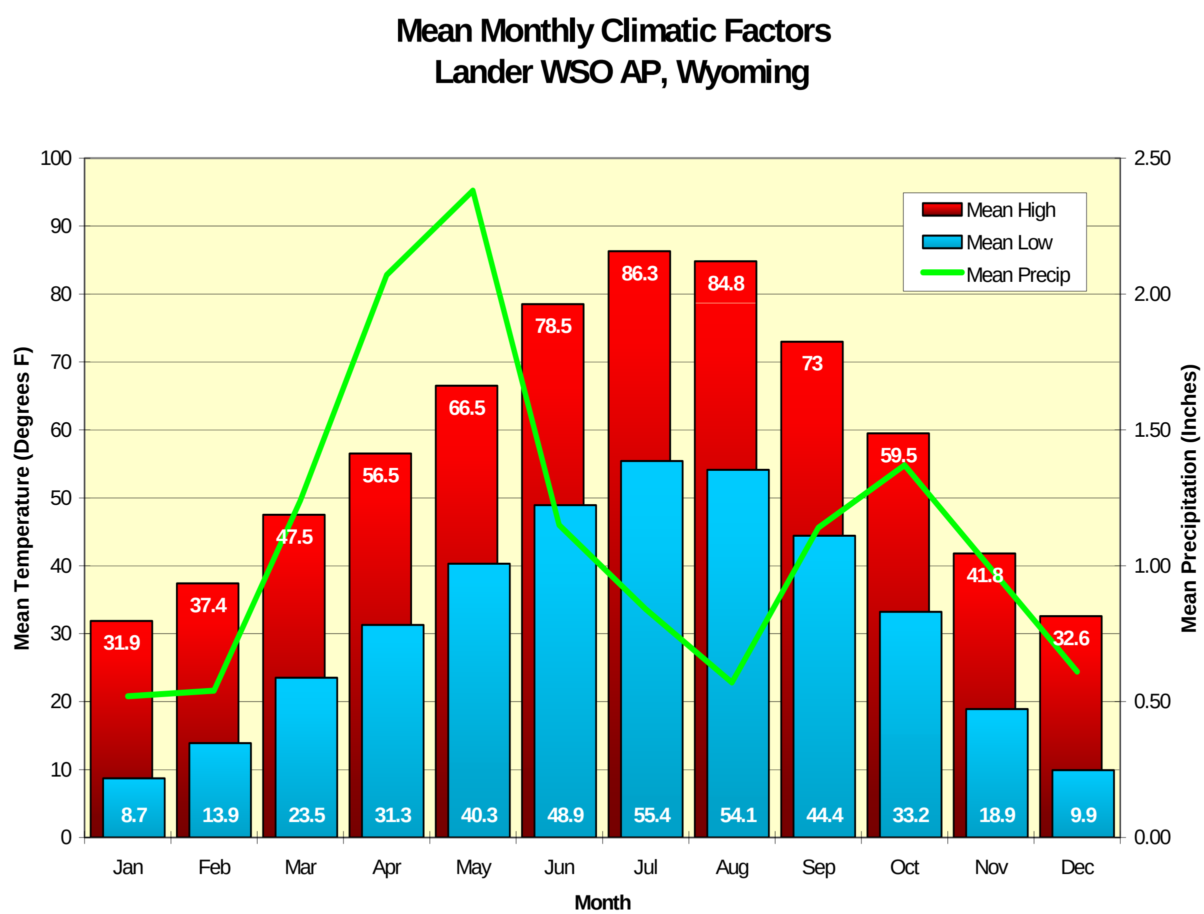


Figure 3.7 Mean Monthly Climatic Factors for Lander, Wyoming.

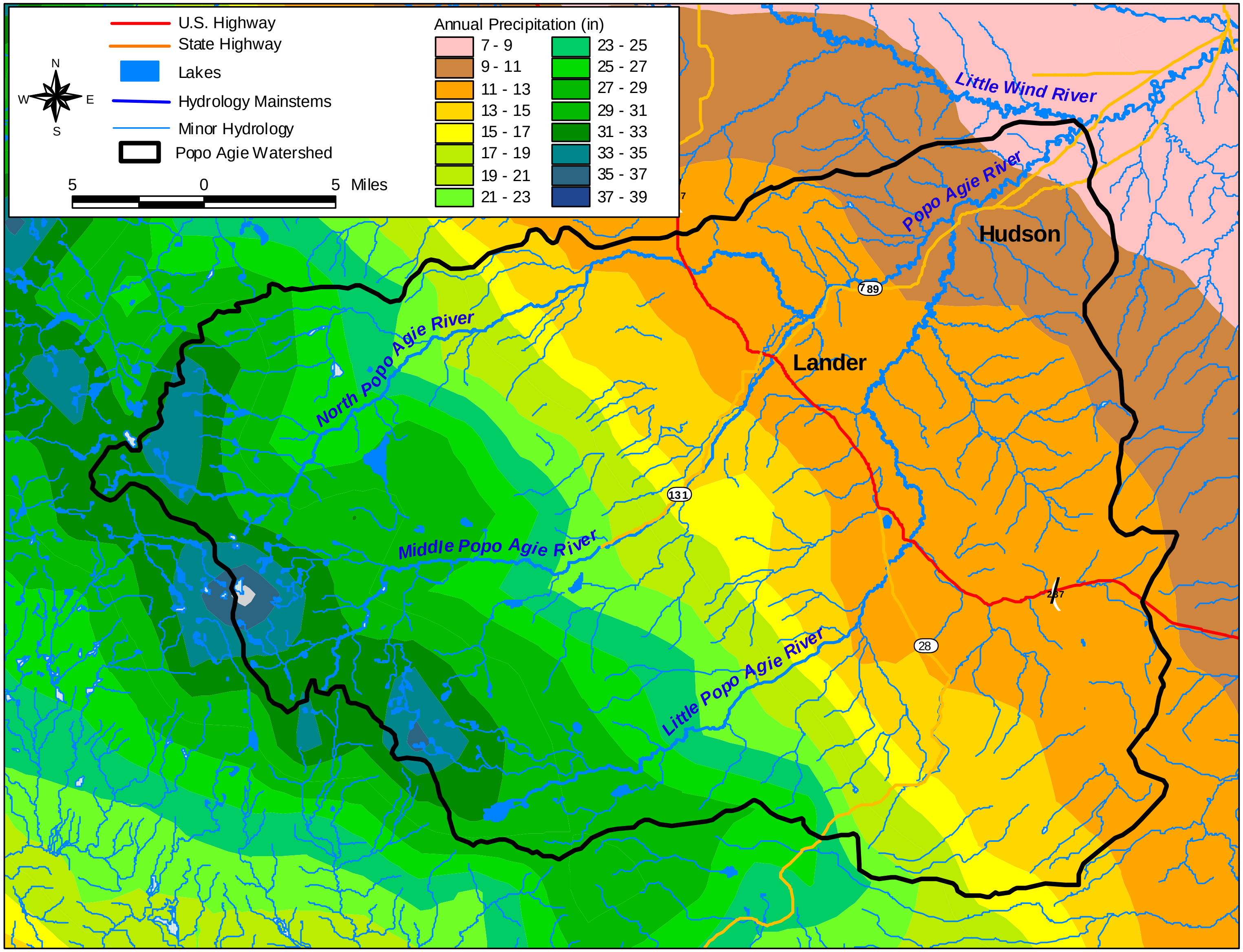


Figure 3.8 Isohytals Within the Popo Agie River Watershed.

3.5 Geology and Soils

The study area lies along the eastern flank of the Wind River Mountains. The Winds were formed during the Laramide Orogeny. They have a broadly exposed granite core characterized by narrow crests between deep glaciated gorges. Figure 3.9 displays the surficial geology map of the watershed. Extensive glacial deposits shown on the map are evidence of the glaciation in the higher reaches of the watershed. In the vicinity of the City of Lander, alluvium dominates the surface geology.

Figure 3.10 shows the generalized bedrock geologic map of the Popo Agie River watershed. Briefly, the older Precambrian rocks are found at the higher elevations in the watershed. The headwaters of each of the three mainstems originate in these formations. As one progresses down from the higher elevations towards the watershed mouth, rock strata sequentially higher (and younger) in the lithology are generally encountered.

Review of bedrock geology of the three mainstems reveals that all originate in the older and harder granites and granodiorites. Overlying these igneous and metamorphic rocks are several limestone and dolomitic formations. These formations are encountered in the middle elevations of each mainstem basin. The lower elevations of the study area consist of various sandstones and siltstones that make up the upper portions of the Wind River lithology. Cody Shale, Frontier Formation and Wind River Formations comprise the majority of the lower reaches of the study area.

Generalized soils information was obtained through Wyoming Geographic Information Science Center. Figure 3.11 presents a generalized soils map of the Popo Agie River watershed, which was prepared using these data. Appendix B presents the descriptions associated with the various mapping units found in this figure. This map provides a generalized description of soils within the study area; detailed soils information and mapping is available in the publication "Soil Survey of Fremont County, Wyoming: Lander Area" available from the NRCS. This map is intended for use in broad scale planning and general assessment of large areas of land.

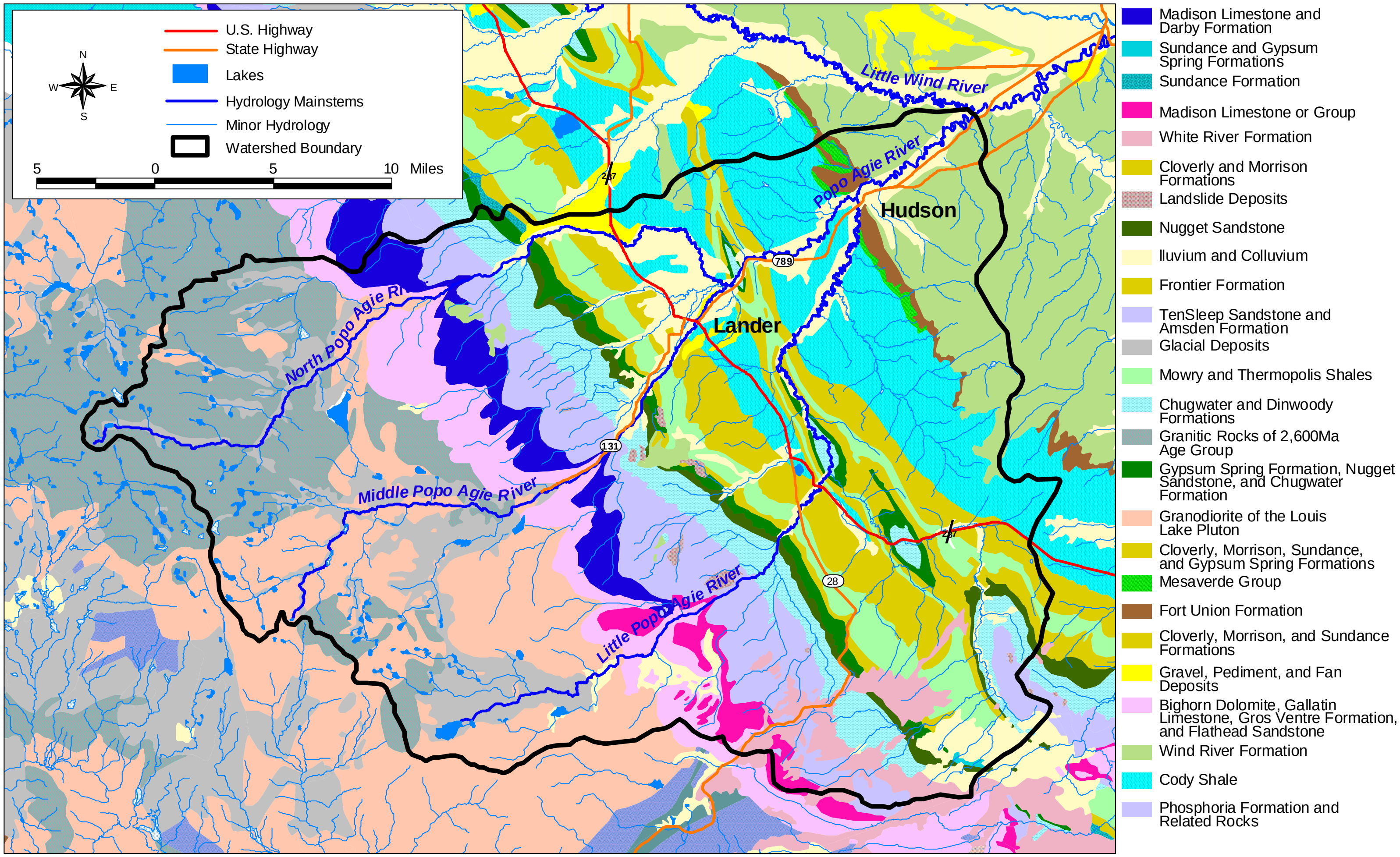


Figure 3.9 Bedrock Geology of the Popo Agie River Watershed.

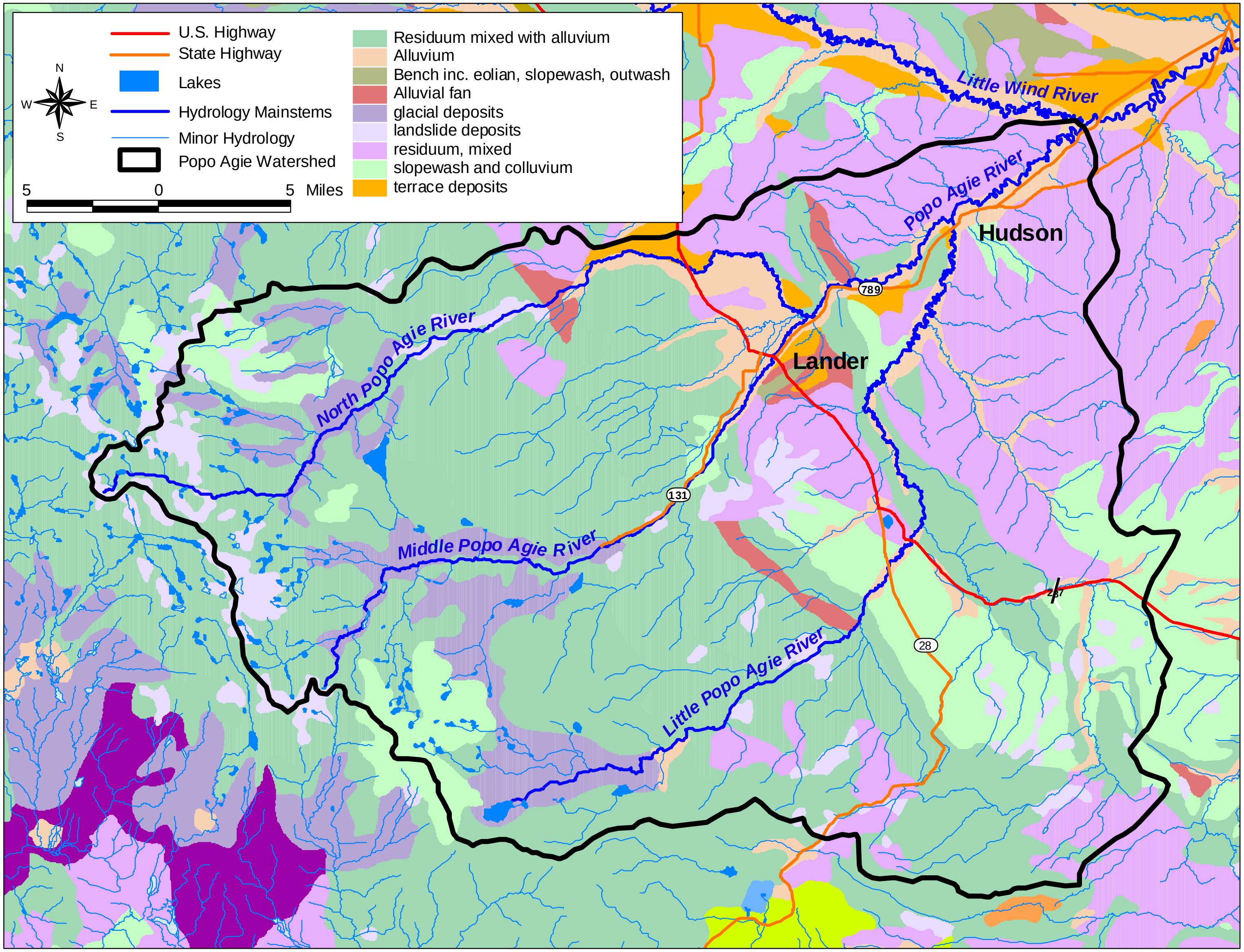


Figure 3.10 Surficial Geology of the Popo Agie River Watershed.

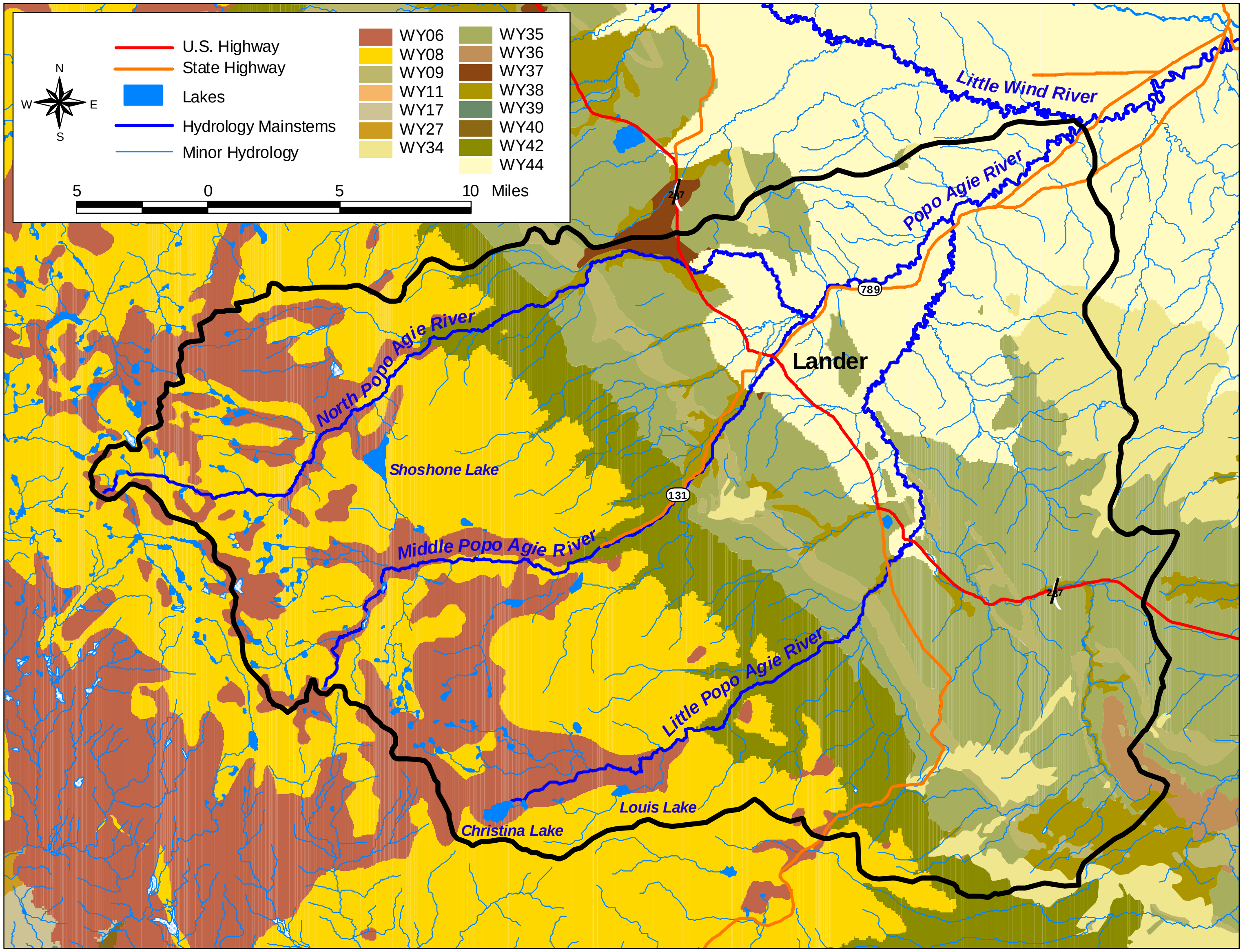


Figure 3.11 General Soils Map of the Popo Agie River Watershed.

3.6 Surface Water Hydrology

3.6.1 Basin Characteristics

The Popo Agie River is a subbasin of the Wind River / Bighorn River system. It is tributary to the Little Wind River which subsequently is tributary to the Wind River. The Popo Agie River watershed, as measured at its confluence with the Little Wind River, is approximately 803 square miles. The watershed has considerable relief; at its mouth, the elevation is less than 5,000 feet msl. At its highest point, Wind River Peak, elevations exceed 13,000 feet msl.

The watershed consists of three principal subbasins: the North Popo Agie River, the Middle Popo Agie River, and the Little Popo Agie River. Below the confluence of the North Popo Agie and the Middle Popo Agie rivers, the mainstem is called the Popo Agie River (or Big Popo Agie River). Figure 3.12 displays the delineation of watersheds associated with each of the three principal tributaries to the Popo Agie River. Likewise, Figure 3.13 shows the delineation of sub-watersheds associated with the three principal tributaries. Basin characteristics computed within the GIS are summarized in Table 3.3.

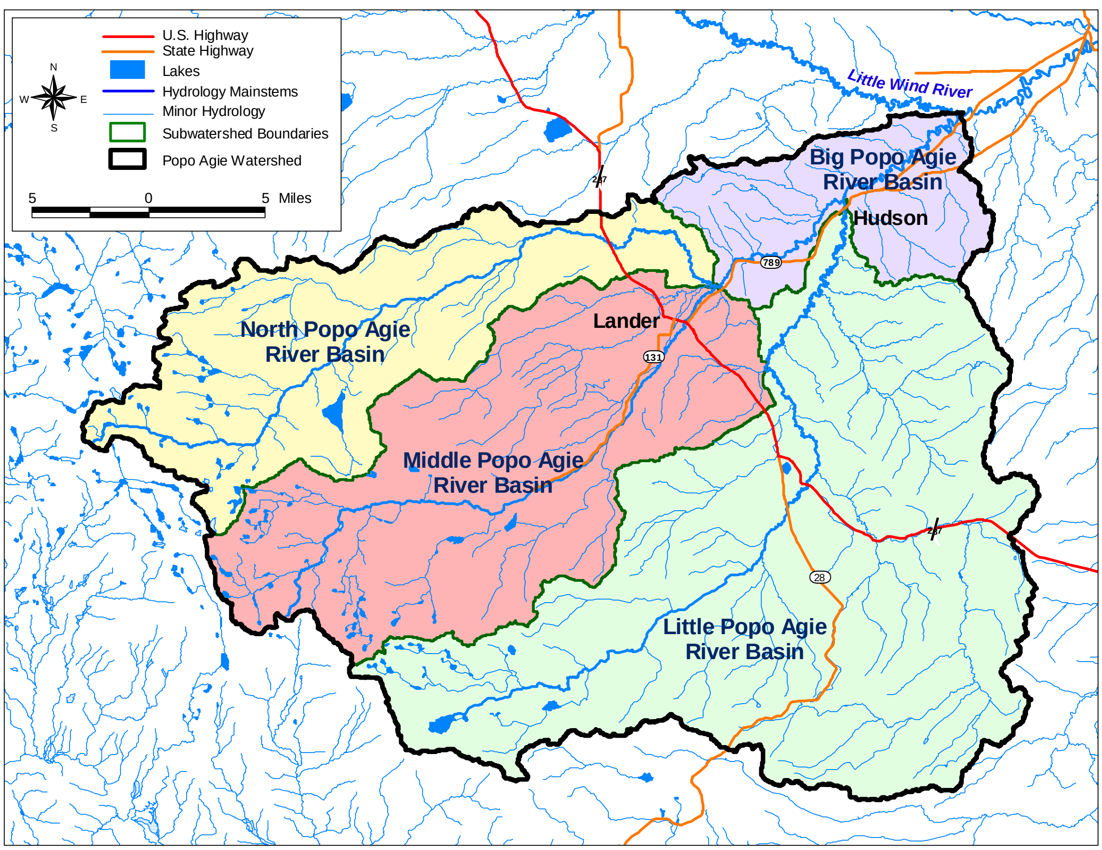


Figure 3.12 Mainstem Watersheds Within the Popo Agie River Watershed.

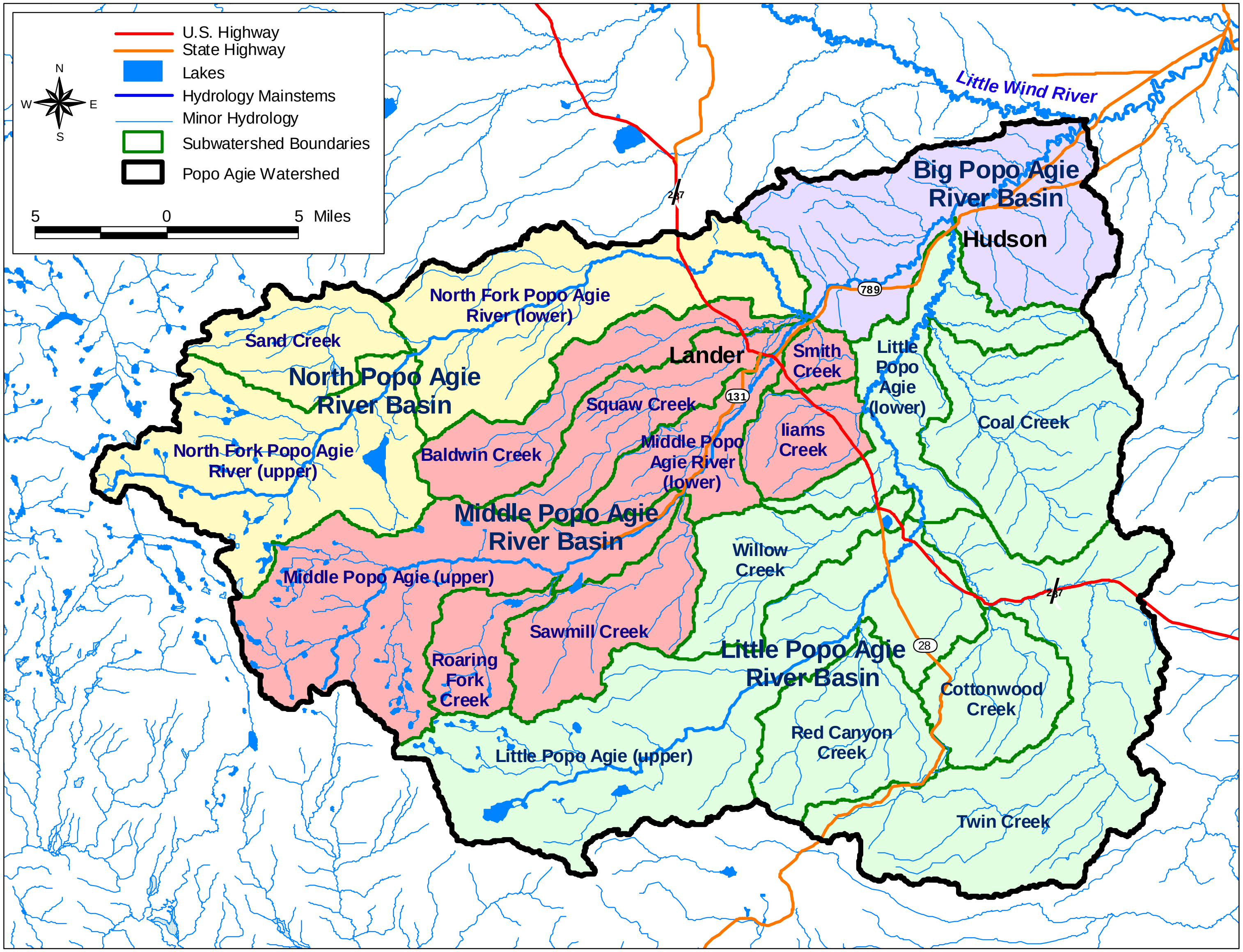


Figure 3.13 Delineation of Mainstem Subbasins Within the Popo Agie River Watershed.

Table 3.3 Popo Agie River Watershed Basin Characteristics.

Basin	Basin Code (1)	Sub-Basin	Area (Acres)	Area (Square Miles)	Elevation Minimum (Ft MSL)	Elevation Maximum (Ft MSL)	Elevation Relief (Ft MSL)	Elevation Mean (Ft MSL)
North Popo Agie River			***95,792***	***149.7***	***5,225***	***12,785***	***7,560***	***8,758***
	100800030204	Lower North Popo Agie River	23,921	37.4	5,225	9,791	4,566	6,258
	100800030202	Middle North Popo Agie River	27,381	42.8	5,865	11,339	5,474	8,563
	100800030203	Sand Creek-Popo Agie River	15,707	24.5	7,259	12,139	4,881	9,946
	100800030201	Upper North Popo Agie River	28,782	45.0	8,374	12,785	4,412	10,372
	100800030212	Lower Popo Agie River	25,447	39.8	4,992	5,665	672	5,255
	100800030211	Upper Popo Agie River	21,705	33.9	5,077	6,019	941	5,362
Middle Popo Agie River			***123,073***	***192.3***	***5,225***	***13,163***	***7,938***	***8,630***
	100800030210	Baldwin Creek	18,232	28.5	5,317	11,090	5,773	7,772
	100800030207	Lower Middle Popo Agie River	21,514	33.6	5,225	9,430	4,205	6,807
	100800030206	Middle Middle Popo Agie River	18,794	29.4	8,029	11,985	3,956	9,599
	100800030208	Roaring Fork Creek	18,561	29.0	6,104	11,086	4,982	8,725
	100800030209	Squaw Creek	15,298	23.9	5,323	10,040	4,717	7,017
	100800030205	Upper Middle Popo Agie River	30,695	48.0	8,889	13,163	4,274	10,572
Little Popo Agie River			***247,941***	***387.4***	***5,077***	***12,444***	***7,367***	***6,792***
	100800030103	Deep Creek-Little Popo Agie River	20,800	32.5	5,563	9,076	3,513	7,223
	100800030110	Government Draw	32,526	50.8	5,159	6,344	1,184	5,649
	100800030104	Little Popo Agie River	16,230	25.4	5,379	8,151	2,772	5,915
	100800030101	Little Popo Agie River-Atlantic Creek	28,281	44.2	8,174	12,444	4,271	9,788
	100800030102	Little Popo Agie River-Canyon Creek	21,689	33.9	5,560	9,952	4,392	8,106
	100800030108	Little Popo Agie River-Liams Creek	35,143	54.9	5,077	7,321	2,244	5,516
	100800030107	Lower Twin Creek	33,290	52.0	5,376	7,042	1,666	6,045
	100800030106	Middle Twin Creek-Little Popo Agie River	23,705	37.0	5,720	7,478	1,758	6,532
	100800030105	Upper Twin Creek	17,419	27.2	6,494	9,036	2,542	7,331
	100800030109	Willow Creek-Little Popo Agie River	18,885	29.5	5,291	9,207	3,916	6,571
Big Popo Agie River			***47,148***	***73.7***	***4,992***	***6,019***	***1,027***	***5,304***
Entire Basin			***513,953***	***803.1***	***4,992***	***13,163***	***8,170***	***7,455***

Note: (1) Basin Code refer to State of Wyoming 6th level hydrologic unit boundary

3.6.2 Stream Gaging Stations

Streamflow data were obtained for several streamgages located throughout the watershed. Of these, only two are currently active. An active gage is located on the Middle Popo Agie River below the Sinks (USGS Gage 06231600). This gage has been in operation since 1959. Prior to 1968, this gage was managed by the USGS, since then it has been managed by the Wyoming State Engineer's office. Data obtained from the State Engineers Office was incorporated into the project database. The gage operates only during the irrigation season (April through September). The other active gage is located on the Little Popo Agie River near Highway 28 (USGS Gage 06233000). This gage has been in operation since 1946 and also records data only during the irrigation season. All available data from each gage were collected and incorporated into the hydrologic database.

Locations of the gaging stations are shown in Figure 3.14. The period of record for each gage and the type of data collected are summarized in Table 3.4.

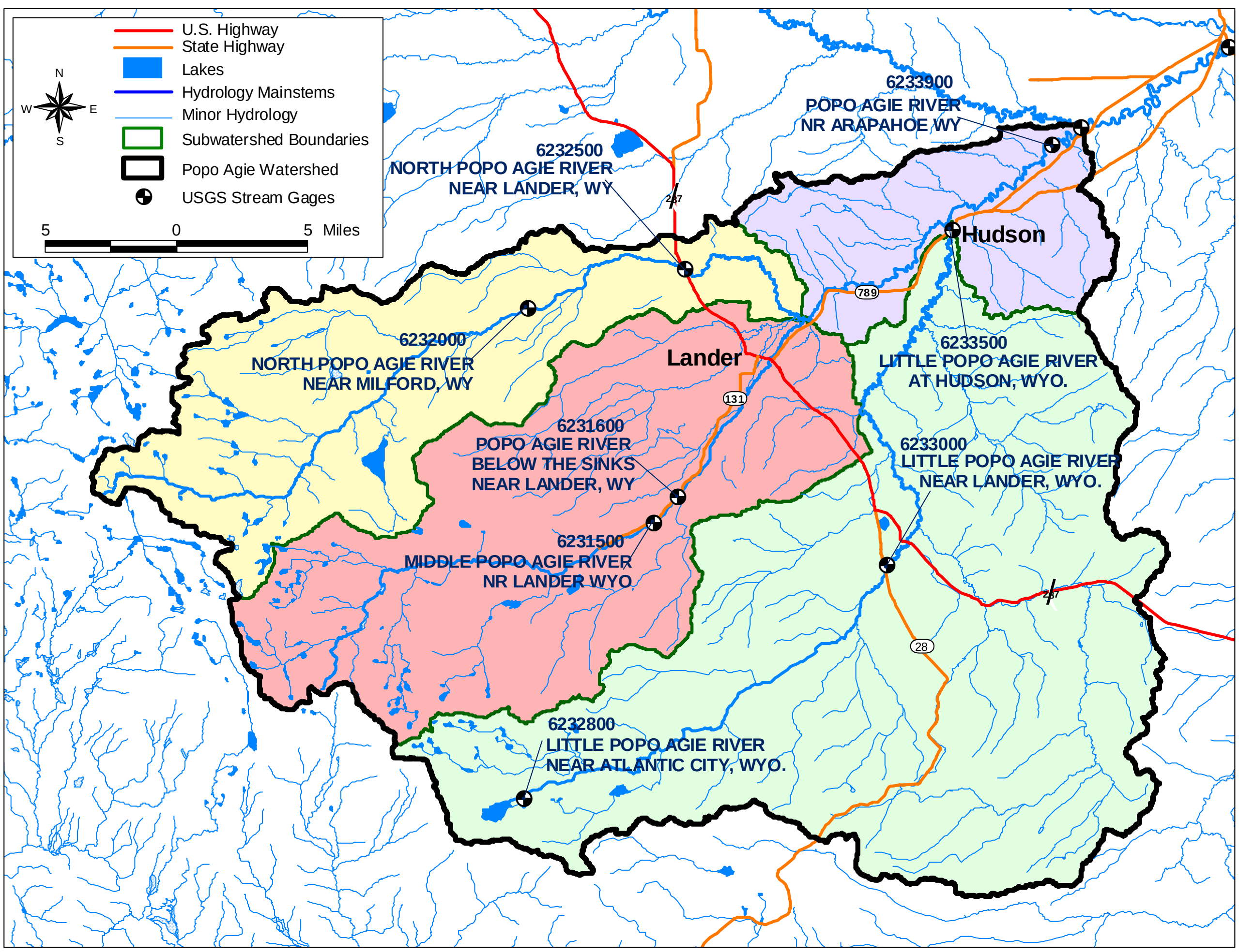


Figure 3.14 Stream Gaging Locations Within the Popo Agie River Watershed.

Table 3.4 Summary of Available Gaging Station Data Availability

Station Number	Station Name	Drainage-basin area (mi2)	Period of record in calendar years: Daily or monthly discharge	Annual Peak discharge	Quality: chemical	Quality: sediment	Quality: biology
06231500	Middle Popo Agie near Lander	86.5	1911-12;1918-24				
06231600	Middle Popo Agie River below the Sinks, near Lander	87.5	1959-00 [1]	1969-74		1965	
06231930	Baldwin Creek below Dickinson Creek, at Lander	NC			1989-93	1989-93	
06231950	Little Dickenson Creek at Lander	NC			1981		1981
06232000	North Popo Agie River near Milford	98.4	1945-63		1990		
06232500	North Popo Agie River near Lander	134	1938-53				
06232600	Popo Agie River at Hudson Siding, near Lander	NC			1983-93		1983-89
06232800	Little Popo Agie River near Atlantic City	5.99	1957-73				
06233000	Little Popo Agie River near Lander	125	1946-01				
06233340	Monument Draw at Upper Station, near Hudson	5.5		1965-72			
06233360	Monument Draw at Lower Station, near Hudson	8.38		1965-84			
06233440	Coal Mine Draw tributary near Hudson	0.63		1965-72			
06233500	Little Popo Agie River at Hudson	384	1907-09;1911-17;1938-53		1966-69;1984		
06233600	Popo Agie River at Hudson	NC	1979-93				1983;1989
06233900	Popo Agie River near Arapahoe	1,464	1979-1995	1979-1995			

Notes [1] Gage managed by State of Wyoming post 1968

3.6.3 Streamflow Characteristics

Mean Annual Hydrographs

The hydrographs associated with each of the three mainstem tributaries of the Popo Agie River are consistent with those associated with the snowmelt runoff process. Figure 3.15 displays the mean annual hydrograph derived for each of the three mainstem gage sites. Table 3.5 summarizes the mean monthly discharge at these and the remaining stream gage locations within the watershed. In general, the three stream gages displayed in Figure 3.16 are located upstream of the majority of diversions. However, each is affected by reservoir storage and releases. As shown in this figure, stream levels begin the year at their minimum levels. These baseflow conditions represent approximately 15 cfs to 20 cfs at the three gage locations. Beginning in April, the streamflow begins to increase with the initiation of snowmelt, with peaks typically occurring in June. Flows then recede through the summer months and baseflow conditions return around November to December.

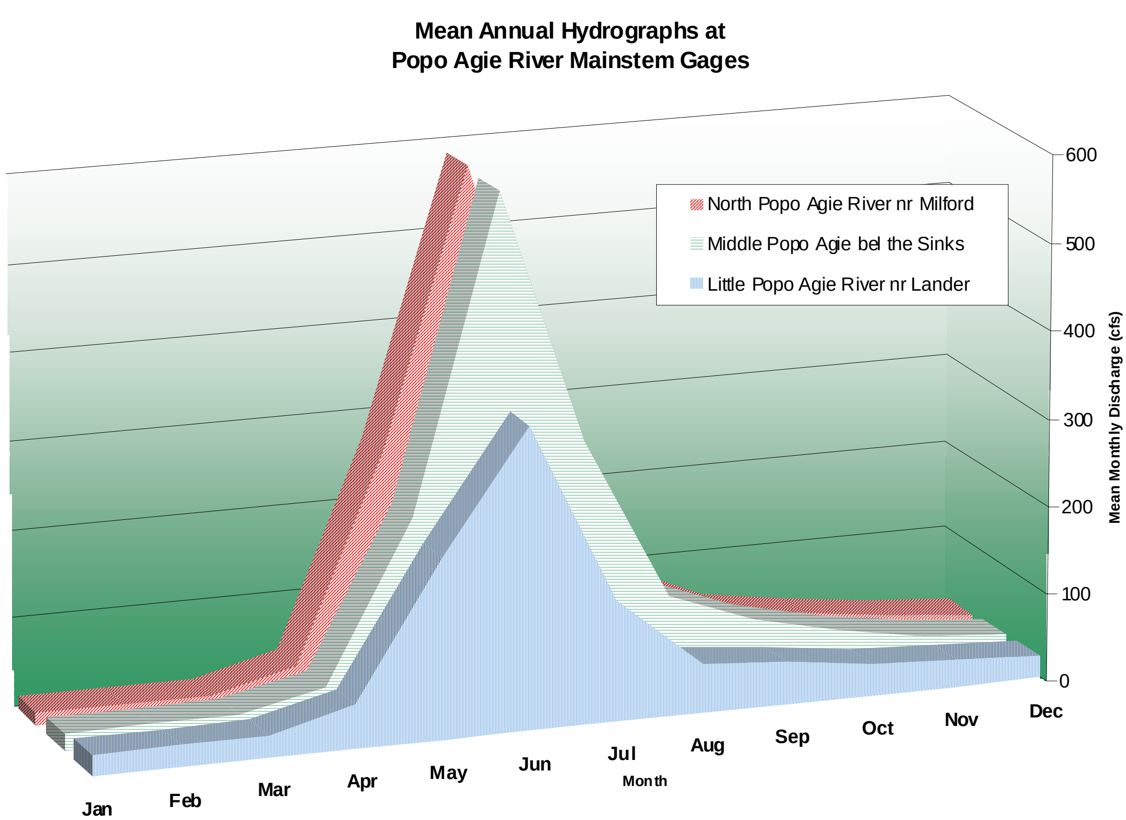


Figure 3.15 Mean Annual Hydrographs at Principal Mainstem Gaging Stations.

Table 3.5 Mean Monthly Streamflow at Popo Agie River Watershed Streamgages.

Stream Gage		Mean Monthly Discharge (cfs)											
Number	**Name**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
USGS 06231500	Middle Popo Agie near Lander	14.3	12.2	15.8	29.9	224	637	288	81.8	47.8	37.7	17.2	17.3
USGS 06231600	Middle Popo Agie River below the Sinks, near Lander	19.4	19.5	20.5	42	223	582	293	105	68.6	46.8	31	22.4
USGS 06232000	North Popo Agie River near Milford	15.5	14.9	14.3	38.8	274	588	274	96.7	54.8	39.5	27.9	19
USGS 06232800	Little Popo Agie River near Atlantic City	0.97	1.03	1	1.3	7.54	35.9	24.1	15.2	15	5.25	1.77	1.14
USGS 06233000	Little Popo Agie River near Lander	23.4	23.7	24.6	48.9	204	342	137	55.9	47.2	35.6	29.7	25.5
USGS 06233500	Little Popo Agie River at Hudson	35.9	37.9	52.2	92.4	236	375	143	44.9	46.6	56.9	50.3	40.7
USGS 06233900	Popo Agie River near Arapahoe	107	109	148	224	686	1333	591	175	171	181	150	120
USGS 06234000	Little Wind River below Arapahoe	143	138	173	381	1127	3279	1627	486	362	368	205	158
USGS 06234000	Little Wind River below Arapahoe	143	138	173	381	1127	3279	1627	486	362	368	205	158
USGS 06235500	Little Wind River Near Riverton	188	211	268	371	1120	2398	999	268	259	327	284	214

Flow Duration Analyses

It is important to note that low streamflow conditions may exist through extended periods of the year, even in reaches upstream of diversion locations. In an effort to further evaluate that nature of streamflow conditions, flow duration analyses were conducted on the three principal stream gages. Figure 3.16 shows the relative portion of the year that a given discharge is equaled or exceeded. For instance, the Middle Popo Agie gage experiences flows higher than 500 cfs approximately 10 percent of the year. Conversely, flows are lower than 500 cfs approximately 90 percent of the year.

A streamflow of 25 cfs has been assumed in this report to represent a target streamflow to promote aquatic habitat. Figure 3.16 shows that for 30 percent of the year, this flow is not achieved at the Middle Popo Agie streamgage. Likewise, the North Popo Agie and Little Popo Agie rivers experience flows less than or equal to 25 cfs approximately 38 percent and 23 percent of the year, respectively. These curves reflect the affects on streamflow of water released from storage. However, given the relatively small size of existing storage reservoirs, it is assumed these releases have minimal effect on the long-term average streamflow conditions.

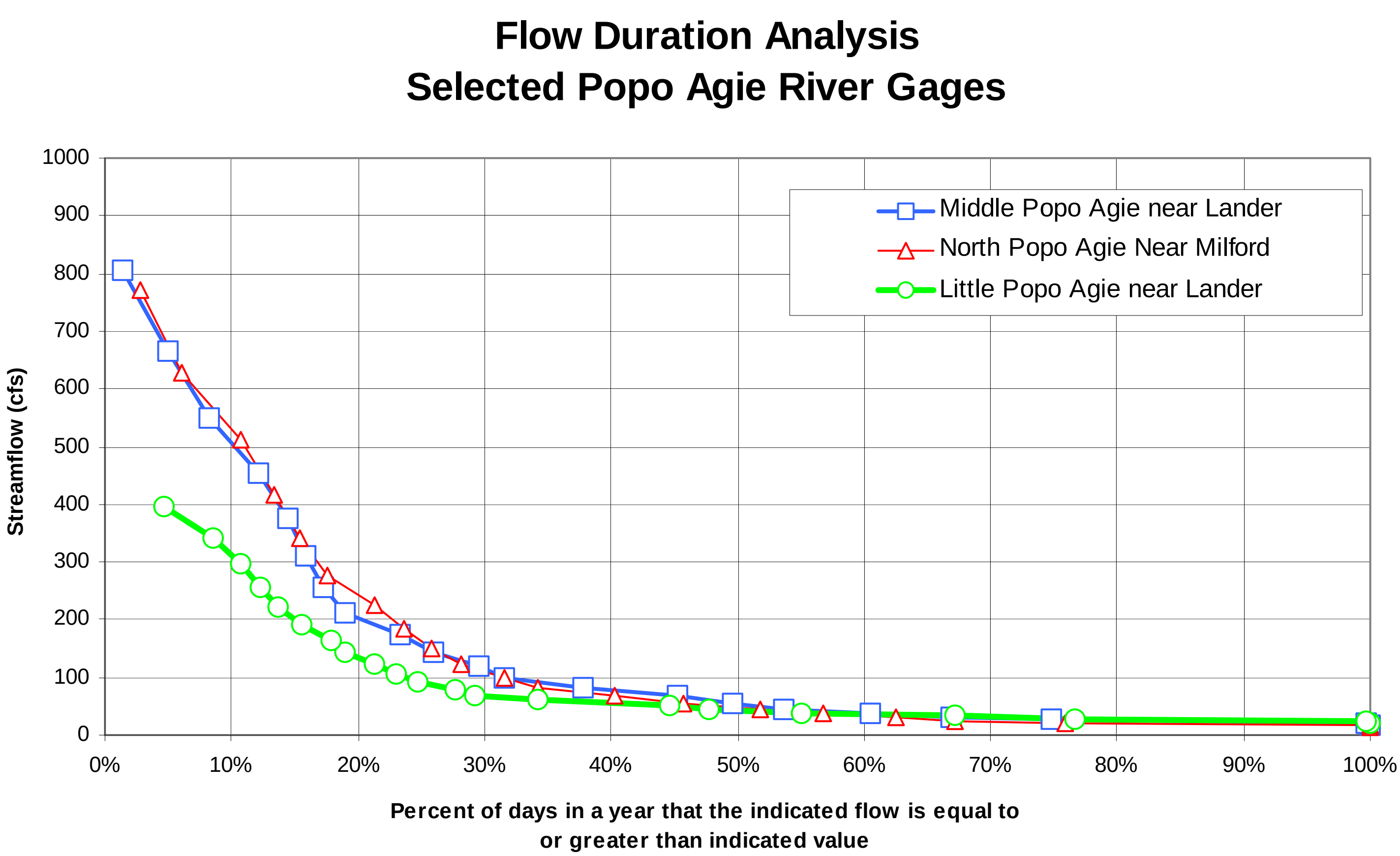


Figure 3.16 Flow Duration Curves for Primary Mainstem Gages.

Flooding

Flooding has been a long-term problem in the Popo Agie River watershed (Figure 3.17); particularly on the Middle Popo Agie River. There have been approximately nine significant flood events on the Middle Popo Agie River since the early 1900's (1917, 1924, 1926, 1944, 1947, 1952, 1963, 1971, and 1995). Major floods, recorded in 1963 and 1995, promulgated modifications to the channel to improve the river's conveyance capacity and reduce impacts associated with flooding. Prior to 1964, flooding sources included the Middle Popo Agie River, Dickinson Creek, Squaw Creek, and Baldwin Creek. The 1963 event on the Middle Popo Agie River was estimated to be approximately 4,180 cfs which exceeded the 500-year flood event. A 100-year rainfall event falling on snow, coupled with a partial breach of Worthen Meadows Reservoir, resulted in most severe flooding recorded in Lander (Federal Emergency Management Agency [FEMA], 1978).

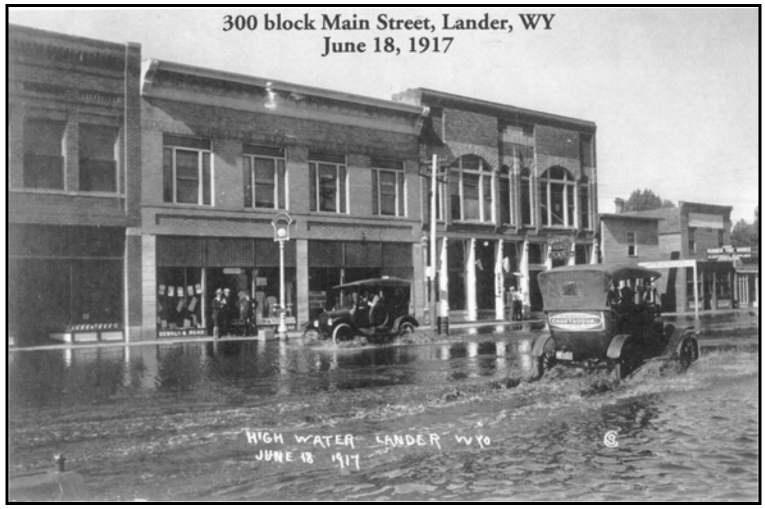


Figure 3.17 Flooding of Lander in 1917.

Much of the damage associated with the 1963 flood was attributed to Dickinson Creek flood flows (Figure 3.18). Dickinson Creek floods when channel flows in the Middle Popo Agie River overtop streambanks and spill to the Dickinson Creek basin. Dickinson Creek flows from the Middle Popo Agie River through the middle of Lander and joins the North Popo Agie River downstream of town. Following the 1963 flood event, major channel modifications were made which included increasing the conveyance capacity of the Middle Popo Agie River channel through Lander to 3,800 cfs. In 1975, a flood warning system was installed that provides 1 to 2 hours notice in the event of a flood.

Figure 3.18 Flood Damage in the City of Lander During 1963 Flood Event.

Flooding again in 1995 promulgated another wave of flood mitigation measures. By 1997, several flood protection projects were completed by landowners and the City of Lander. These efforts were reported to be uncoordinated and were completed without a comprehensive flood protection plan; consequently, flood problems may have been transferred to locations downstream (Lander Water Planning Committee, 1999). Figure 3.19 presents a location that incurs frequent flooding along the Middle Popo Agie River within the City of Lander.

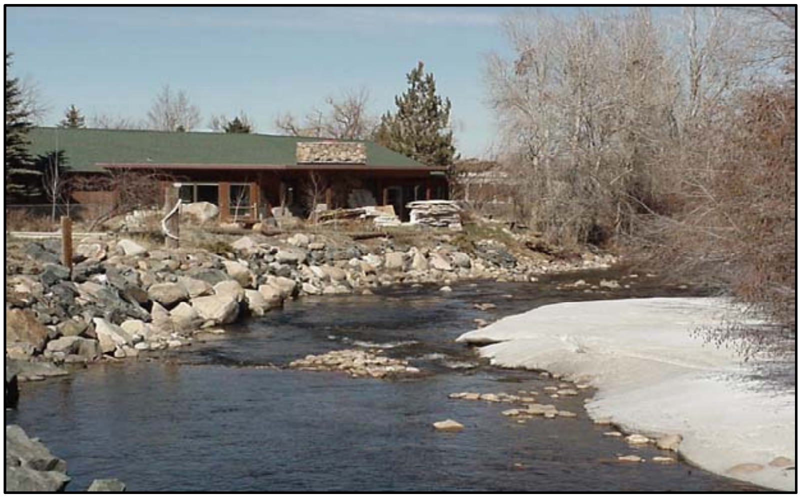


Figure 3.19 Flood Prone area of Middle Popo Agie River at 2nd Street.

Flooding also is reported on the Little Popo Agie River near the Town of Hudson. This location is situated at the confluence with the Big Popo Agie River where backwater from the Big Popo Agie may exacerbate flooding on the Little Popo Agie River and Hudson Draw.

Previous flood studies completed by FEMA in the watershed include:

- City of Lander Flood Insurance Study and Flood Insurance Rate Maps (1978)
- Town of Hudson Flood Insurance Rate Map (1978)
- Fremont County (Unincorporated Areas) Flood Insurance Rate Map (1979)

Figure 3.20 presents the 100-year floodplain delineations included in these studies. Recently, the NRCS has initiated the evaluation of alternatives to reduce or eliminate threats to life and property within the City of Lander. Four flood control alternatives have been presented to date:

- Alternative I - No Project: Under this alternative, existing conditions would persist without implementation of flood control alternatives.

- Alternative II - Diversion: Under this alternative, approximately 1,000 cfs would be diverted from the Middle Popo Agie River, conveyed around the city, and allowed to rejoin the river downstream of town. The two options include construction of either an open channel or buried pipes.

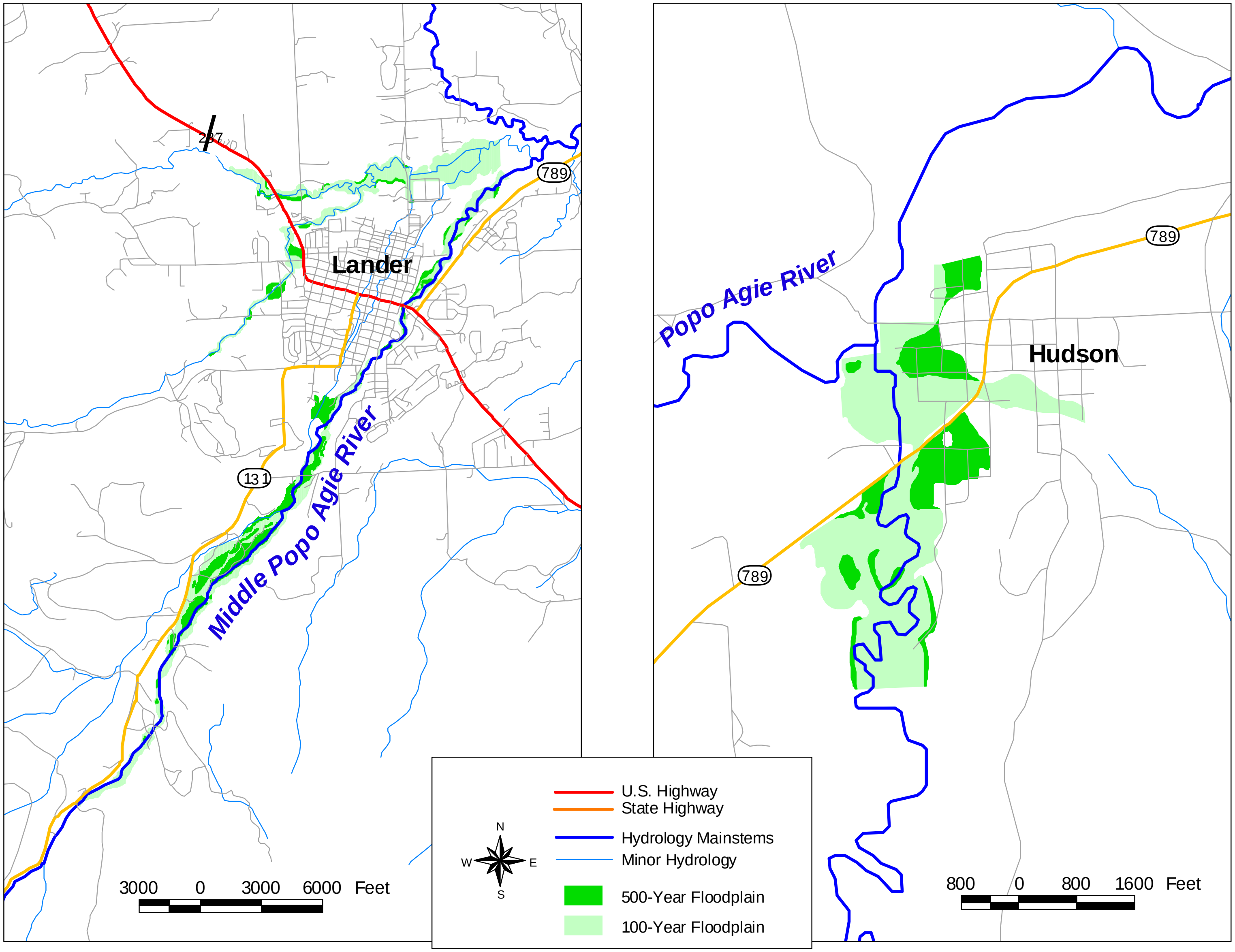


Figure 3.20 Flood Prone Areas in the City of Lander and the Town of Hudson.

- Alternative III - Floodwall or Dike: This alternative consists of improving floodwalls and dikes within the City of Lander.

- Alternative IV - Storage: This alternative, consisting of the construction of flood storage upstream of Lander, was deemed impractical due to site restrictions or costs.

3.7 Water Quality

Existing surface water quality data available for the Popo Agie River watershed were retrieved from the USEPA's STORET Database Retrieval Service and formatted into a usable database. In general, the existing data record represents a collection of miscellaneous datasets; there were no long-term monitoring records. The datasets include periodic records collected by the USGS and the USFS. Figure 3.21 shows the location of monitoring sties for which data exists in the STORET data record.

In 1999, the PACD initiated a monitoring plan and began the collection of baseline water quality data throughout the Popo Agie River Watershed. The initial study was funded through a grant from the Wyoming Association of Conservation Districts. The grant funded the monitoring project for two years (1999 and 2000) of data collection. The primary objectives of the study were to:

1. Describe the existing water quality conditions from alpine to plains regions within the Popo Agie River Watershed,

2. Compare the water quality among like regions of the basin, and

3. Evaluate the water quality against the water body's designated uses.

The monitoring project was guided by a prescribed "*Sampling and Quality Assurance Project Plan*" (PACD, 1999) and the "*Popo Agie Conservation District Quality Assurance Project Plan"* (PACD, 1999). The project complied with the Wyoming Credible Data Act of 1999.

The PACD Project was designed to characterize the various elevation regions in the watershed (Alpine: 10,000 to 10,600 ft, msl; mountain: 7,880 to 8,780 ft, msl; and basin: 5,060 to 5,880 ft, msl). Six sites were selected on each of the three mainstems plus two additional low elevation basin sites on the Big Popo Agie River. Consequently, a total of 20 sites were monitored.

Results of the first two years of the PACD water quality study were presented in the PACD's "Water Quality Monitoring Project: 1999-2000 Final Report". Data collected

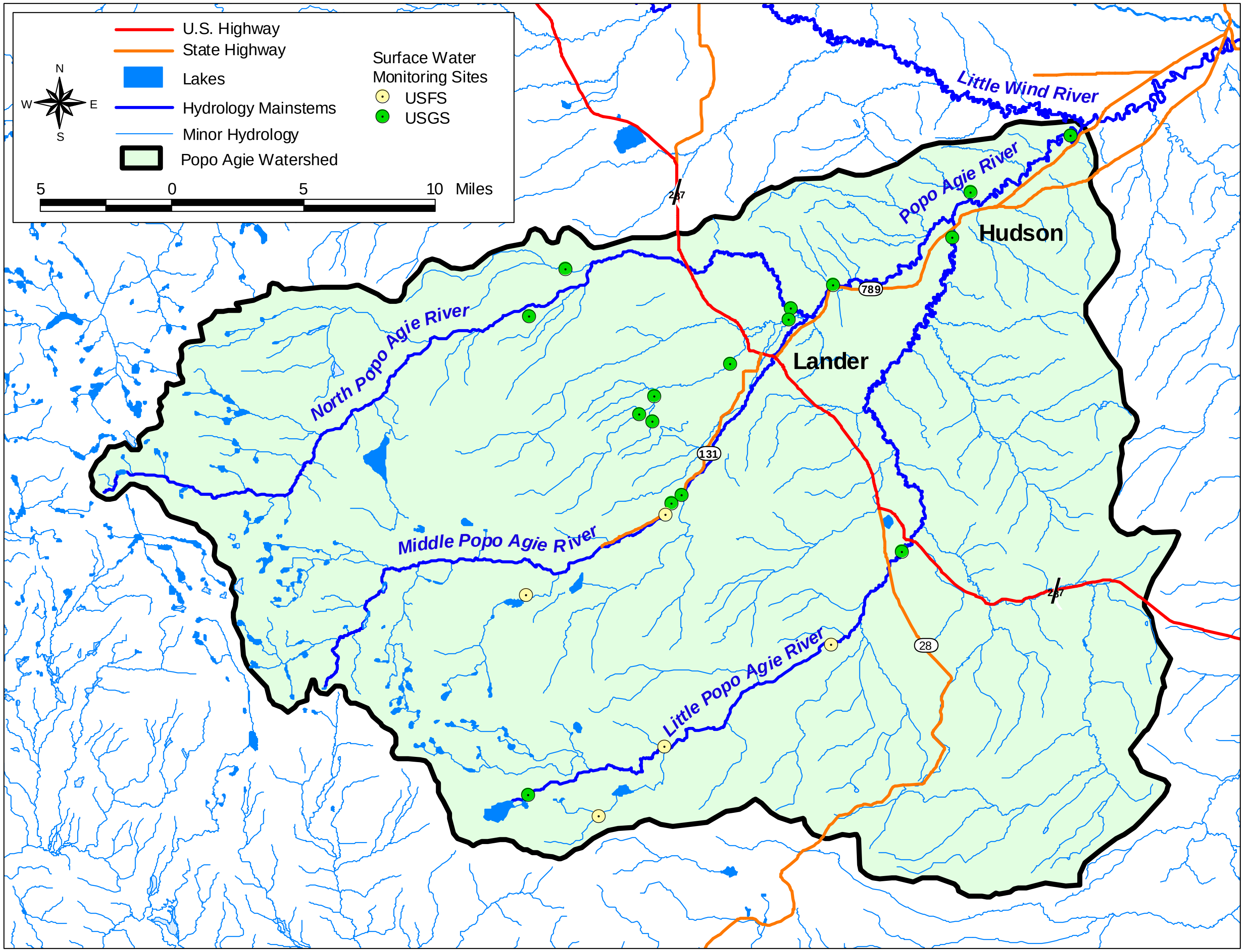


Figure 3.21 Location Map Water Quality Monitoring Sites in the Popo Agie River Watershed.

during the investigation have been incorporated into the project files as a spreadsheet database. Figure 3.22 shows the location of monitoring sites included in the PACD study.

The monitoring project was continued for an additional two years with the intention of building upon the success of a watershed planning process for the Popo Agie River Watershed by continuing a comprehensive monitoring and assessment project. Based upon preliminary analysis of the initial water quality monitoring (i.e., 1999 – 2000), sampling efforts were redistributed to focus on the foothills or plains reaches of the basin. The primary objectives of the extended study are to:

1. Continue to monitor the overall watershed condition/trends of the plains and foothills reaches of the Popo Agie River Watershed, and

2. Monitor tributary contributions to the Little and Middle Popo Agie Rivers and determine their baseline water quality conditions.

The 1999 and 2000 PACD monitoring report concluded that data from alpine and montane sites were representative of these zones. Less variation in physical and chemical water quality measurements existed at montane and alpine sites than in basin sites. Because of this, and due to the higher probabilities of impacts associated with human related activities lower in the watershed, the extended study is focusing on foothill and basin reaches. The alpine and montane sites have been discontinued. Several additional monitoring sites were included in the extended study in an effort to characterize the water quality of tributaries to the three mainstems. Consequently, the water quality monitoring study will include Baldwin Creek, Squaw Creek, Willow Creek, Red Canyon Creek, and Twin Creek.

Because of numeric levels of fecal coliform, the Middle Popo Agie River was included in the State's 2002 list of streams with impaired water quality [(303(d) list)]. In response to this, the PACD initiated an aggressive monitoring effort to examine this issue. The PACD selected nine locations along the Middle Popo Agie River between Sinks Canyon and Main Street that are currently being monitored in an effort to define the sources of coliform observations.

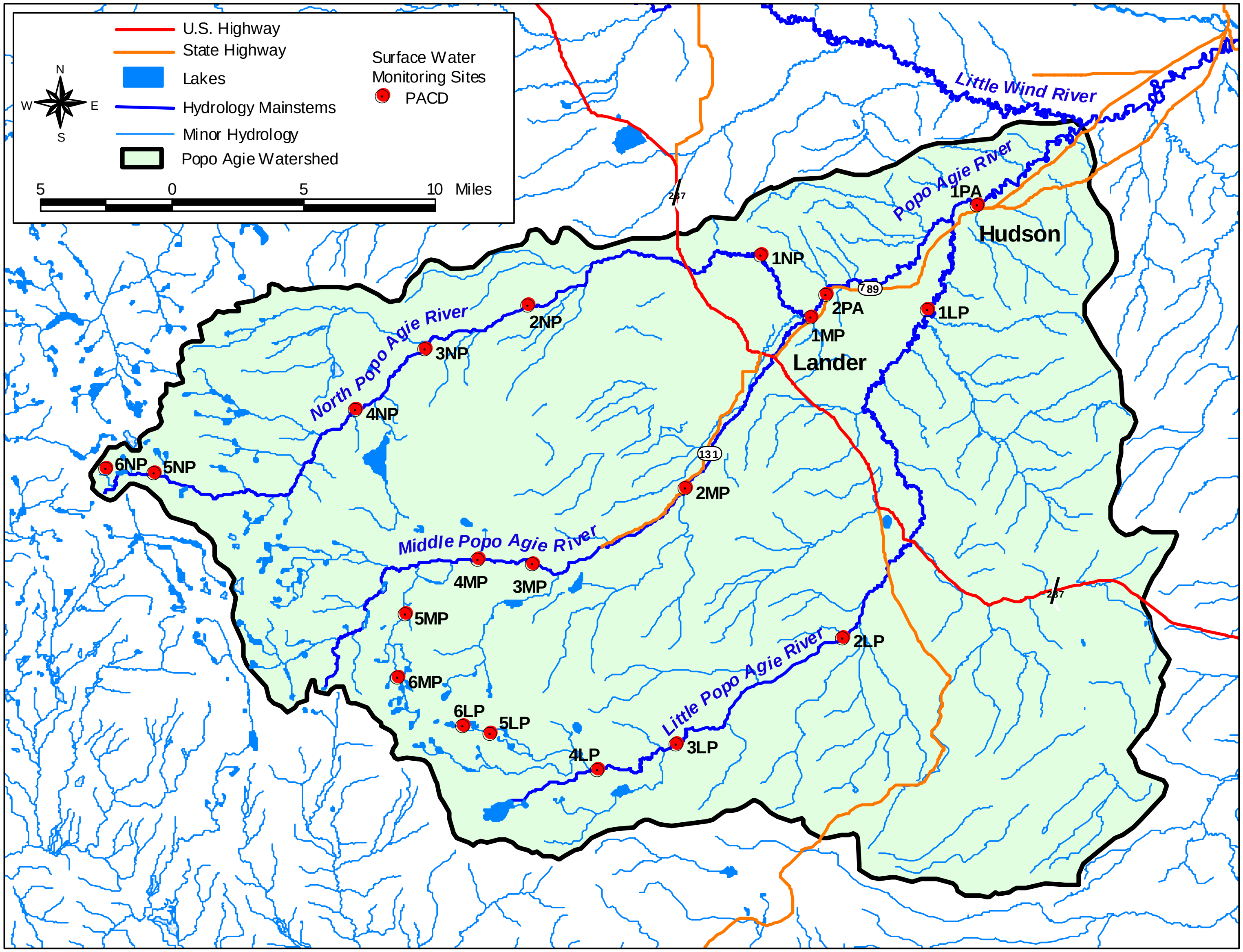


Figure 3.22 Location Map of PACD Water Quality Monitoring Sites: 1999-2000 Investigation.

GEOMORPHIC INVESTIGATION

Chapter 4

4.1 General

In the Popo Agie River watershed, stream channels vary from pristine high mountain alpine streams left relatively untouched by man, to larger alluvial rivers, the character of which have been greatly influenced by man's activities. Urbanization, irrigation diversions, flood control, and grazing all contribute to the existing condition of the basin's stream channels.

The field of fluvial geomorphology is the study of how land is formed under processes associated with running water. The balance between processes such as erosion, deposition, and sediment transport determines the character and condition of a stream. The objective of the geomorphic evaluation is to determine the nature of this balance, and where the balance has been upset.

The condition of a stream can be assessed with respect to its basic form (width, depth, slope, etc.), as well as its state of equilibrium, or geomorphic stability (Thorne, et al, 1996; Johnson, et al., 1999). Stable, or equilibrium channels are generally defined as those that have achieved a balance between flow energy and sediment delivery, such that sediment is transported at the rate at which it is delivered, and the form and pattern of the channel is maintained (Thorne, et al., 1996). Dynamically stable channels are adjustable in nature, and "stability" does not preclude lateral migration and associated dynamics such as bank erosion and sediment deposition.

In geomorphically stable conditions, minor changes in either sediment supply or transport energy result in gradual adjustment of channel form to accommodate those changes (Lane, 1955). Channels destabilize when changes in those factors are extreme enough that rapid and dramatic alterations in pattern or form occur. Common indicators of channel instability include active downcutting and accelerated bank erosion, major changes in channel width/depth ratios, and increased flooding due to sediment deposition. Geomorphic function is achieved when a channel is in equilibrium, while undergoing processes such as lateral migration, sediment reworking, and occasional overbank flooding that effectively create and sustain quality habitat elements, such as bars, pool/riffles, step/pools, and healthy, regenerating riparian corridors.

Impairments to geomorphic function reflect a significant loss of the functional potential of the green channel segment. These impairments are typically described in general, qualitative terms, and any rehabilitation of impaired channel segments requires a more thorough, site-specific assessment of impacts, impairments, and feasible remedies.

4.2 Rosgen Classification System

The literature presents descriptions of numerous systems for classifying and evaluating river systems. Of these, perhaps the most widely used today is the Rosgen classification system. This system, based upon the stream's existing channel morphology, was utilized in this study. Parameters such as the sinuosity, slope, width/depth ratio and size of channel materials are evaluated and used to classify the stream into one of the various "types" included in the system. There are four levels of classification in the Rosgen system, each being more detailed than the previous level. Figure 4.1 displays the hierarchy of the assessment levels and the general nature of effort associated with each.

Much of the Level I geomorphic characterization is qualitative and utilizes aerial photography and topographic maps. Streams are divided into 8 broad types on the basis of their channel and floodplain geometry. Rosgen's classification system stream types can be thought of in their relative location within the watershed, from their headwaters through lowlands. The major stream types reflect their location in the watershed. For example, "A" type streams are located in headwaters, "C" & "E" stream types are located in meandering lowlands, etc.

The Level II effort provides a more detailed description of the stream using measurements at selected locations. Stream types are further subdivided into 94 subtypes based upon degree of entrenchment, width-to-depth ratio, water surface slope, streambed materials, and sinuosity (Figure 4.2). Consequently, the Level II characterization is more quantitative than the Level I effort. Levels III and IV require more extensive data collection and quantification of river characteristics. The Popo Agie River Watershed Study included Level I and Level II assessments of channel conditions.

4.3 Popo Agie River Level I Classification

4.3.1 Level I Methods

The purpose of the Level I geomorphic classification is to provide an inventory of the Popo Agie River watershed's overall stream morphology, character, and condition.

It is intended to serve as an initial assessment for use in more detailed assessments and to determine the location and approximate percentage of river types within the basin. The results of the Level I classification can be integrated directly into the project Geographic Information System (GIS) providing a graphical "snapshot" of the basin. Based upon this initial effort, potential stream reference reaches can be identified for further study in the Level II classification effort. The end product of the Level I classification is the determination of the major stream

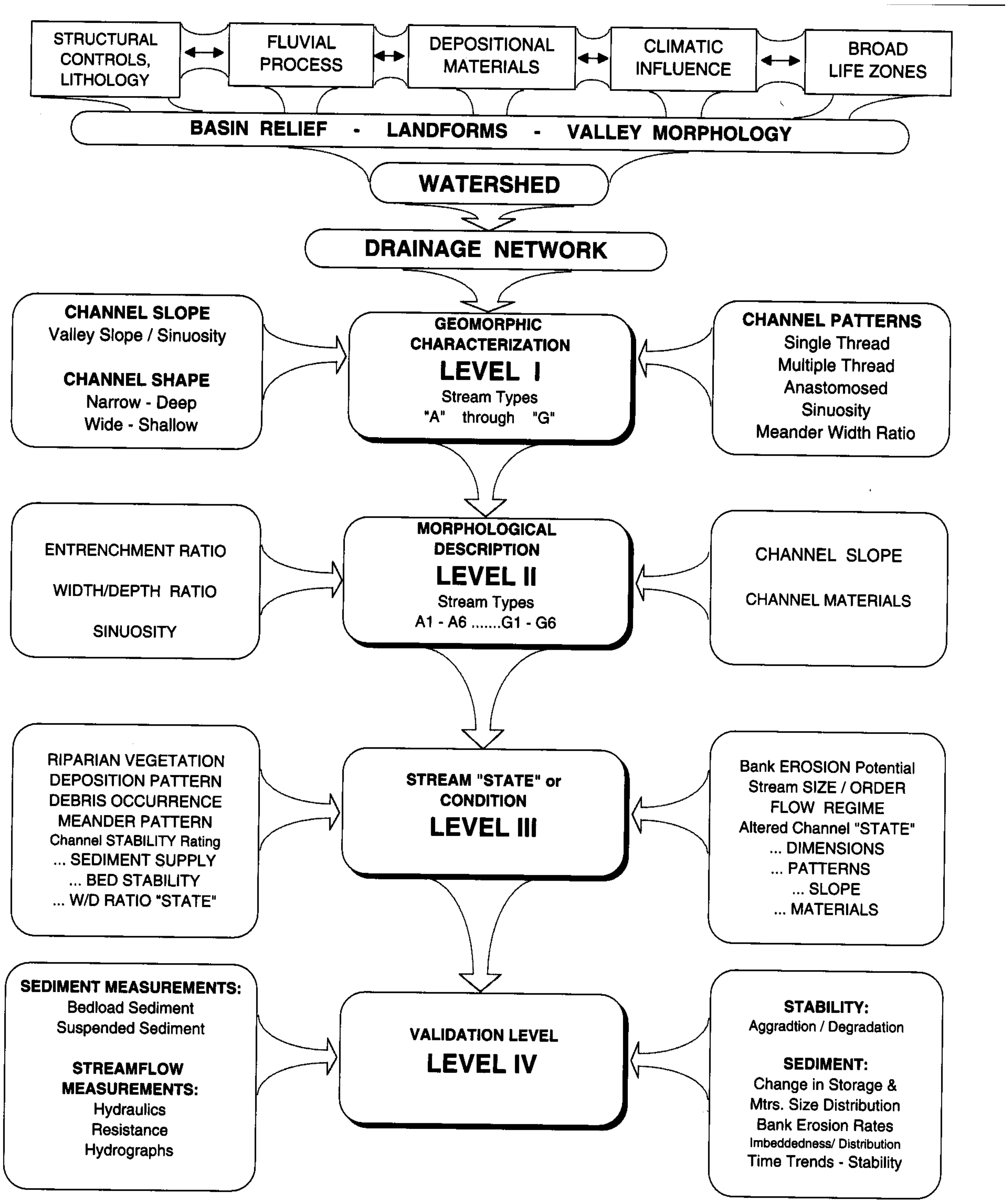


Figure 4.1 Hierarchy of the Rosgen Classification System (Rosgen, 1996).

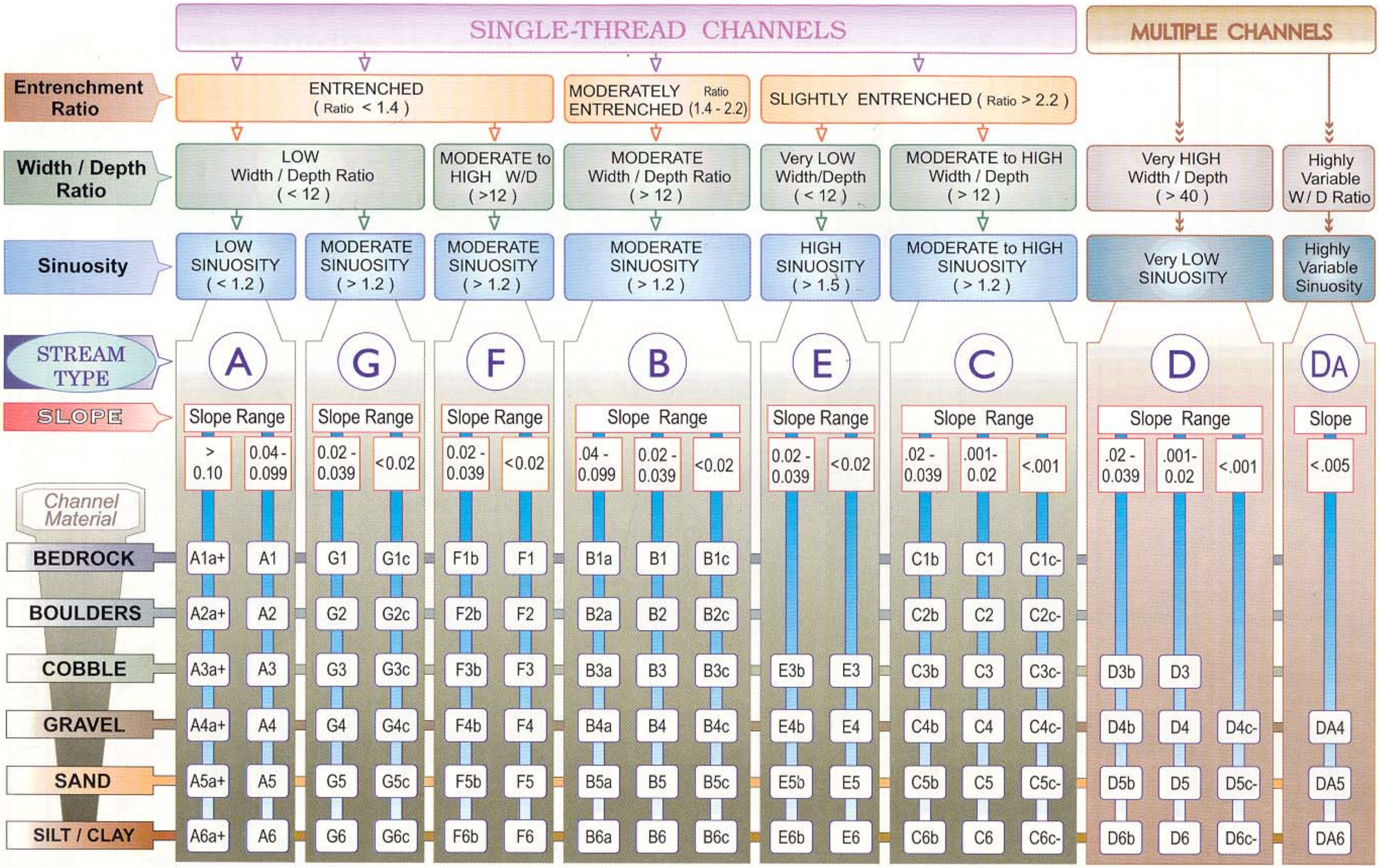


Figure 4.2 Rosgen Classification Matrix (Rosgen, 1996).

types, A through G. Table 4.1 presents a brief summary of the different stream types found within the Rosgen system and Figure 4.3 shows the relative locations of these types within a typical watershed. Brief descriptions of the various stream types encountered in the Popo Agie River Watershed Study are presented in the following paragraphs.

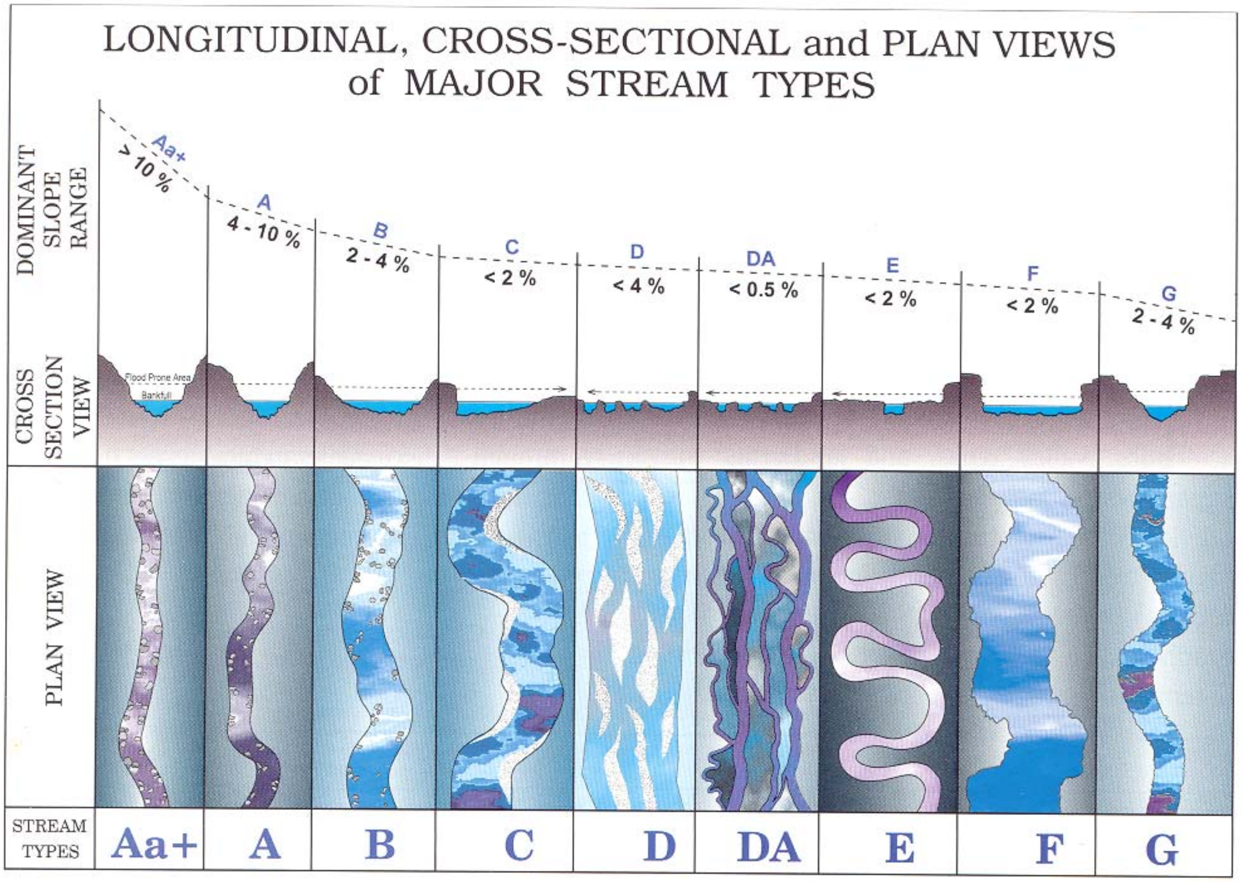


Figure 4.3 Major Stream Types within the Rosgen Classification System (Rosgen, 1996).

Table 4.1 Summary of Rosgen Stream Type Characteristics (Rosgen, 1996).

Stream Type	General Description	Entrenchment Ratio	W/D Ratio	Sinuosity	Slope	Landform/ Soils/Features
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.	<1.4	<12	1.0 to 1.1	>.10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0 to 1.2	.04 to .10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step/pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	.02 to .039	Moderate relief, colluvial deposition, and/or structural. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate w/scour pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains.	>2.2	>12	>1.2	<.02	Broad valleys w/terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<.04	Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment, w/abundance of sediment supply. Convergence/divergence bed features, aggradational processes, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.	>2.2	Highly variable	Highly variable	<.005	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition w/well-vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high wash load sediment.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<.02	Broad valley/meadows. Alluvial materials with floodplains. Highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low width/depth ratios.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	>12	>1.2	<.02	Entrenched in highly weathered material. Gentle gradients, with a high width/depth ratio. Meandering, laterally unstable with high bank erosion rates. Riffle/pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	.02 to .039	Gullies, step/pool morphology w/moderate slopes and low width/depth ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

A-Type Channels are relatively steep channels that form in headwater areas as well as within bedrock canyons (Figure 4.4). These channels are entrenched and confined by steep valley margins such that little to no floodplain area borders them. As the boundaries of A-type channels are typically highly resistant to erosion, these stream types are generally quite resilient with respect to human impacts. The most common cause of geomorphic change within A-type channels is due to large-scale sediment transport events, (landslides, debris flows, debris jam failure) that may result in blockage or deflection of channel flow.

Figure 4.4. Example A Type Channel – Middle Popo Agie River below the Sinks.

B-Type Channels tend to form downstream of headwater channels, in areas of moderate slope where the watershed transitions from headwater environments to valley bottoms (Figure 4.5). B-channels are characterized by moderate slopes, moderate entrenchment, and stable channel boundaries. Due to the relatively steep channel slopes and stable channel boundaries, B-channels are moderately resistant to human impacts, although, their reduced slopes relative to headwater areas can make them prone to sediment deposition and subsequent adjustment following a large sediment transport event such as an upstream landslide, debris flow, or flood.

Figure 4.5. Example B Type Channel – North Popo Agie River above Surrell Creek.

C-Type Channels are typically characterized by relatively low slopes, meandering planforms (i.e., the shape one would see if viewing from above, as in a map or aerial photo), and pool/riffle sequences (Figure 4.6). The channels tend to occur in broad alluvial valleys, and they are typically associated with broad floodplain areas. C-channels tend to be relatively sinuous, as they follow a meandering course within a single channel thread. In stream systems in which the boundaries of C-type channels are composed of alluvial sediments, channels tend to dynamic in nature, and susceptible to rapid adjustment in response to disturbance.

Figure 4.6. Example C Type Channel – North Popo Agie River Downstream of Hwy 287.

E-Type Channels are somewhat similar to C channels, as they form as single threads with defined, accessible floodplain areas (Figure 4.7). However, E channels are different in that they tend to have fine-grained channel margins, which provide cohesion and support dense bankline vegetation. The fine-grained, vegetation-reinforced banklines allow for the development of steep banks, very sinuous planforms, and relatively deep, U-shaped channel cross sections. E-type channels commonly form in low gradient areas with fine-grained source areas, mountain meadows, and in beaver-dominated environments. E-channels tend to have very stable planforms, and efficient sediment transport capacities due to low width/depth ratios.

Figure 4.7. Example E Type Channel – Twin Creek at Hwy 287.

F-Type Channels typically have relatively low slopes (<2%), similar to C and E channel types. The primary difference between C/E channels and F channels is with respect to entrenchment. F channels are entrenched, which means that the floodplain is quite narrow relative to the channel width. The entrenchment of alluvial F-type channels typically is an indicator of an historic downcutting event. F-type channels may form in resistant boundary materials (e.g., U-shaped bedrock canyons), and relatively erodible alluvial materials (e.g., arroyos). When the boundary materials are erodible, the steep valley walls are prone to instability, and channel widening commonly occurs within the entrenched channel cross section (Figure 4.8).

Figure 4.8. Example F Type Channel – Little Popo Agie River near Mouth.

The Level I classification effort was conducted primarily using existing information incorporated into the project GIS. Several analytical tools were developed and integrated into the GIS which allowed the evaluation of various geomorphic parameters (sinuosity, slope, stream station determination). The data collated and incorporated in the Geomorphology GIS include digital aerial photography, USGS topographic maps, Landsat color infrared imagery, a digital elevation model (DEM), and digitized hydrography information.

Each reach was evaluated in light of the characteristics required at the Level I classification. These parameters, as indicated in Figure 4.1 were channel slope, channel shape, channel patterns, and valley morphology. Note that in the Level I classification, these parameters are not typically quantified and the relative magnitude (i.e., “moderate”, “slightly”, etc.) is utilized to classify the stream. These parameters were quantified and the Level I assessments verified during the Level II effort.

4.3.2 Level I Classification Results

Results of the Level I classification effort are presented in Figure 4.9. This figure displays a map of the Popo Agie River watershed depicting the various stream types. Table 4.2 presents a summary of the Level I geomorphic parameters used in this characterization.

The North Popo Agie, Middle Popo Agie, and Little Popo Agie rivers all originate in steep terrain of the Wind River Mountains. Within the mountainous areas, the channels are steep, and bounded by very coarse, resistant materials that include hillslope colluvium, glacial deposits, and bedrock. As a result, the channels are laterally stable, and geomorphically resilient with respect to human impacts. Channel change in these upper subreaches typically results from

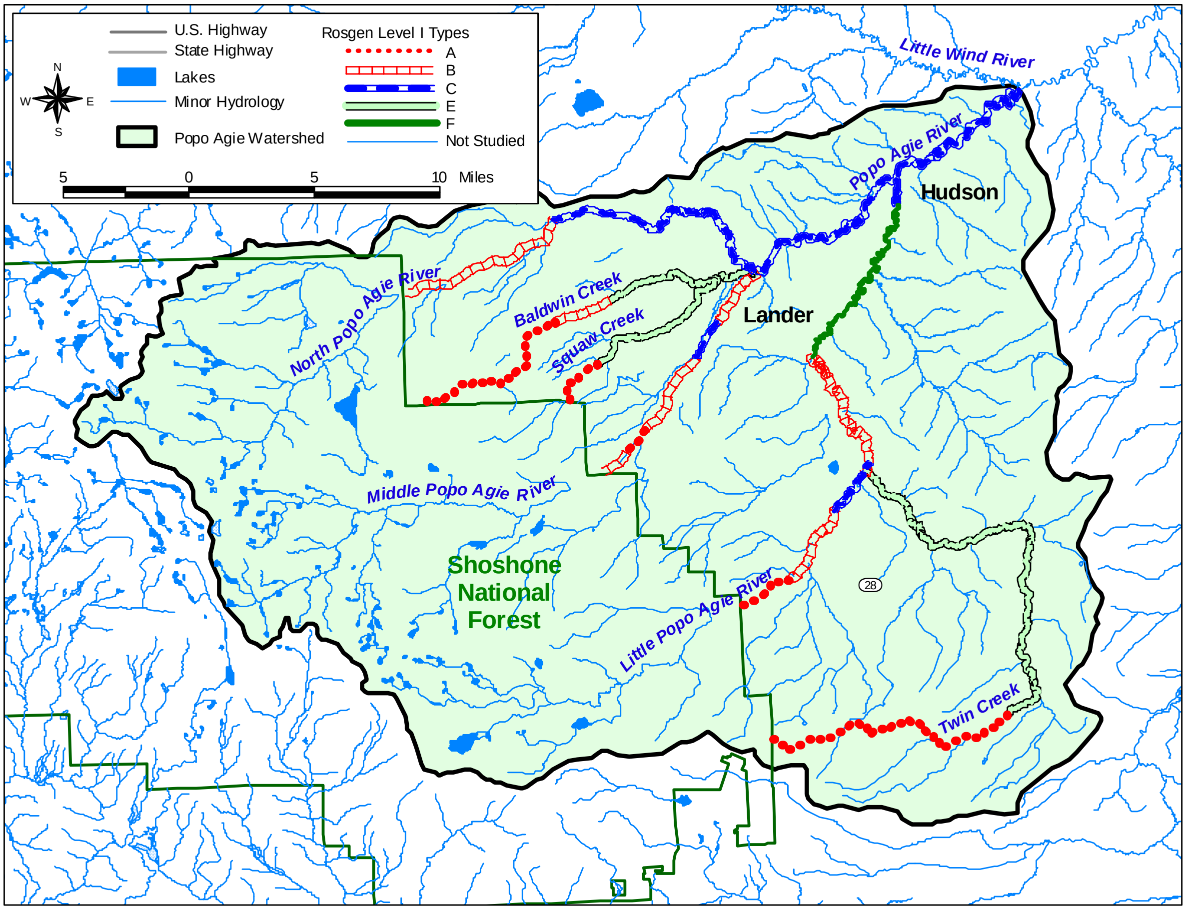


Figure 4.9 Rosgen Level I Geomorphic Classification.

Table 4.2 Summary of Level I Geomorphic Data.

River	Reach Start	Reach End	Sinuosity	Slope	Entrenchment	Width/Depth Ratio	Level I Type
Lower Popo Agie River	1	2	1.7 to 2.1	0.002 to .004	slight >2.2	Mod to High >12	C
Lower Popo Agie River	2	3	1.3 to 1.6	.004 to .010	slight >2.2	Mod to High >12	C
Lower Popo Agie River	3	4	1.1 to 1.2	.001 to .004	slight >2.2	Mod to High >12	C
North Fork Popo Agie River	1	2	1.38	0.004	slight >2.2	Mod to High >12	C
North Fork Popo Agie River	2	3	1.47	.0014 to .004	slight >2.2	Mod to High >12	C
North Fork Popo Agie River	3	4	1.18	.004 to .009	slight >2.2	Mod to High >12	C
North Fork Popo Agie River	4	5	1.18	.008 to .010	slight >2.2	Mod to High >12	C
North Fork Popo Agie River	5	6	1.1	.011 to .025	slight >2.2	Mod to High >12	C
North Fork Popo Agie River	6	7	1.1	.035 to .046	moderate (1.4 to 2.2)	Mod to High >12	B
North Fork Popo Agie River	7	8	1.07	.017 to .025	moderate (1.4 to 2.2)	Mod to High >12	B
North Fork Popo Agie River	8	9	1.03	0.08	moderate (1.4 to 2.2)	Mod to High >12	B
Middle Fork Popo Agie River	1	2	1.19	0.015	moderate (1.4 to 2.2)	Mod to High >12	B
Middle Fork Popo Agie River	2	3	1.09	0.01 to 0.02	moderate (1.4 to 2.2)	Mod to High >12	B
Middle Fork Popo Agie River	3	4	1.05	.008 to .020	slight >2.2	Mod to High >12	C
Middle Fork Popo Agie River	4	5	1.05	.008 to .020	moderate (1.4 to 2.2)	Mod to High >12	B
Middle Fork Popo Agie River	5	6	1.05	.040 to .050	Entrenched < 1.4	Low < 12	A
Middle Fork Popo Agie River	6	7	1.05	.040 to .050	Entrenched < 1.4	Low < 12	A
Little Popo Agie River	1	2	2.2 to 2.8	.0002 to .0007	Entrenched < 1.4	Mod to High >12	F
Little Popo Agie River	2	3	1.3	0.002	Entrenched < 1.4	Mod to High >12	F
Little Popo Agie River	3	4	2.1	.002 to .003	Entrenched < 1.4	Mod to High >12	F
Little Popo Agie River	4	5	1.4 to 1.7	.002 to .005	moderate (1.4 to 2.2)	Mod to High >12	B
Little Popo Agie River	5	6	1.1	.002 to .009	slight >2.2	Mod to High >12	C
Little Popo Agie River	6	7	1.81	.005 to .009	slight >2.2	Mod to High >12	C
Little Popo Agie River	7	8	1.22	.001 to .009	moderate (1.4 to 2.2)	Mod to High >12	B
Little Popo Agie River	8	9	1.04	.02 to .08	Entrenched < 1.4	Low < 12	A
Twin Creek	1	2	2	0.01	slight >0.2	Very Low (<12)	E
Twin Creek	2	3	2	0.002	slight >0.2	Very Low (<12)	E
Twin Creek	3	4	>1.5	low	slight >0.2	Very Low (<12)	E
Twin Creek	4	5	>1.2	0.003 to 0.015	slight >0.2	Very Low (<12)	E
Twin Creek	5	6	>1.2	.007 to .009	slight >0.2	Very Low (<12)	E
Twin Creek	6	7	> 1.2	0.01	Entrenched < 1.4	Low < 12	A
Baldwin Creek	1	2	1.6	.004 to .007	slight >0.2	Very Low (<12)	E
Baldwin Creek	2	3	1.6	.004 to .007	slight >0.2	Very Low (<12)	E
Baldwin Creek	3	4	>1.2	.011 to .014	slight >0.2	Very Low (<12)	E
Baldwin Creek	4	5	> 1.5	< .025	moderate (1.4 to 2.2)	Low < 12	B
Baldwin Creek	5	6	>1.1	>.05	Entrenched < 1.4	Low < 12	A
Baldwin Creek	6	7	>1.1	>.05	Entrenched < 1.4	Low < 12	A
Squaw Creek	1	2	> 1.2	0.006 to 0.01	slight >0.2	Very Low (<12)	E
Squaw Creek	2	3	> 1.2	.016 to .019	slight >0.2	Very Low (<12)	E
Squaw Creek	3	4	> 1.2	0.015	slight >0.2	Very Low (<12)	E
Squaw Creek	4	5	> 1.2	.03 to .11	slight >0.2	Very Low (<12)	E
Squaw Creek	5	6	< 1.2	0.05	Entrenched < 1.4	Low < 12	A

punctuated hillslope processes rather than gradual channel migration. The channels are A-type or B-type channels (Table 4.2), which reflects their steep slope and stable boundaries.

As the major stream channels descend into the Wind River Basin, the lateral confinement is reduced, the slope lessens, and the boundary materials become less coarse. As a result of these downstream changes in boundary conditions, the lower subreaches tend to display meandering channel dynamics; that is, pool/riffle development and lateral channel migration. The channels transition from B channels, which are located in transition zones at the foot of the mountains, to C channels, which are gravel bed meandering streams that dominate the central basin.

As most agricultural and urban development has taken place away from the mountain front, associated impacts such as flow diversions, flood control projects, and riparian land development have had the greatest cumulative geomorphic impact on these lower channel subreaches. The combination of more laterally active channels and more intensive human impacts has rendered the lower subreaches most prone to impairment due to factors such as dewatering, levee construction, rigid bank protection emplacement, channelization, and riparian clearing. In the Lyons Valley, for example, channelization has resulted in the downcutting of the historic meandering C-type channel and formation of an entrenched, impaired F-type channel.

Whereas the larger streams (North, Middle, and Little Popo Agie Rivers) emerge into the basin as meandering C channels, the smaller streams, including Twin Creek, Baldwin Creek, and Squaw Creek, are dominated by relatively fine-grained, sinuous E-type channels. The fine-grained, vegetated upper banks of these channels tend to result in the formation of overhanging upper banks, where the bank toe undercuts the upper bank, creating a cantilever bank cross section. In general, these streams are moderately resistant to changes in hydrology or sediment load; however, they are prone to rapid destabilization due to gravitational bank failure, which can be caused by loss of vegetative reinforcement or trampling by humans or livestock.

4.4 Level II Classification

4.4.1 Level II Methods

The purpose of the Level II classification was to obtain more detailed morphological description of the system. This was accomplished by obtaining field data pertaining to channel entrenchment, dimensions, patterns, profile, and boundary materials. The results of the Level I classification were reviewed prior to initiation of the Level II classification. Representative reference reaches were selected for Level II classification based upon the Level I stream type. An effort was made to establish a minimum of one Level II reference reach for each of the major stream types within the limitations posed by land access restrictions. Figure 4.10 displays these reference reach locations and the major stream type (i.e., A through G) in which they are located.

An effort was made to identify "reference reaches" for specific channel types that could be utilized in future restoration efforts. The intent was to identify unimpaired, "ideal" channel segments of a given channel type that could be replicated within impaired reaches of similar type to improve channel stability and/or function. Due to the inherent variability in the system, however, as well as the extent of systemic human impacts, the application of a broad "reference reach" approach to channel restoration is likely inappropriate. Such an approach could potentially be applied on a smaller scale, with the direct application of reference reach characteristics to an adjacent impaired reach, rather than a broad replication of a general reference reach to an entire extent of a given channel type. Furthermore, ongoing impacts within the system such as flow diversions and urbanization indicate that restoration efforts should include the assessment of existing and anticipated future conditions of hydrology and sediment supply, and thus be based on fundamental processes of channel hydraulics and sediment transport.

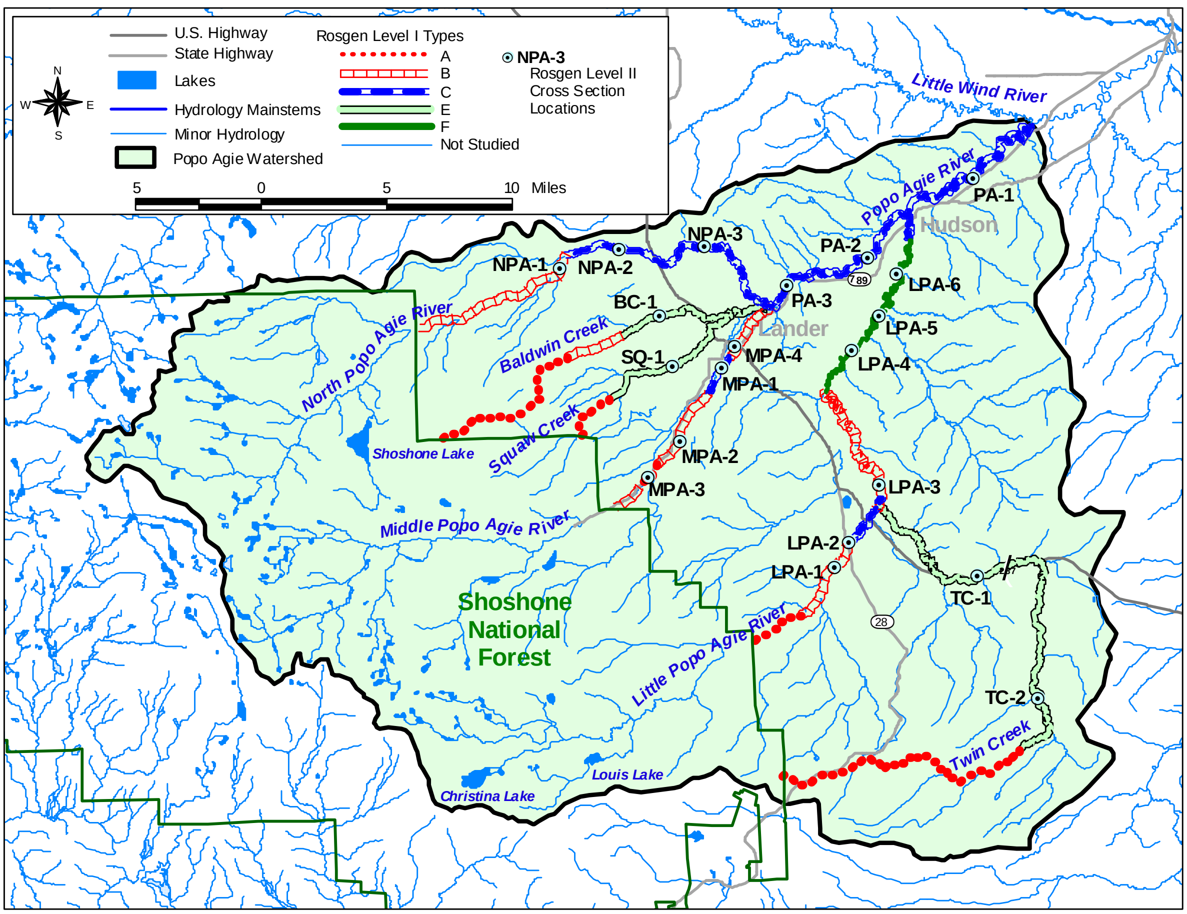


Figure 4.10 Level II Geomorphic Reference Reach Locations.

At each of the cross section locations, numerous tasks were completed. Several geomorphic parameters were evaluated, as indicated in Figure 4.1, including channel slope, channel shape, channel patterns, valley morphology, entrenchment ratio, width depth ratio, and channel materials. In addition, a determination of bankfull stage was completed at each station. Bankfull stage corresponds to "the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends or meanders, and generally doing work that results in the average morphologic characteristics of channels" (Dunne and Leopold, 1978). The relative elevation of bankfull stage at each location was identified by observing several key indicators, including: the presence of a floodplain, depositional features, vegetative indicators, staining on rocks, etc.

4.4.2 Level II Classification Results

Results of the Level II classification are presented in Figure 4.11. This section contains a summary of channel classification results by subreach, as well as a description of observed impairments and potential approaches to channel rehabilitation. These summaries are derived from quantitative data from individual cross sections, coupled with supplementary field observations. Table 4.3 presents a tabulation of geomorphic parameters obtained at each of the cross sections.

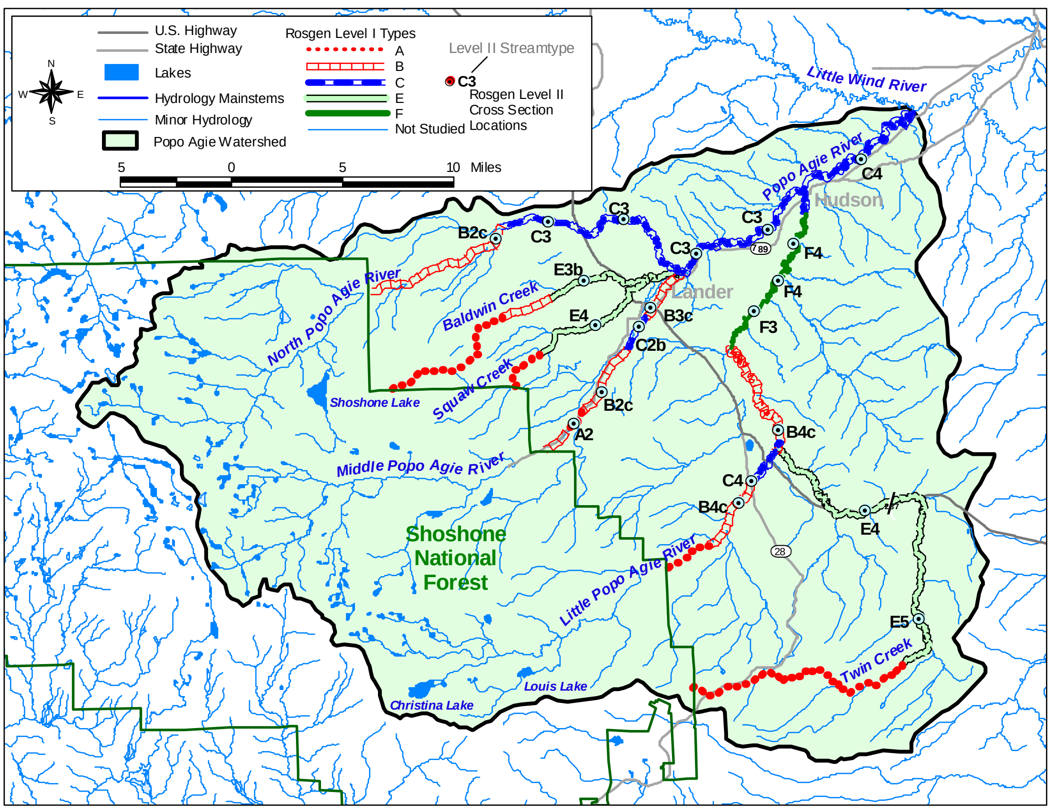


Figure 4.11 Results of the Rosgen Level II Stream Classification Task.

Table 4.3 Summary of Rosgen Level II Cross Section Data.

River	ID	River	GPS Point (no.)	Bankfull Width (ft)	Mean Depth (ft)	Width/Depth Ratio (ratio)	Width of Floodprone Area (ft)	Entrenchment (ratio)	Bed Material D50 (in)	Slope (ft/ft)	Sinuosity (ratio)	Stream Type
Big Popo Agie	PA-1	Popo Agie	226	148	3.6	41.1	326	2.2	2	0.0035	1.67	C4
	PA-2	Popo Agie	227	100	2.8	35.7	300	3.0	3	0.0029	1.30	C3
	PA-3	Popo Agie	228	108	4.2	25.7	194	1.8	4	0.0040	1.12	C3
North Popo Agie	NPA-1	North Popo Agie	238	40.5	3.38	12.0	125	3.1	15	0.0200	1.08	B2
	NPA-2	North Popo Agie	239	49.5	3.54	14.0	200	4.0	6	0.0080	1.09	C3
	NPA-3	North Popo Agie	241	62	3.26	19.0	500	8.1	4	0.0045	1.51	C3
Middle Popo Agie	MPA-1	Middle Popo Agie	218	56.1	3.7	15.2	100	1.8	6	0.0050	1.09	C2b
	MPA-2	Middle Popo Agie	219	57	3.2	17.8	96	1.7	15	0.0200	1.05	B2c
	MPA-3	Middle Popo Agie	220	61	4.3	14.2	75	1.2	24	0.0400	1.05	A2
	MPA-4	Middle Popo Agie	255	39	3.3	11.8	50.8	1.3	6	0.0080	1.15	B3c
Little Popo Agie	LPA-1	Little Popo Agie	229	58	2.8	20.7	120	2.1	3	0.0050	1.20	B4c
	LPA-2	Little Popo Agie	232	50	3.6	13.9	140	2.8	2	0.0076	1.45	C4
	LPA-3	Little Popo Agie	234	60	3.2	18.8	103	1.7	2	0.0040	1.25	B4c
	LPA-4	Little Popo Agie	235	54	3.03	17.8	80	1.5	4	0.0032	1.14	F3
	LPA-5	Little Popo Agie	236	52	2.43	21.4	77	1.5	1	0.0020	2.80	F4
	LPA-6	Little Popo Agie	237	44.5	3.25	13.7	69.5	1.6	2	0.0020	1.65	F4
Twin Cree	TC-1	Twin Creek	245	12.5	2.2	5.7	50	4.0	2	0.0090	1.63	E4
	TC-2	Twin Creek	248	10	2.7	3.7	114	11.4	sand	0.0070	1.80	E5
Baldwin Creek	BC-1	Baldwin Creek	256	15.5	2.1	7.4	90	5.8	4	0.0210	1.09	E3b
Squaw Creek	SQ-1	Squaw Creek	258	9.6	2.7	3.6	60	6.3	1	0.0120	1.06	E4

North Popo Agie River

Channel Types

The upper reaches of the North Popo Agie River are confined within a bedrock canyon as it flows off of the flanks of the Wind River Range. From the mouth of the canyon near the USFS boundary to approximately the confluence of Surrell Creek, the North Popo Agie River is a B-type channel, with steep slopes, little floodplain access, and a coarse cobble/boulder substrate (Figure 4.12). Downstream of the Surrell Creek confluence, the lateral confinement, entrenchment, and channel slope all drop markedly, and the channel transitions into a C-type channel, maintaining the fundamental characteristics of a C-type channel to its mouth (Figure 4.13).

Figure 4.12 Site NPA-1: Type B2 Channel.

Figure 4.13 Site NPA-2: Type C3 Channel.

Impairments

The North Popo Agie River can be generally characterized as geomorphically stable, and flows through a significant riparian corridor. Locally, however, the channel appears aggradational, and riparian grazing and clearing is evident throughout the system. Riparian degradation due to active grazing, and cropland encroachment is evident from the Surrell Creek confluence downstream to its confluence with the North Popo Agie River (Figure 4.14).

Figure 4.14 Riparian Degradation Due to Grazing (North Popo Agie River Upstream of Hwy 287).

From the Surrell Creek confluence to Highway 287, the geomorphic stability of the North Popo Agie River is impacted by a natural tendency for sediment deposition within the reach. Downstream of the Surrell Creek confluence, the transition from the steep (2% gradient), confined, B-type channel into a C-type channel with a slope of approximately 1% correlates to the transition from a corridor characterized by a confined, single thread channel to a wide, active migration corridor with intermittent divided flow reaches. These divided flow segments are likely a consequence of reduced sediment transport energy and subsequent sediment deposition associated with the reduced slope and lateral confinement.

Due to the natural tendency for reduced transport energy between Surrell Creek and Highway 287, the river course within the reach should be expected to be laterally dynamic and prone to occasional shifting within the corridor or active channel. The application of aggressive engineering measures to prevent such shifting can result in long-term channel maintenance, because depositional channels that are aggressively contained tend to perch above their surrounding floodplain, and increase risks of major avulsion (channel relocation). Existing buildings within the subreach appear to be largely located outside of this natural "migration corridor". Any long-term management approach should include the anticipation of this natural tendency for channel shifting, and minimization of large-scale channel confinement between Surrell Creek and Highway 287.

Middle Popo Agie River

Channel Types

The upstream portion of the study reach of the Middle Popo Agie River flows through Sinks Canyon, which is a narrow bedrock canyon. At narrow portions of the canyon, such as at the Sinks Canyon Gaging Station (Figure 4.15), the channel is very steep and entrenched, and is an A-type channel. Where the canyon locally widens out, the channel slope tends to drop, the entrenchment is reduced, and the channel has B-type characteristics. As the river leaves the canyon, it flows through a semi-confined valley as a

Figure 4.15 Site MPA-3: Type-A2 Channel.

B-type channel past Central Wyoming College Field Station (Figure 4.16). Further downstream, as the lateral confinement and slope are both reduced, the river transitions into a C channel type (Cross Section MPA-1, Figure 4.10), until it reaches the City of Lander, where flood control engineering has resulted in a deeply entrenched B channel (Cross Section MPA-4, Figure 4.10). Downstream of Lander, the river transitions back to a C-type channel, and maintains this form to its mouth.

Figure 4.16 Site MPA-2: Type-B2c Channel.

Impairments

The observed upper reaches of the Middle Popo Agie River appear geomorphically stable and largely functional with respect to geomorphic processes and riparian conditions.

Where the Middle Popo Agie River flows through the City of Lander, it serves as a floodwater conveyance corridor through town. Geomorphic impairment within the downtown reach is a consequence of the flood control efforts. The straight, deep, and trapezoidal condition of the channel indicates that it has been deepened and straightened to improve conveyance and thereby reduce flooding. This cross section and planform reconfiguration has resulted in floodplain isolation and loss of planform and bedform variability. Bankline erosion control methods such as gabions have been applied to protect existing infrastructure in overbank areas. These projects arrest channel migration and limit floodplain function, and thereby geomorphically impair the channel. The riparian corridor has been degraded due to the channel modifications. The channel condition was rated as “fair” by a Level III assessment in the downtown area (Figure 4.17).

Figure 4.17 Bank Stabilization and Channelization of Middle Popo Agie River (Site MPA-4: Type-B3c Channel).

Any significant reduction of the identified geomorphic impairments within the reach would likely be difficult and costly. Urban channels can be designed to maintain flood conveyance, yet support aesthetic and habitat features such as bedform variability, planform variability, and a riparian corridor. Currently, the overbank areas do support mature riparian vegetation, although the natural regeneration of that riparian corridor will be limited due to the limited access to that surface. Planform variability is difficult to achieve due to the urban encroachment on the channel margins and the required channel alignment at bridges. One alternative for an extensive urban channel rehabilitation project through town would consist of the design and construction of a 2-stage channel cross section, containing a low-flow cross section inset within the required floodway. This approach requires extensive design efforts to ensure channel stability and required conveyance conditions. Smaller-scale approaches could be applied to improve habitat, such as the emplacement of boulders in the channel bed, although the effects of such a project on hydraulic roughness and flow conveyance would require careful consideration.

The NRCS has recently proposed construction of a series of rock vortex weirs in the reach between Mortimer Lane and the confluence with the North Popo Agie River in conjunction with their flood control efforts. While potentially beneficial to the reach (gradient control, profile variability, concentration of flow), the NRCS design criteria should ultimately result in no increase in elevations of the 100-year flood profile.

Little Popo Agie River

Channel Types

The Little Popo Agie River emerges from the mountains as a relatively confined, entrenched, B-type channel (Figure 4.18). As the confinement and slope are reduced in the downstream direction, the channel transitions into more of a typical, meandering gravel bed stream near Highway 28 (Figure 4.18). At the Twin Creek confluence, which is on the upstream end of Dallas Dome, a broad alluvial fan crosses the Little Popo Agie River valley. This large deposit of relatively fine-grained sediment

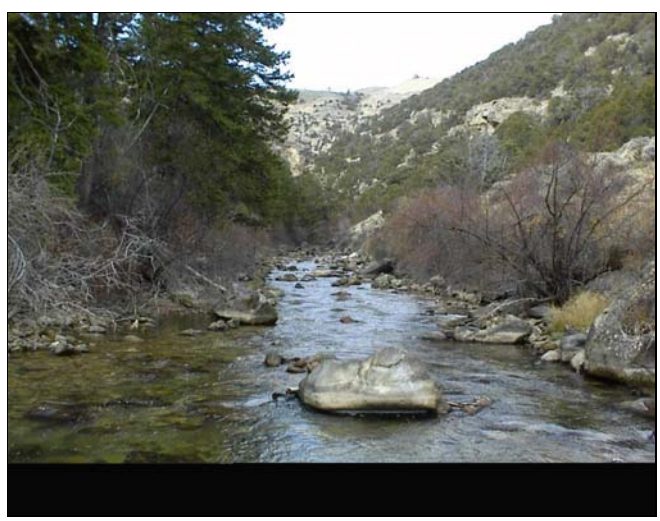


Figure 4.18 Little Popo Agie River at Mouth of Canyon (Type-B Channel).

indicates that Twin Creek has historically contributed large volumes of sediment to the Little Popo Agie River system. At the confluence, the Little Popo Agie River transitions abruptly from a meandering, unconfined C-type channel upstream, to an entrenched, confined B-type channel through the fan (Figure 4.19). Downstream of the fan, the river flows through Dallas Dome, where extremely shallow oil reservoir depths are evidenced by active oil seeps in the toe of the riverbank. Through the Dallas Dome field, bedrock valley walls narrowly confine the Little Popo Agie River valley. The channel is entrenched within terraces, and is a B-type channel. Downstream, the channel emerges into Lyons Valley.

Figure 4.19 Little Popo Agie River at Dallas Dome (Type-B4c Channel).

Lyons Valley contains an extensive length of F-type channels, which are deeply entrenched meandering channels that are typically unstable due to channel downcutting (Figure 4.20).

Figure 4.20 Little Popo Agie River near Mouth (Type-F Channel).

Impairments

Upstream of Lyons Valley, impairments consist of localized grazing that has reduced riparian vigor, and limited extents of bank protection that will arrest channel migration and limit long-term riparian health. Historic incision of the channel upstream of Lyons Valley resulted in riparian degradation due to perching of the old floodplain surface as a terrace. Currently, an incised floodplain surface is progressively developing, and some recovery of the riparian corridor has occurred. The most extensive geomorphic impairments, however, are located within the Lyons Valley, where the channel has severely downcut into fine soils. A Level III assessment within the Lyons Valley resulted in a channel condition rating of “poor”. Channel downcutting reflects an excess of sediment transport energy with respect to sediment supply, and is a common indicator of geomorphic disequilibrium. Alternatively, increased transport energy may occur due to increased flows, or increased channel slope. In the Lyons Valley, the channel has been locally straightened and shortened, thereby increasing the channel slope. Consequently, erosion of the channel bed (incision) has been exacerbated (Figure 4.21). The downcutting in the valley is due in part to this channelization, although without a more comprehensive assessment, it is impossible to identify all factors impacting the geomorphic stability, or to develop a more comprehensive assessment of geomorphic evolution of the Little Popo Agie River.

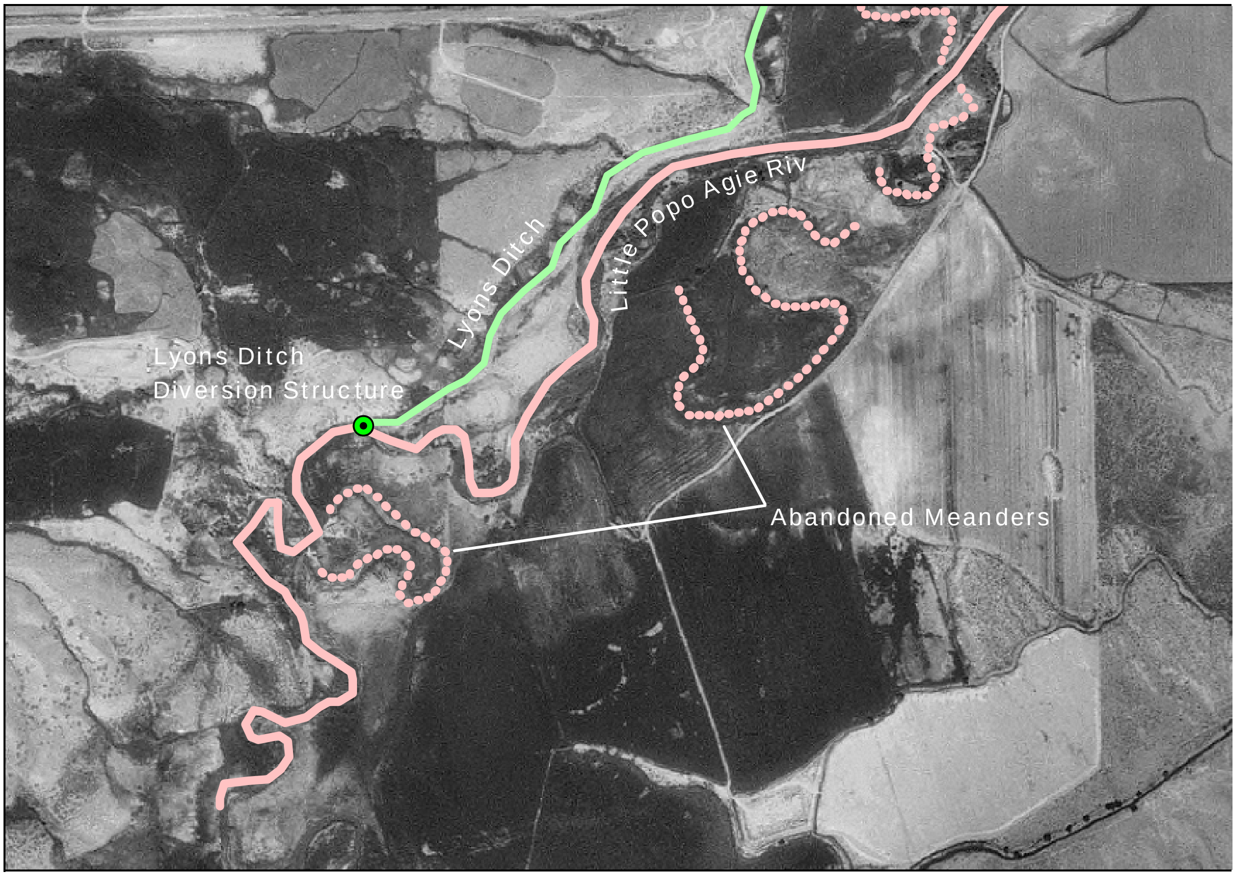


Figure 4.21 Channelization of Lower Little Popo Agie River.

The channel incision process tends to follow a relatively predictable series of evolutionary stages (Schumm, et al, 1994). First, the channel begins to erode its bed, downcutting vertically. This process typically migrates in the upstream direction. The downcut channel then begins to widen, as the steep vertical banks are unstable and begin to collapse. As the channel widens, bank angle is reduced, and the banks become more stable. Ultimately, the channel widens enough to allow the formation of depositional berms on the incised channel margin that may be colonized by vegetation. These deposits eventually form a surface bounding the incised channel that serves as a new floodplain that is lower in elevation from the original floodplain. The original floodplain becomes perched as a terrace, and is effectively isolated from the channel.

The consequences of the incised channel evolution process can be severe. Large-scale bank instability results in extensive bank failure and sediment production. As the groundwater table drops with the channel bed, the depth to groundwater from the original floodplain surface increases, commonly to the point where pre-incision vegetation patterns are not sustainable. Eventually, however, a new equilibrium condition will be achieved, as the channel develops a new equilibrium profile, and flood energies are dispersed on the new incised floodplain surface.

Multiple approaches to restoration can be applied to incised river channels (Rotar and Boyd, 1999). Common objectives in such restoration efforts are to promote channel stability, as well as to connect the channel to its historic floodplain. The reconnection of the channel to its historic floodplain requires raising the channel bed, which can be achieved through grade controls and channel infilling, or reconstruction of a new channel. These approaches can have difficult and costly challenges, however, such as tying in the project end points to the incised channel grade, or preventing post-project channel relocation (avulsion). Another approach to incised channel stabilization is to completely armor the channel banks and add grade control structures. This process will reduce sediment inputs, but will not provide a dynamic, functional channel configuration. Perhaps the most geomorphically beneficial approach to incised channel restoration is to promote the natural recovery process of channel widening and incised floodplain development. This can be achieved by excavating a new floodplain surface adjacent to the channel to provide an area for flood energy dissipation and new riparian corridor establishment. Any work in incised channel restoration requires an assessment of the status of the current channel stability, so that the potential for further downcutting is known and accommodated for in the channel restoration design.

Popo Agie River

Channel Types

The Popo Agie River is a cobble/gravel bed, meandering stream that has a high width-depth ratio, and substantial natural floodplain access along its mapped extent. As such, the channel is a C-type channel.

Impairments

Field evidence indicates that the study reach of the Popo Agie River is geomorphically stable, although the natural tendency for channel migration of the C-type channel has resulted in some aggressive bank protection efforts (Figure 4.22). Additionally, riparian clearing and bank grading have damaged the riparian corridor (Cross Sections PA-1 and PA-2, Figure 4.10). Levees are locally present on both sides of the channel, and the channel received a Level III rating of "fair" (Cross Section PA-3, Figure 4.10).

Figure 4.22 Bank Stabilization Efforts on the Popo Agie River (Site PA-3: Type-C3 Channel).

The impairments to the project reach of the Popo Agie River relate largely to riparian clearing, bank grading, bankline erosion control, and levee construction. Each of these impacts serves to limit riparian reinforcement of banks, and general riparian succession. Means of reducing these impacts may include floodplain/bankline revegetation; relocation of levees to a "setback" position so that less floodplain area is isolated from the channel; migration corridor delineation; and application of alternative bank protection methods that incorporate upper bank vegetation.

Twin Creek

Channel Types

Figure 4.23 Twin Creek at TC-1: Type E4 Channel.

Twin Creek is classified as an E-type channel along its entire mapped length, indicating that the channel has a low width-depth ratio, moderate slope, and stable planform. The lower reaches of Twin Creek have historically downcut, such that the channel configuration is nested within terraces (Figure 4.23). Upstream of Carr Reservoir, the channel is still an E-type channel, although local bank instability may be reflective of some level of active downcutting (Cross Section TC-2, Figure 4.10).

Impairments

In the vicinity of Cross Section TC-1, the historic channel downcutting has progressed to the point where the channel has naturally restabilized. Upstream, however, downcutting appears locally active, indicating that the process is incomplete in the upper watershed. The presence of a broad alluvial fan at the mouth of Twin Creek is evidence of historically high sediment loading to the Little Popo Agie River. The indicators of downcutting in subreaches upstream of Carr Reservoir are unclear with respect to large-scale trends, although it is possible that some level of vertical instability is migrating upstream. The systemic destabilization of a watershed though upstream-migrating channel incision can be remedied through the stabilization of the channel grade in unimpacted reaches. This would require a more detailed assessment of degradational trends in the mid-watershed, and determination of optimal means of stabilizing the grade. In areas of ongoing downcutting, alternatives to improve function can include the excavation of a floodplain along the entrenched channel, which will accelerate the natural recovery process, and reduce sediment loading downstream. Aggressive bank stabilization will also reduce sediment loading, but will not allow the formation of a functional cross section through the reach.

Baldwin Creek

Channel Types

From its headwaters to a point just south of Red Butte, Baldwin Creek is a steep, confined, bedrock-controlled, A-type channel. As the creek flows northeastward, the confinement is reduced, and the channel transitions into an entrenched, B-type channel. This entrenchment is greatly reduced in the downstream transition, and Baldwin Creek transitions to an E-type channel approximately 2.5 miles upstream of Highway 287 (Figure 4.24).

Figure 4.24 Baldwin Creek in Restored Reach (Type E3 Channel).

Impairments

Historic impacts on Baldwin Creek have included the removal of vegetation along 17 miles of the channel due to grazing, agricultural clearing, and subdivision development

(USEPAa, USEPAb). These impacts resulted in channel destabilization and production of large volumes of sediment from the watershed. To address this excessive sediment loading, a restoration project was implemented on this system by the PACD and WDEQ-WQD. This project, in combination with a restoration project on the Squaw Creek, has included riparian fencing, plantings, water gaps, streambank stabilization, irrigation water control structures and pipelines, grade stabilization structures, pasture and hayland management, planned grazing systems, and irrigation water management. Post-project monitoring has indicated an average reduction of total suspended solids by 38 percent from 1993 to 1996 (USEPAa).

The field assessment on Baldwin Creek consisted of a qualitative assessment of channel type, coupled with a Level II quantitative assessment at a representative Type E channel location. The assessment identified no major indicators of channel instability along the reach. Locally, however, the riparian corridor has been degraded through land use/grazing practices. The historic instabilities described on the system have evidently been effectively treated by the recent restoration efforts. Continued efforts in land use management would further promote riparian recovery in the watershed.

Squaw Creek

Channel Types

Squaw Creek flows out of the Wind River Range as a steep, canyon-bound A-type channel. Approximately 1 mile upstream of the confluence with Grimmetts Gulch, the channel emerges from the canyon and transitions into an E-type channel, as it is relatively narrow and deep, and is bound by a substantial floodplain surface that is accessible to channel overflows. Along its course, the channel banks tend to be thickly vegetated with grasses and limited woody vegetation (Figure 4.25).

Figure 4.25 Squaw Creek at Site SQ-1 in Restored Reach (Type-E4 Channel).

Impairments

Excessive sediment production in the Squaw Creek drainage has been attributed to grazing, agricultural clearing, and subdivision development (USEPAa, USEPAb). Restoration projects have been implemented on the system by the PACD and WDEQ. The purpose of the projects was to stabilize the channel and reduce erosion rates. These projects have included riparian fencing, plantings, water gaps, streambank stabilization, irrigation water control structures and pipelines, grade stabilization structures, pasture and hayland management, planned grazing systems, and irrigation water management. Monitoring results indicate that the projects have been successful in reducing sediment loads in the channel.

The E-type channel characteristics of Squaw Creek, including the deep narrow cross section and bounding floodplain area typically reflect efficient sediment transport processes, and stable bank configurations. Historically, however, the destabilization of the channel banks due to human impacts has resulted in excessive erosion and sediment loading. The restabilization of those banks using rigid measures such as large riprap will effectively reduce bank erosion, but will compromise long-term geomorphic function, as well as habitat elements such as undercut banks. Where feasible, channel stability can also be achieved through revegetation of the destabilized banks, as well as aggressive management of grazing in the riparian areas. The tendency for E-type channels to develop undercut banks renders them especially prone to gravitational collapse due to livestock access.

4.5 Summary

The geomorphic investigation consisted of the classification of the Popo Agie River and principal tributaries using the Rosgen classification system. Level I and Level II characterizations were completed. This effort consisted of evaluation of existing mapping, aerial photos, and GIS information including digital elevation models and digitized hydrography, and field investigations. Observations of geomorphic function and stream channel condition were made throughout the study. Results of the Level I and Level II classifications are presented in Figures 4.9 and 4.11 respectively. Table 4.4 presents an overview of the impairments noted during the study. The remainder of this section presents a summary of the observations of each stream evaluated.

The North Popo Agie River emerges from the flanks of the Wind River Range as a steep, coarse A/B type channel that displays no evidence of systemic geomorphic impairment. Upper reaches are geomorphically stable, with balanced sediment source/transport conditions, and vigorous riparian regeneration. Downstream of the Surrell Creek confluence, a reduction in channel slope results in increased tendencies for sediment deposition and channel migration. *Riparian clearing has reduced vegetative bank reinforcement and resistance to lateral erosion.*

Table 4.4 Summary of Geomorphic Impairments.

Stream	Reach	Riparian Vegetation(1)	Riparian Degradation (1)	Channel Encroachment(1)	Rigid Planform(1)
North Popo Agie	Confluence of North Popo Agie River and Surrell Creek to confluence with Middle Popo Agie River	✔			
Middle Popo Agie	Mortimer Lane to confluence with North Popo Agie River	✔		✔	✔
Little Popo Agie	Lyons valley to confluence with Popo Agie River	✔	✔		
	Confluence with Twin Creek to mouth of canyon	✔			
Popo Agie	Confluence North Popo Agie and Middle Popo Agie to Hudson Siding	✔		✔	✔
Twin Creek	Confluence with Little Popo Agie to upstream crossing of Hwy 287	✔	✔		
Baldwin Creek	Confluence with Middle Popo Agie to mouth of canyon	✔			
Squaw Creek	Confluence with Baldwin Creek to mouth of canyon	✔			

(1) Riparian Vegetation: loss of riparian condition and habitat due to grazing, crop encroachment, and loss of riparian buffers
Riparian Degradation: bank erosion, channel downcutting
Channel Encroachment: levees, loss of floodplain access
Rigid Planform Control: loss of meander capacity

Within Sinks Canyon, the Middle Popo Agie River is a steep, bedrock-confined A/B channel, that is geomorphically functional with respect to sediment transport, bankline integrity and riparian dynamics. Downstream of Central Wyoming College Field Station, the confined river transitions to an alluvial C channel. *In the City of Lander, the channel has been artificially entrenched into a forced B-channel type for flood control, transitioning downstream back into an unconfined meandering C channel. The flood control channel through Lander is geomorphically impaired due to riparian degradation, floodplain detachment, and rigid planform control.*

The Little Popo Agie River emerges from the mountain front as a relatively confined B-type channel, transitioning to a meandering C-channel type near the Highway 28 Bridge. Through Dallas Dome, the river is relatively entrenched as if flows through the low hills of the oil field. Within these reaches, relatively minor impairments consist of localized riparian degradation, and rigid planform control that will affect long-term riparian rejuvenation. *Downstream of Dallas Dome, the channel flows into the Lyons Valley, where it transitions to a geomorphically unstable incised F-type channel that has downcut in response to historic channel straightening (channelization). This channel section is significantly impaired due to the current instability, which consists of active erosion of oversteepened banks, excessive sediment production, loss of floodplain access, and riparian degradation.*

Twin Creek is characterized as a relatively small, sinuous, fine-grained E-type channel. *The upper portions of the project reach, upstream of Carr Reservoir, have incised, and are relatively unstable and locally impaired due to excessive bank and bed erosion. Downstream* *reaches have naturally recovered from historic downcutting and developed a new stable channel cross section/floodplain configuration.*

Baldwin Creek transitions from a relatively steep, confined, bedrock-controlled A-type channel to an entrenched B-type channel near Red Butte. Approximately 2.5 miles upstream of Highway 287, the B-channel transitions to a sinuous, unconfined E-channel. Historic riparian degradation and resultant sediment sourcing along Baldwin Creek resulted in the implementation of restoration measures within the river corridor. *Monitoring of the restoration efforts indicate that the techniques employed have been highly successful at reducing sediment production from the watershed.*

Squaw Creek is geomorphically similar to Baldwin Creek, as it transitions from a bedrock canyon A-type channel to an unconfined, sinuous E-channel in the alluvial basin. *Excessive sediment production in the watershed attributed to land use change has been addressed via substantial restoration efforts in the stream corridor.*

IRRIGATION SYSTEM EVALUATION

Chapter 5

5.1 Introduction

Irrigation practices dominate water usage within the watershed. According to data published by the United States Geologic Survey, agricultural uses accounted for over 96 percent of the basin's total use of surface water in 1990 (Figure 5.1). Based upon a review of tabulated water rights, there are over one hundred irrigation ditches spread throughout lower reaches of the watershed. The number of acres irrigated by these ditches ranges from less than 40 to several thousand. Some of the smaller ditches convey less than one cfs while the larger systems may convey fifty to sixty cfs.

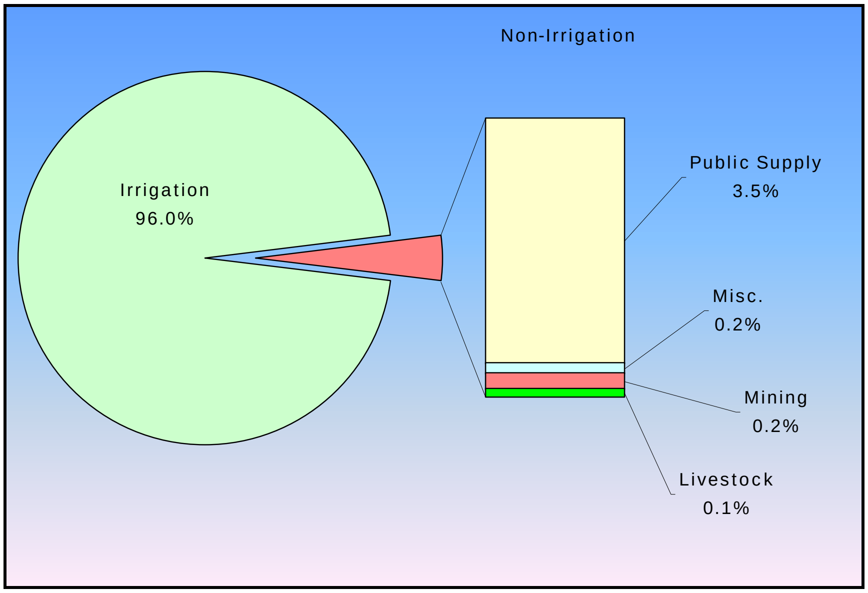


Figure 5.1 Use of Surface Water in the Popo Agie River Watershed.

Many components of the ditch systems are suffering from age and deterioration. Several ditches were built prior to statehood and have been nursed along over the years through the efforts of irrigators. Not all ditches are managed by ditch companies. Many are individually owned while the larger ones are typically managed by ditch companies that assess fees to the water users. Consequently, there is a wide range in the quality of ditches, associated infrastructure, management and measurement.

Given the magnitude of the use of water for irrigation and the range in condition of irrigation infrastructure, there is significant opportunity for water conservation through improvement of existing conveyance systems, management, measurement, and water application. In an effort to identify these opportunities, a field inventory of selected ditch systems was conducted. This effort included:

- Interviewing ditch representatives and irrigators;
- Field inventory of hydraulic structures;
- Inventory of ditch conditions;
- Assessment of the hydraulic efficiency of the structures;
- Photographic documentation of the structures and their condition; and
- Location of the structures using GPS technology.

Key information pertaining to all structures inventoried during this project are included within the GIS database.

5.2 Irrigation System Selection

Ten irrigation systems were selected for the inventory effort. These systems were selected following the review of existing information, interviews with representatives of the PACD and the NRCS, and field observations. Based upon the review of previously available information, it was determined that this group was representative of the medium to large irrigation systems. The objectives of the irrigation system inventory were to: (a) identify those structures in need of rehabilitation: and (b) evaluate the opportunity for conservation savings associated with irrigation system improvements. The ditches evaluated in this study and their source were:

- Big Cottonwood Ditch (North Popo Agie River)
- Cemetery Ditch (Middle Popo Agie River)
- Dutch Flat / Taylor Ditch (Middle Popo Agie River)
- Enterprise Ditch (Middle Popo Agie River)
- Gaylor Warnock Ditch (Middle Popo Agie River)
- Lyons Ditch (Little Popo Agie River)
- Nicol – Table Mountain Ditch (Middle Popo Agie River)
- North Fork Ditch (North Popo Agie River)
- Snavely / Grant Young Ditch (Popo Agie River)
- Wise Ditch (Little Popo Agie River)

Figure 5.2 displays the general location of these ditches.

A representative of each ditch was interviewed prior to conducting the field inventory. The ditch representatives provided valuable insight into the ditch condition, issues, and management. In general, the interviews were conducted in conjunction with a field tour of the ditch facilities.

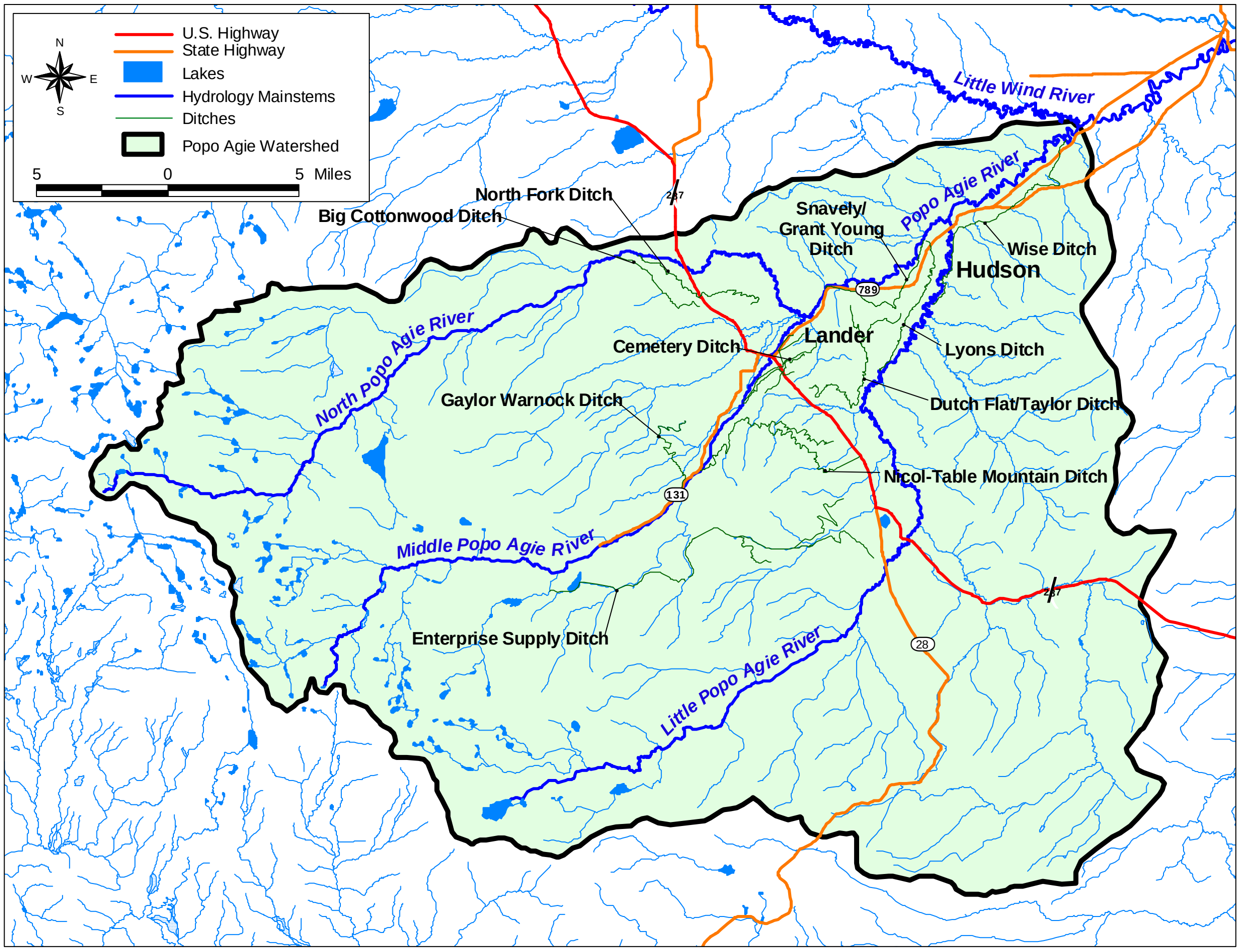


Figure 5.2 Location Map of Inventoried Ditch Systems.

Several types of structures were identified and evaluated during the field inventory. These structures include the following categories: (a) diversion headgates; (b) check structures; (c) measurement devices; (d) wasteway structures; and (e) crossings (roads, pipelines). An assessment was also conducted of the ditch conditions with specific observations noted to areas of seepage loss, erosion and degradation, vegetation encroachment, and access limitations.

5.3 Ditch Evaluation

In the following sections, the condition and noteworthy observations of each ditch are discussed. A map of each ditch is included. Each map shows:

- the general location of the ditch and its alignment;
- its water source;

- primary laterals;
- key structures (headgates, measurement devices, flumes, siphons, liners, etc); and
- noteworthy observations (seepage sites, erosion sites, hillslope instability, etc.).

On each ditch map, sites located using GPS methods are shown. These sites, indicated as red triangles, are numbered and serve as keys to the inventory forms included in the Project Notebook and the project GIS. Sites included in the seepage study (described in Section 5.4) are shown as green circles.

The ditch evaluation specifically includes an inventory of the existing facilities, identification of potential problems, and a summary of recommended improvements. Detailed summaries of each ditch system are included in Appendix C.

In general, the field inventory was limited to those structures/locations visited during the initial field tour with the ditch representatives. All structures in the ditch system were not observed. It is our understanding that the sites maintained represent the majority of the structures and significant concerns considered important to each ditch company.

Several of the ditches evaluated had been previously investigated by the NRCS in the 1980's. Those reports included numerous specific improvements; many of which are still valid. Consequently, the NRCS recommendations were incorporated herein.

5.3.1 Big Cottonwood Ditch (North Popo Agie River)

The Big Cottonwood Ditch headgate is located on the right bank of the North Popo Agie River approximately 2.75 miles upstream of Highway 287. The first 4.2 miles consist of a single delivery ditch with farm turnouts; the ditch then splits into four smaller laterals. The project inventory ended at the splitter box.

The main delivery ditch is an earthen channel with well-constructed drop structures and turnouts. The majority of lands irrigated under the ditch lie within the North Popo Agie River watershed; however, a portion of the irrigated acreage lies within the Baldwin Creek watershed where return flows eventually contribute to the Middle Popo Agie River.

Figure 5.3 presents a location map of the Big Cottonwood Ditch. Ditch managers did not recognize seepage as a significant concern and little evidence of seepage was evident. The following general observations were noted:

- There is a seven-foot wide Parshall flume located near the ditch headgate. The flume appears to be in good condition with only minor repairs/maintenance recommended. The approach to the flume, however is not ideally suited for accurate flow measurement (curved approach).

• Ditch managers hav

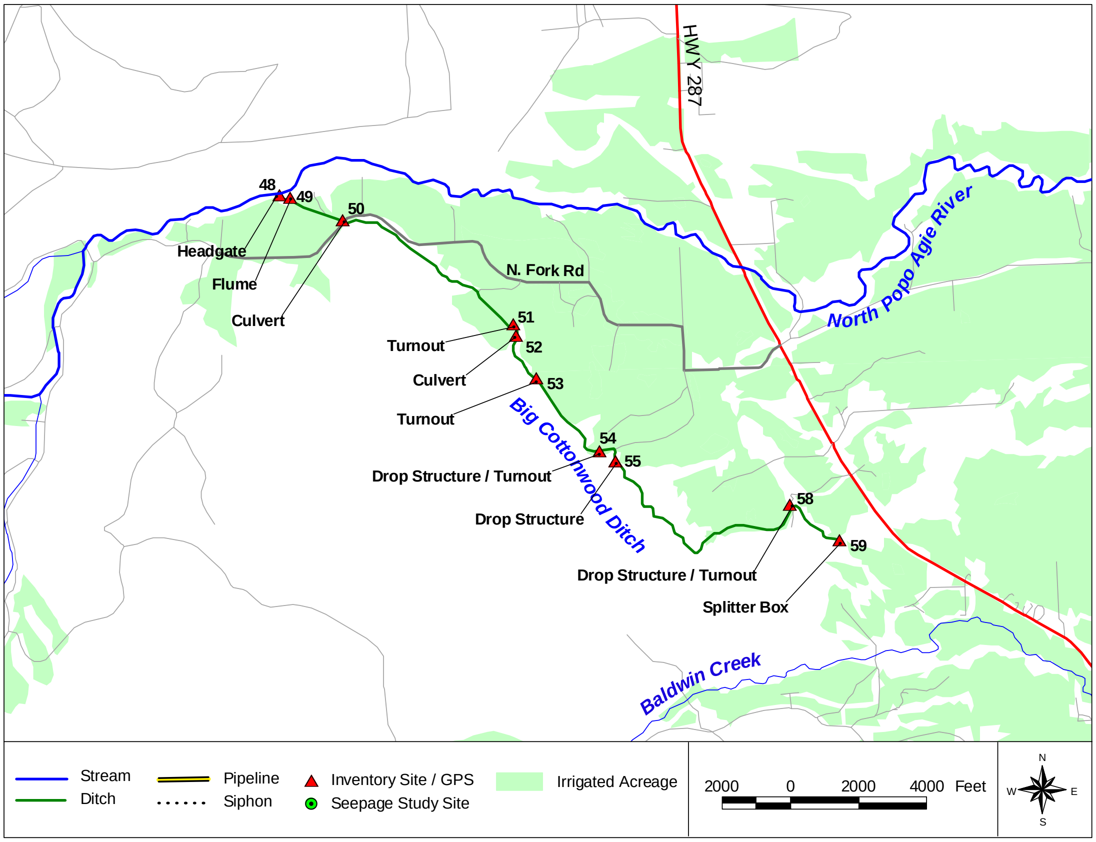


Figure 5.3 Location Map of the Big Cottonwood Ditch Inventory Sites.

- Ditch managers have placed a short section of arched corrugated metal pipe (109 inches) at a location where seepage had been evident. Reportedly, a breach of the ditch nearly occurred at this location, threatening the integrity of the ditch and homes below the ditch.

At the time of the field investigation, there was still evidence of minor seepage at this location.

- Within the reach inventoried, the structures are aged but in relatively good condition. These structures consist of several drop structures and turnouts.

- Conveyance appears restricted at the culvert crossing under North Fork Road. The ditch reportedly overtops frequently during storm events. A wasteway from the Mountain Range Ditch, located above the Big Cottonwood Ditch, occasionally spills water to the ditch.

- At mile point 4.2, a splitter box divides flow proportionally into four laterals (Figure 5.4). This structure is in poor condition. There are no measurement devices at this location.

Figure 5.4. Splitter Box on Big Cottonwood Ditch.

- No measurement devices were observed at any of the farm turnouts located within the reach inventoried.

5.3.2 Cemetery Ditch (Middle Popo Agie River)

The Cemetery Ditch has some of the most senior rights on the Middle Popo Agie River. Its headgate is located on the right bank of the river approximately 1,000 feet upstream of Mortimer Lane. Immediately downstream of the headgate, very little flow is observed in the river during the peak irrigation season. Approximately 300 to 400 feet downstream, flow is partially restored through irrigation returns.

The ditch winds through several subdivisions in the City of Lander and the City Golf Course, ultimately crossing under Highway 287 in the vicinity of the local Ford auto dealership. The majority of lands irrigated under the ditch lie downstream of Highway 287 and are managed by the Wyoming State Training School. Approximately 900 feet downstream of Highway 287, a division box splits flow between the Henry and Beebe laterals. The Cemetery Ditch inventory ended at the diversion box. Figure 5.5 presents a map of the Cemetery Ditch, which shows its alignment and the locations of features evaluated during the field inventory.

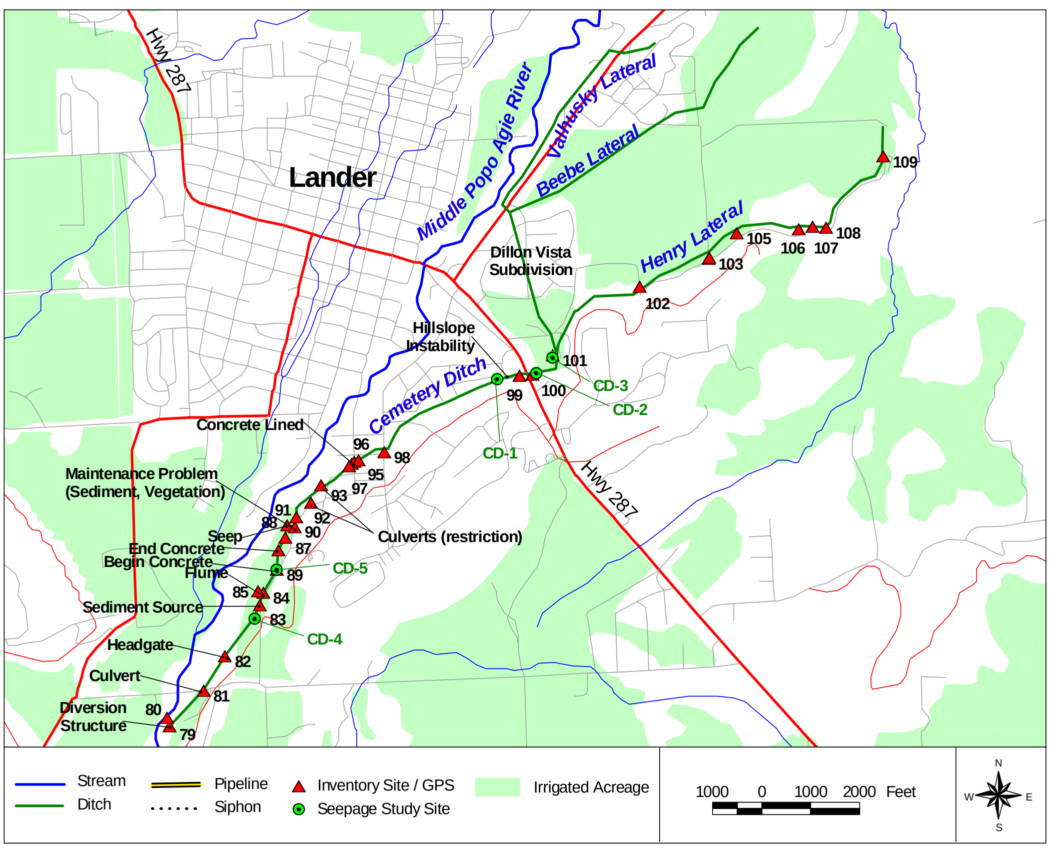


Figure 5.5 Location Map of the Cemetery Ditch Inventory Sites.

This ditch was studied in detail by the NRCS in 1983. Results of that study are incorporated herein. Observations noted during the inventory and evaluation of the Cemetery Ditch are presented below.

- In its upper reaches, the ditch meanders through several housing subdivisions and the City Golf Course. The encroachment of the subdivisions upon the ditch has created several maintenance problems for the ditch company. Several concrete lining projects have been completed in an effort to mitigate basement flooding and to reduce seepage losses. Culverts under several driveways crossing the ditch appear to restrict ditch conveyance capacity (Figure 5.6). There were also several locations where homeowners have installed pumps on the ditch for lawn irrigation.

Figure 5. 6 Cemetery Ditch in Subdivision Showing Example of Driveway Culvert Restricting Conveyance.

- In the vicinity of Highway 287, the ditch crosses the toe of an unstable hillslope. This reach is locally called the "Ford slip" for its proximity to a Ford auto dealership. The site was investigated in 1998 by GEI Consultants, Inc. on behalf of the Wyoming Water Development Commission. The Level II Feasibility study recommended several alternatives to stabilize the failure that has been attributed to seepage from the Dutch Flat/Taylor Ditch which parallels and lies above the Cemetery Ditch.

- Conveyance of the ditch has been reported to be adequate during normal operations; however, capacity is inadequate to convey double appropriations when water is available for diversion under the water rights.

- Access to the ditch has been complicated by the urban growth and development of homesites and landscaping in the vicinity of Lander. Consequently, maintenance of the ditch can be problematic.

- Several locations were identified where surface water inflow during storm events may occur. The previous NRCS study reported flooding to be problematic on the ditch. Ditch representatives state that the issue has been mitigated by raising ditch banks where flooding may have been likely. No wasteways enabling emergency flood relief were observed.

- There is a 5-foot wide Parshall flume located near the ditch headgate. With the exception of two small flumes located in the Dillon Vista subdivision, there were no other measurement devices identified during the field inventory.

- Condition of farm turnout structures observed during the inventory ranged from poor to good.

- The majority of the ditch appeared to be in generally good condition. With the exception of the hillslope failure noted above, there was minimal evidence of erosion or degradation. Seepage was evident at several locations. These sites were included in the seepage investigation discussed in Section 5.4 of this report.

- The division box downstream of Highway 287 splits the ditch into the Henry Lateral and the Beebe Lateral. The Henry Lateral is an earthen ditch that continues northeasterly to lands irrigated by the Training School. The Beebe Lateral begins at the box as a pipeline (2100 feet) under the Dillon Vista subdivision. According to the NRCS report, the pipeline is 15 inches in diameter with a design capacity of approximately 6 cfs, which is adequate for single appropriations. At higher flows, a manhole within the subdivision reportedly overtops causing localized flooding. The ditch company has attempted to mitigate flooding by creating a concrete berm around the manhole directing flows to the street.

5.3.3 Dutch Flat/Taylor Ditch (Middle Popo Agie River)

The Dutch Flat/Taylor Ditch headgate is located on the right bank of the Middle Popo Agie River approximately 0.4 miles upstream of Mortimer Lane. The ditch constitutes a transbasin diversion with the majority of irrigated lands lying within the Little Popo Agie River watershed. The ditch roughly parallels the Cemetery Ditch for approximately 2 miles to Highway 287. Two laterals branch off of the Dutch Flat/Taylor Ditch.

The NRCS studied the ditch in greater detail in 1983. Results of that report are incorporated herein. Figure 5.7 presents a location map of the Dutch Flat/Taylor Ditch. Several sites were identified where ditch seepage may occur; these locations are also shown on the location map. The general observations noted during the evaluation of the ditch are discussed below.

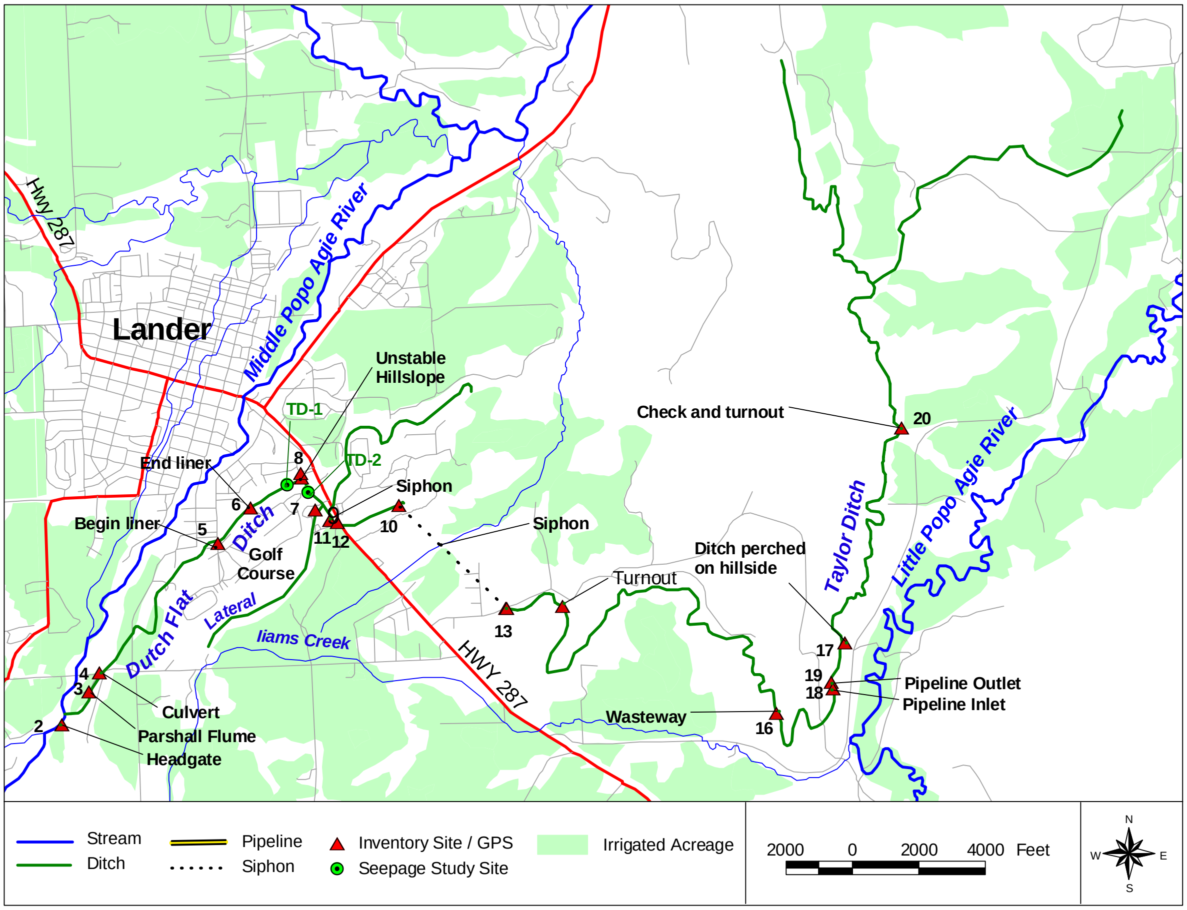


Figure 5.7 Location Map of the Dutch Flat/Taylor Ditch Inventory Sites.

- In the vicinity of Highway 287, the ditch crosses an unstable hillslope. This reach is locally called the "Ford slip" for its proximity to a Ford auto dealership. The site was investigated in 1998 by GEI Consultants, Inc., on behalf of the Wyoming Water Development Commission. The Level II Feasibility study recommended several alternatives to stabilize the failure that has been attributed to seepage from the Dutch Flat/Taylor Ditch. Several efforts to line the ditch are evident; however, these improvements do not appear effective. Seepage and standing water were evident on the hillslope during the field investigation (Figure 5.8).

Figure 5. 8 Dutch Flat / Taylor Ditch in Vicinity of Unstable Hillslope.

- A 28-inch diameter siphon crosses under the Smith Creek drainage. The siphon has been reported to limit conveyance of the ditch system and represents a continual maintenance problem for the ditch company (Figure 5.9).

Figure 5.9 Taylor / Dutch Flat Ditch Siphon Inlet.

- A wasteway is located approximately 6.25 miles down-stream of the headgate in the reach of the ditch upstream of the Lyons Valley. The structure is in fair condition, however, access to the structure is poor and relief of flood flows during an emergency could be problematic. No other wasteways or flood protection was noted.

- A 64-inch diameter siphon is located at Highway 287. This siphon appeared in good condition. It is equipped with trash racks on both the upstream and downstream sides of the highway.

- Aquatic vegetation, noted in the ditch downstream of the siphon outlet, may retard channel conveyance. It is our understanding that there is no vegetation management program for the ditch.

- A five-foot Parshall flume is located on the main ditch. It is in good condition, however, it is not installed level which provides unreliable flow measurement.

- No measurement devices were observed on any of the farm turnouts inventoried.

- A geotextile liner has been utilized in the reach of the ditch that crosses the City Golf Course. The inlet end of the material appears to be improperly installed and failure may occur. The bed and banks of the ditch may not have been properly cleared of vegetation and protruding rocks prior to its installation. Consequently, the fabric hangs loosely and may be prone to tearing (Figure 5.10).

Figure 5. 10 Installation of Geomembrane on the Dutch Flat/Taylor Ditch.

5.3.4 Enterprise Ditch (Middle Popo Agie River)

The Enterprise Ditch System represents one of the more ambitious endeavors to irrigate lands within the Popo Agie River watershed. The ditch acts as a transbasin system that diverts water from the Middle Popo Agie River watershed and applies it to lands in the Little Popo Agie River basin. Getting the water from its point of diversion to the irrigated lands involves a series of conveyance elements and diversions, including remote segments cut through bedrock.

Water is initially diverted from Roaring Fork Creek within the Middle Popo Agie River watershed. From its headgate, it is conveyed to Frye Lake by means of a one-half mile length ditch. Frye Lake is located on Townsend Creek and stores the diverted flows as well as Townsend Creek runoff. It has a useable capacity of approximately 1,700 acre-feet (NRCS, 1986). Water is released from Frye Lake into Townsend Creek, which is tributary to Sawmill Creek.

A diversion from Sawmill Creek diverts flow into a 2.6-mile ditch conveying water across the basin divide to Crooked Creek. This reach of the ditch is perched high on a steep hillslope and is cut though native shales and sandstones (Figure 5.11). Flows are diverted from Crooked Creek into another earthen ditch which carries them to the top of the divide between Beason and Crooked Creeks. At that point, the water cascades down the side of the steep hillslope to Beason Creek. This represents a drop of approximately 1,000 vertical feet. Flows are then conveyed through Beason Creek, Blue Hill Lateral and Deadman Gulch Lateral. The study inventory ended at the diversions from Beason Creek to the Blue Hill and Deadman Gulch Laterals.

Figure 5.11 Rock Cut Segment of the Enterprise Ditch between Sawmill Creek and Crooked Creek.

The Natural Resources Conservation Service studied the Enterprise Ditch in greater detail in 1986. Results of that study are incorporated herein. Figure 5.12 presents a location map of the Enterprise Ditch system and the locations of features inventoried during the field investigation. The following general observations were noted and described below.

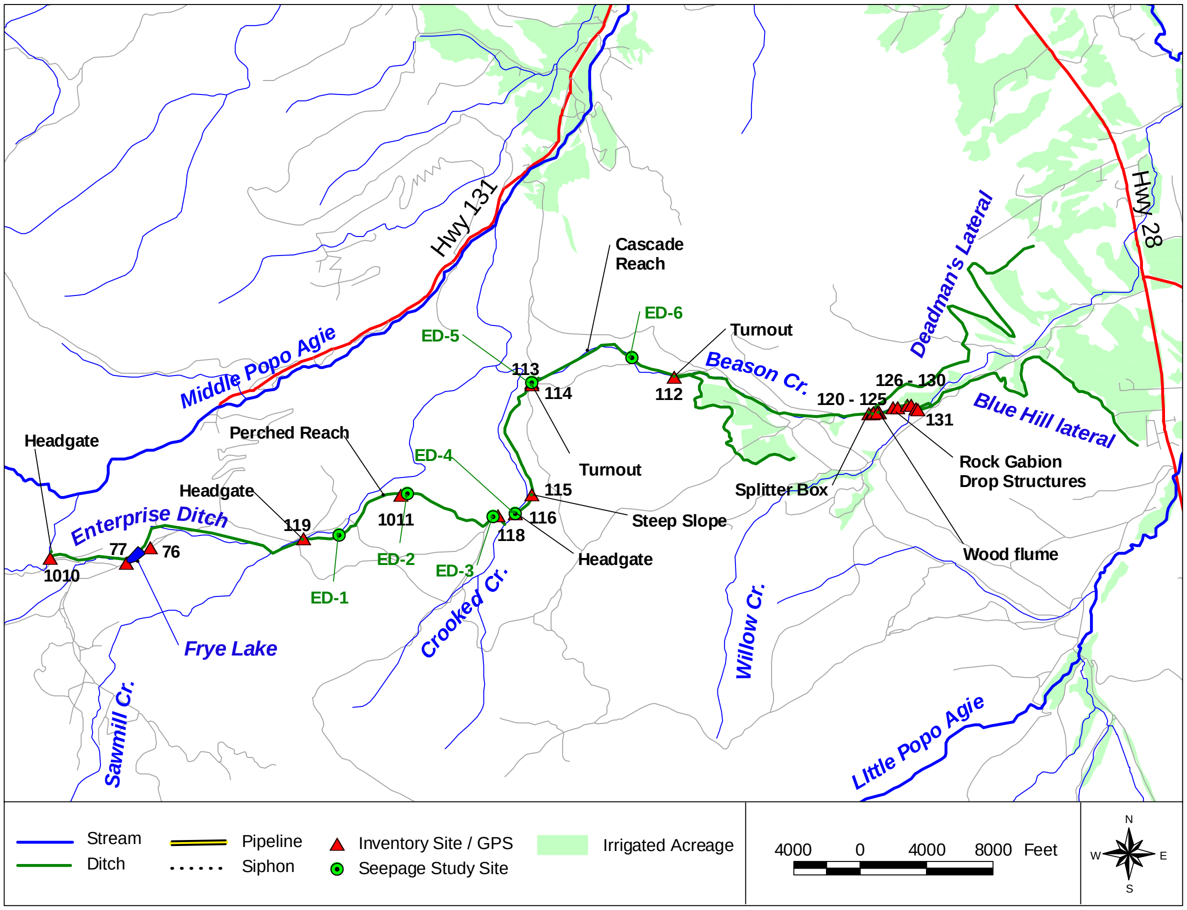


Figure 5.12 Location Map of the Enterprise Ditch Inventory Sites.

- Access to much of the ditch system is difficult. Headgates on Roaring Fork Creek, Sawmill Creek, and Crooked Creek require lengthy travel via four wheel drive vehicles, making maintenance and operations laborious.

- Measurement devices are generally lacking on the ditch system. There is a Pashall flume on the ditch near the headgate on Roaring Fork Creek (this site was not inventoried). However, no measurement devices were noted at any of the other headgates within the system nor on any farm/lateral turnouts observed.

- Conveyance capacity appears limited at several locations. The ditch reach between Sawmill Creek and Crooked Creek was constructed through limestone bedrock. This reach showed very little freeboard during the field investigation.

- Beason Creek is a component of the Enterprise Ditch conveyance system. The stream is situated amid highly erosive soils, consequently, the duration and magnitude of the irrigation diversions have resulted in significant bed and bank erosion of Beason Creek. Review of NRCS records shows that efforts to stabilize the creek began in the early 1980's. A series of recently constructed rock gabion structures may have arrested some of the erosion in the channel bed; however, they appear to be in need of repair and remediation (Figure 5.13).

- Storm flows could threaten the integrity of the ditch. Each headgate is equipped with a highflow bypass allowing stormflows to return back to the stream. However, surface water enters directly into the ditch at numerous locations and only one wasteway was noted in the system.

Figure 5. 13 One of Five Rock Gabion Drop Structures Located on Beason Creek.

- Existing infrastructure inventoried during the study ranges from poor to fair condition. Figure 5.14 shows a photograph of a turnout/drop structure located on Beason Creek. This structure, constructed of a combination of plywood and concrete, serves in part, as a grade control structure for the creek. The structure is in poor condition and its imminent failure could cause further degradation of Beason Creek.

- Evidence of ditch seepage was observed at several locations. Seepage studies were conducted on several reaches.

Figure 5. 14 Turnout and Drop Structure in Poor Condition on Enterprise Ditch.

It should be noted that the field investigation was limited to a preliminary inventory of the Enterprise Ditch; the Blue Hill and Deadman Gulch Laterals were not inventoried. According to the NRCS investigation (1986), numerous improvements and rehabilitation projects were needed on the laterals.

5.3.5 Gaylor Warnock Ditch (Middle Popo Agie River)

The Gaylor Warnock Ditch headgate is located on the left bank of the Middle Popo Agie River near the mouth of Sinks Canyon. The conveyance facilities consist of a single delivery ditch with farm turnouts; there are no laterals. The ditch is primarily earthen with several short sections conveying irrigation flows in a pipe. Most of the lands irrigated under the ditch lie within the Hornecker Creek watershed which is tributary to the Middle Popo Agie River. A portion of the irrigated lands lie within the Squaw Creek basin which is also tributary to the Middle Popo Agie River. The ditch has relatively junior water rights (1917, priority date) and as a result, the diversions into the ditch are limited to stock flows during low flow periods.

Figure 5.15 presents a location map of the Gaylor Warnock Ditch. Several sites were identified where ditch seepage may occur; these locations are also shown on the location map. Observations noted during the inventory and evaluation of the Gaylor Warnock Ditch are presented below.

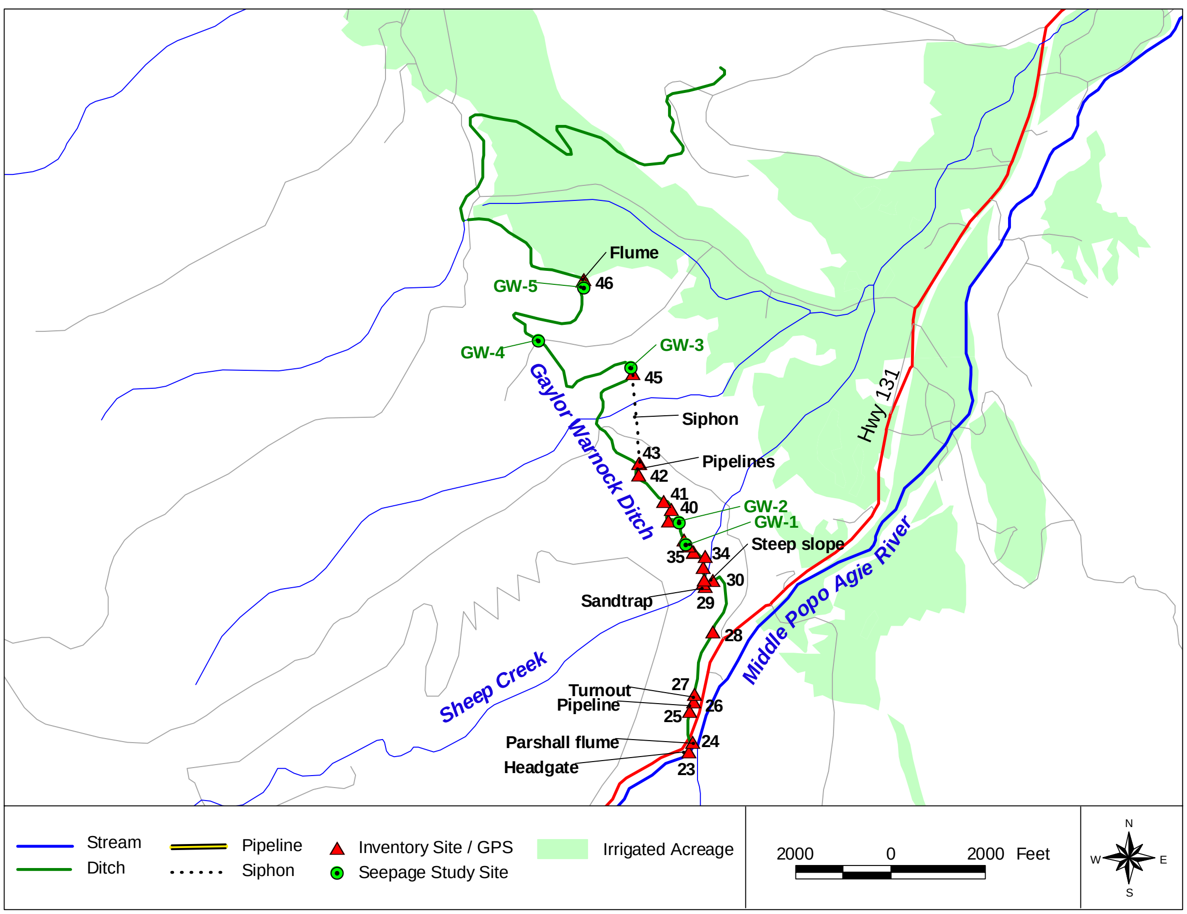


Figure 5.15 Location Map of the Gaylor Warnock Ditch Inventory Sites.

- The ditch headgate has been recently rehabilitated and is in good condition. A 3-foot Parshall flume is located at the headgate. The flume is in good condition, however, there are several flow obstructions in the approach channel (rocks) that may affect its accuracy. The flume also does not also appear to be installed level.

- Approximately 250 linear feet of the ditch conveyance facilities consist of a 30-inch diameter steel pipe. The pipe is located above County Road 131 (Sinks Highway). It is our understanding that proposed road improvements will necessitate reconstruction of this portion of the ditch (Figure 5.16).

Figure 5.16 Gaylor Warnock Pipeline along CR 131.

- A second flume is located near the tail end of the ditch where the irrigation deliveries are limited to one user. This flume is in fair condition but needs rehabilitation and maintenance. The structure is partially undercut and a portion of the ditch flow may bypass the structure.

- Much of the upper portions of the ditch are choked with dense shrubs. This vegetation retards flows, increases evapotranspiration, and makes access difficult.

- Seepage from the ditch is a continual concern according to the ditch representative. Ditch and NRCS representatives state that sink holes have occurred in the ditch which have threatened its integrity.

- An oversteepened reach occurs in the ditch upstream of Sheep Creek. Flows in this reach of the ditch cascade over large boulders and bedrock and appear to generate significant sediment from erosion of the ditch bank.

- A sediment trap/release located downstream of the steepened reach has an ineffective slide gate which does not appear fully operable. At the time of the field inventory, a significant portion of the flows being diverted was lost below the gate (Figure 5.17).

Figure 5. 17 Sediment Trap on Gaylor Warnock Ditch.

- Several 48-inch corrugated metal pipes have been installed within the ditch in an effort to reduce seepage. Due to the low flows diverted during the field investigation, the effectiveness of these seepage mitigation measures could not be determined.

- A 24-inch siphon was recently constructed with the assistance of the NRCS. This structure bypasses approximately 2,800 feet of problematic ditch reach. The structure is in good condition.

5.3.6 Lyons Ditch (Little Popo Agie River)

The Lyons Ditch headgate is located on the left bank of the Little Popo Agie River in the Lyons Valley. The main delivery system consists of a single ditch with farm turnouts; there are no laterals. Figure 5.18 presents a location map of the Lyons Ditch. Several sites were identified where ditch seepage may occur; these locations are also shown on the location map. However, ditch representatives stated that they did not feel the ditch experiences significant losses to seepage. Consequently, no seepage studies were performed on this ditch. The general observations noted during the evaluation of the ditch are itemized below.

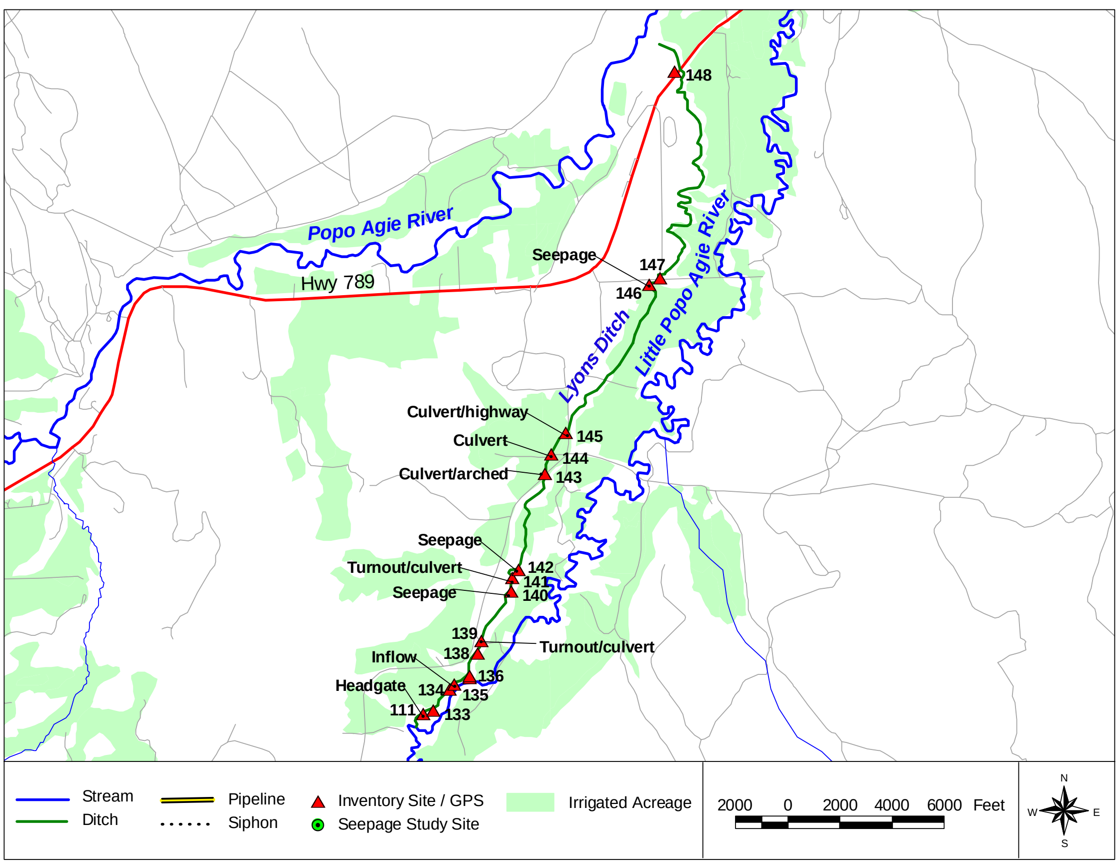


Figure 5.18 Location Map for the Lyons Ditch Inventory Sites.

- The Lyons Ditch diversion structure spans the width of the Little Popo Agie River (Figure 5.19). It lies upstream of a reach that has been channelized in the past. The structure serves as a grade control for the river and has, at least partially, arrested degradation associated with channel response to the realignment project.

Figure 5.19 Lyons Ditch Diversion Structure on Little Popo Agie River.

- Dense aquatic vegetation appears to significantly reduce conveyance capacity of the ditch. This condition is exacerbated by the ditch's relatively flat slope. With the exception of physically digging the vegetation out with a trackhoe, it us our understanding that no vegetation management occurs (Figure 5.20).

- The ditch crosses the Lyons Valley road several times as well as several farm roads, consequently there are numerous culvert crossings. Conveyance does not appear to be limited by these crossings.

Figure 5.20 Aquatic Vegetation in Lyons Ditch.

- The farm turnouts inventoried are generally in poor condition. They typically consist of a slide gate. Check structures to facilitate the diversion of water into the turnout structures were noticeably absent.

- No measurement devices were observed on the ditch or any of the turnouts inventoried.

5.3.7 Nicol – Table Mountain Ditch (Middle Popo Agie River)

The Nicol–Table Mountain Ditch represents one of the larger trans-basin diversions within the watershed. The ditch conveys diversions from the Middle Popo Agie River to irrigated lands within the Little Popo Agie River basin. Its headgate is located on the right bank of the Middle Popo Agie River approximately 1.3 miles downstream of Sinks Canyon. The ditch system consists of a main delivery ditch for approximately 5.7 miles before it splits into the North Lateral and the Parker-McBride Lateral. The North Lateral is approximately 4.6 miles long and the Parker-McBride Lateral is approximately 6.5 miles long. The two laterals are aligned roughly parallel to each other with the Parker-McBride Lateral located above the North Lateral.

The field inventory of the Nicol-Table Mountain Ditch included those sites and structures indicated by the ditch managers. The entire length of the ditch was not inspected. This ditch was also studied in greater detail by the NRCS in 1986. Results of that report are included herein.

Figure 5.21 presents a location map of the Nicol-Table Mountain Ditch. Several sites were identified by the ditch managers as locations where ditch seepage may occur; these locations are also shown on the location map. The general observations noted during the evaluation of the Nicol-Table Mountain Ditch are presented below.

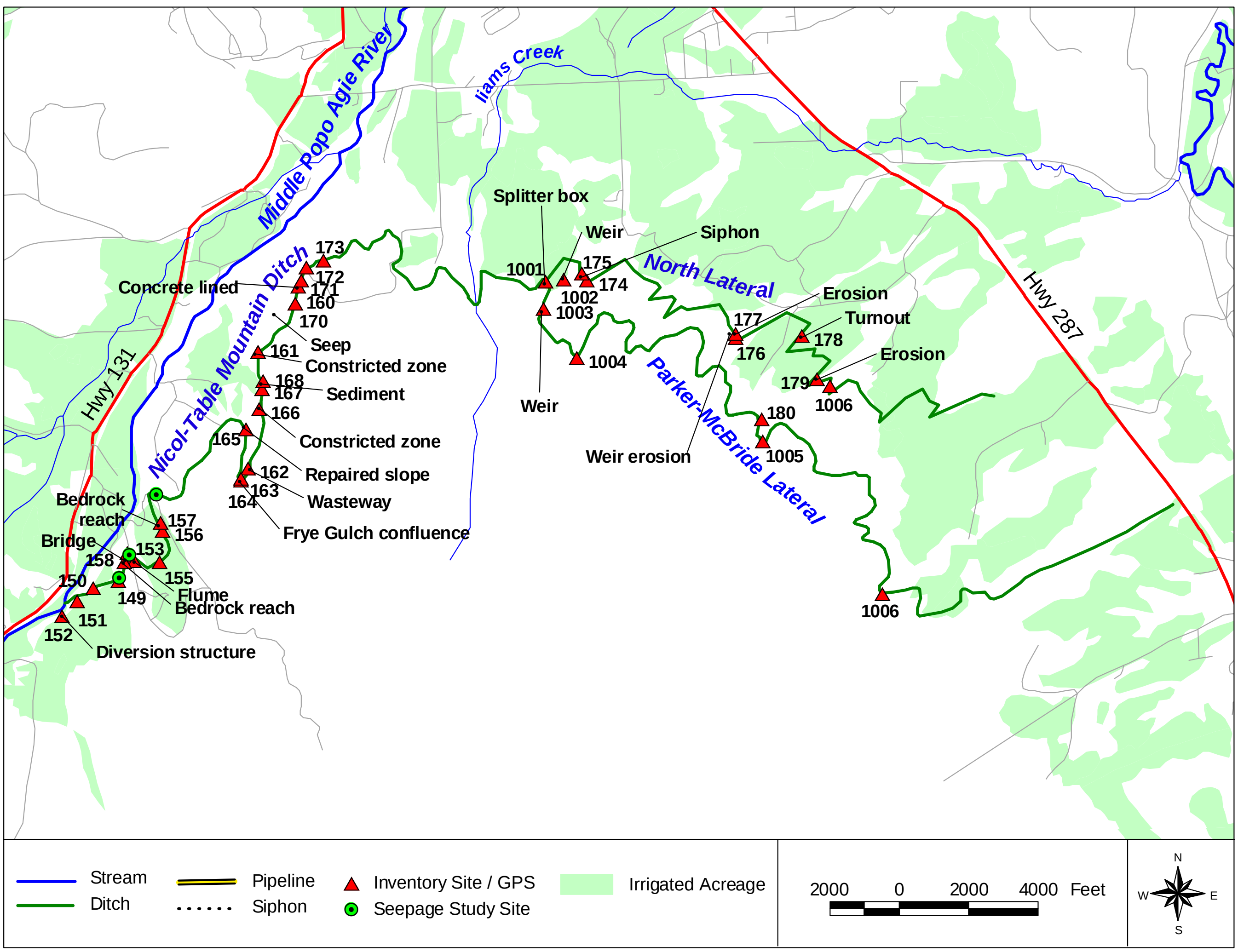


Figure 5.21 Location Map of the Nicol-Table Mountain Ditch Inventory Sites.

- Most of the ditch system is earthen and, in many places, the bed consists of soft shales and sandstone. Erosion, sedimentation, and seepage were noted as continual maintenance problems associated with the ditch. A minor amount of the ditch has been lined with concrete in an effort to improve conveyance capacity and reduce seepage losses. Hillslope instability has also caused maintenance problems for the ditch company.

- Much of the existing infrastructure is aged and deteriorating. The diversion and headgate structures on the Middle Popo Agie River are in poor condition and are in need of replacement (Figure 5.22). Concrete in both structures is spalling and deteriorated. Gates are in poor condition and cannot be closed.

Figure 5.22 Nicol-Table Mountain Ditch Diversion Structure.

- Measurement devises on the ditch consist of a 6-foot Parshall flume on the main delivery ditch and sharp-crested weirs located on each of the laterals. Scour downstream of the flume is causing bank and bed degradation. The weirs on the laterals were recently constructed and are in good condition. No measurement devices were observed at any of the farm turnouts evaluated during the field investigation.

- In several locations, the ditch was excavated through sandstone bedrock. Fractured / jointed bedrock, rough ditch beds, low freeboard, and limited cross sectional area combine to limit the capacity of the ditch. Field observations of these reaches also suggest that seepage may be occurring. Figure 5.23 shows one of these reaches located upstream of the flume at GPS location number 159.

Figure 5.23 Sandstone Bedrock Reach of the Nicol-Table Mountain Ditch with Reduced Conveyance Capacity.

- Stormwater captured by the ditch was reported in the NRCS report to be a significant problem. The system collects storm runoff in several locations and there is only a limited capacity to relieve the ditch of these flows in a controlled manner. There is a wasteway on the main ditch at Frye Gulch. On the Parker-McBride Lateral, there are wasteways at the flume and near the end of the lateral. Frye

Gulch also contributes significant sediment, in addition to storm flows into the delivery ditch. Spills from the Parker-McBride Lateral can damage the North Lateral.

- Hillslope instability is problematic and has been identified as a significant issue with the ditch. The NRCS report identified eleven areas where hillslope instability threatened the integrity of the ditch.

- Ditch erosion is occurring at several locations (Figure 5.24). Over-steepened reaches, such as that on the North Lateral downstream of the split with the Parker-McBride Lateral have resulted in bed and bank erosion, sedimentation of downstream reaches, and ditch instability.

Figure 5-24 Example of Erosive Reach on Nicol-Table Mountain Ditch.

- Many of the farm turnouts on the ditch system are aged and in need of rehabilitation. However, the ditch company has made an effort to improve structures by replacing them on an as-needed basis. Several farm turnouts located on the North Lateral have been recently constructed and are in good condition.

- A concrete-lined reach of the main ditch was improved in 2001. Concrete berms were placed on both banks in an effort to improve ditch conveyance capacity.

5.3.8 North Fork Ditch (North Popo Agie River)

The North Fork Ditch headgate is located on the right bank of the North Popo Agie River approximately 2.0 miles upstream of Highway 287. The main delivery system consists of a single ditch with farm turnouts; there are no laterals. The ditch is entirely earthen; there are no lined or piped reaches. The entire ditch is approximately 7.0 miles long. There are approximately 4.5 miles of ditch above any turnouts.

Figure 5.25 presents a location map of the North Fork Ditch. Few sites were identified where ditch seepage may occur; these locations are also shown on the location map. The general observations noted during the evaluation are itemized below.

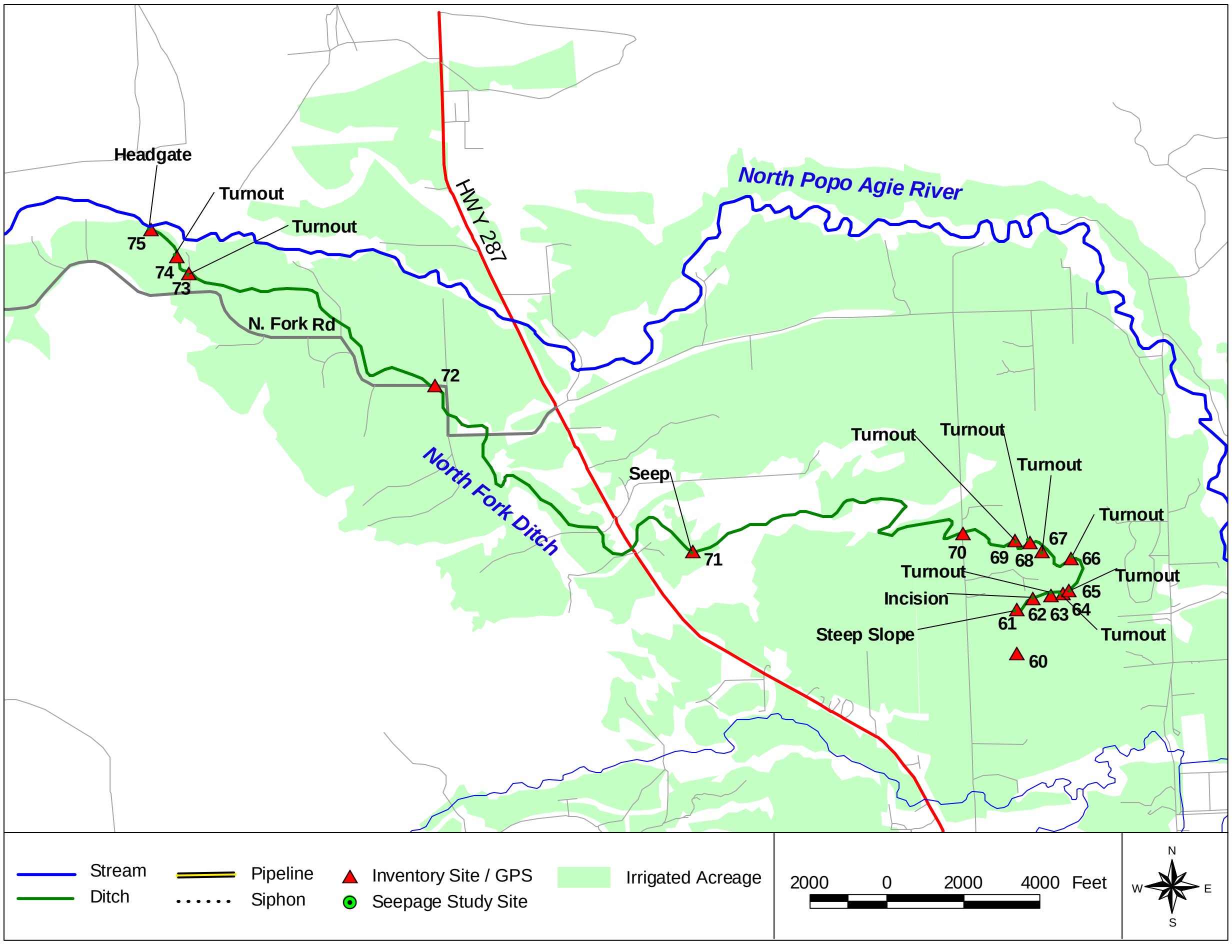


Figure 5.25 Location Map of the North Fork Ditch Inventory Sites.

- Diversion from the North Popo Agie River is facilitated by a concrete structure. The structure is in poor condition and appears to require frequent maintenance (Figure 5.26). The ditch headgate is located immediately adjacent to this structure. It is in fair condition and appears operable.

- Several deteriorated structures were observed in the upstream reach of the ditch. These structures appeared to be abandoned.

Figure 5. 26 North Fork Ditch Headgate and Diversion Structure.

- No measurement structures were observed in the ditch system, including the ditch headgate and farm turnouts.

- Farm turnouts were generally in poor condition, consisting of deteriorated concrete check structures or wood/ tarpaulin structures (Figure 5.27).

- Most of the ditch appears to be stable and non-erosive. However, a steep reach near the tail end of the ditch (GPS location 60-61) is degraded and erosive.

Figure 5.27 Turnout Structure on North Fork Ditch.

5.3.9 Snavely / Grant Young Ditch (Popo Agie River)

The Snavely / Grant Young Ditch is located on the right bank of the Popo Agie River near Hudson Siding. The main delivery system consists of a single ditch with approximately 14 individual farm turnouts. There are no laterals. The ditch has no designated ditch rider; individual users control their own turnouts. Historically, the Snavely and Grant Young ditches operated independently. Following loss of the Snavely headgate, the ditches were combined into the single ditch that exists today.

Figure 5.28 presents a location map of the Snavely / Grant Young Ditch . The general observations noted during the inventory and evaluation of the ditch as presented below.

- Dense aquatic vegetation appears to significantly reduce conveyance capacity of the ditch (Figure 5.29). This condition is exacerbated by the ditch's relatively flat slope. It us our understanding that no vegetation management occurs.

- There is no physical structure at the actual point of diversion on the Middle Popo Agie River. Diversions are accomplished by means of a cobble berm extending to the middle of the channel. This method appears adequate during normal and wet years. During drier years, diversion of irrigation flows appears more difficult.

Figure 5.29 Aquatic Vegetation in Snavely / Grant Young Ditch.

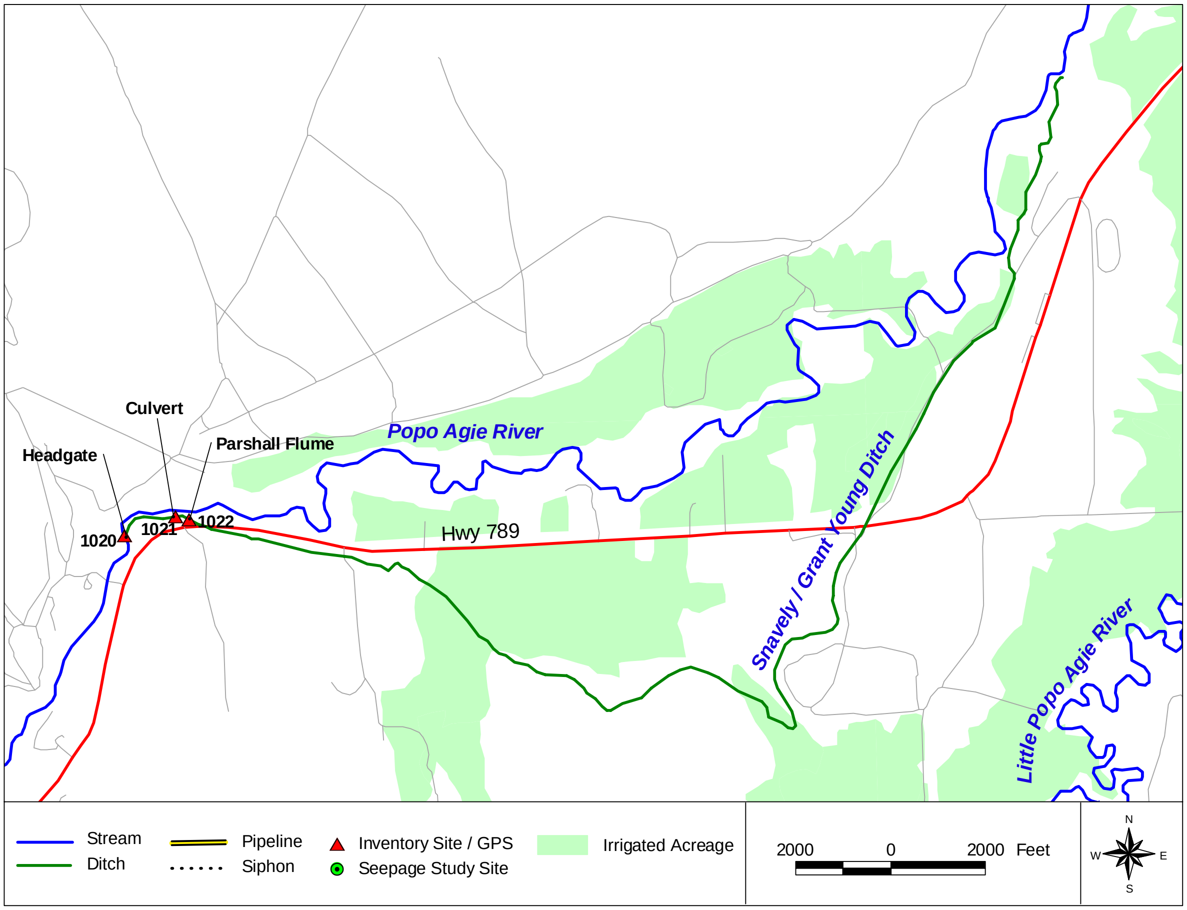


Figure 5.28 Location Map of the Snavely / Grant Young Ditch Inventory Sites.

- Stormwater is captured by the ditch during significant precipitation events and potentially threatens the integrity of the ditch. There are no wasteways on the ditch system.
- Seepage was not identified as a significant concern throughout most of the ditch's length. One potential seepage location was observed upstream of Highway 289.
- A Parshall flume, previously installed upstream of Highway 289, had been removed to accommodate highway improvements.
- No measurement devices were observed on any of the farm turnouts.

5.3.10 Wise Ditch (Little Popo Agie River)

The Wise Ditch headgate is located on the right bank of the Little Popo Agie River approximately 3.2 miles upstream of the Town of Hudson. The main delivery system consists of a single ditch with farm turnouts; there are no laterals. The majority of the ditch is earthen, however, there are limited reaches of concrete or plastic liners. The ditch follows the edge of the Little Popo Agie River valley to the Town of Hudson and continues northerly along the Popo Agie River.

Figure 5.30 presents a location map of the Wise Ditch. Several sites were identified where ditch seepage may occur; these locations are also shown on the location map. General observations noted during the inventory and evaluation of the Wise Ditch are presented below.

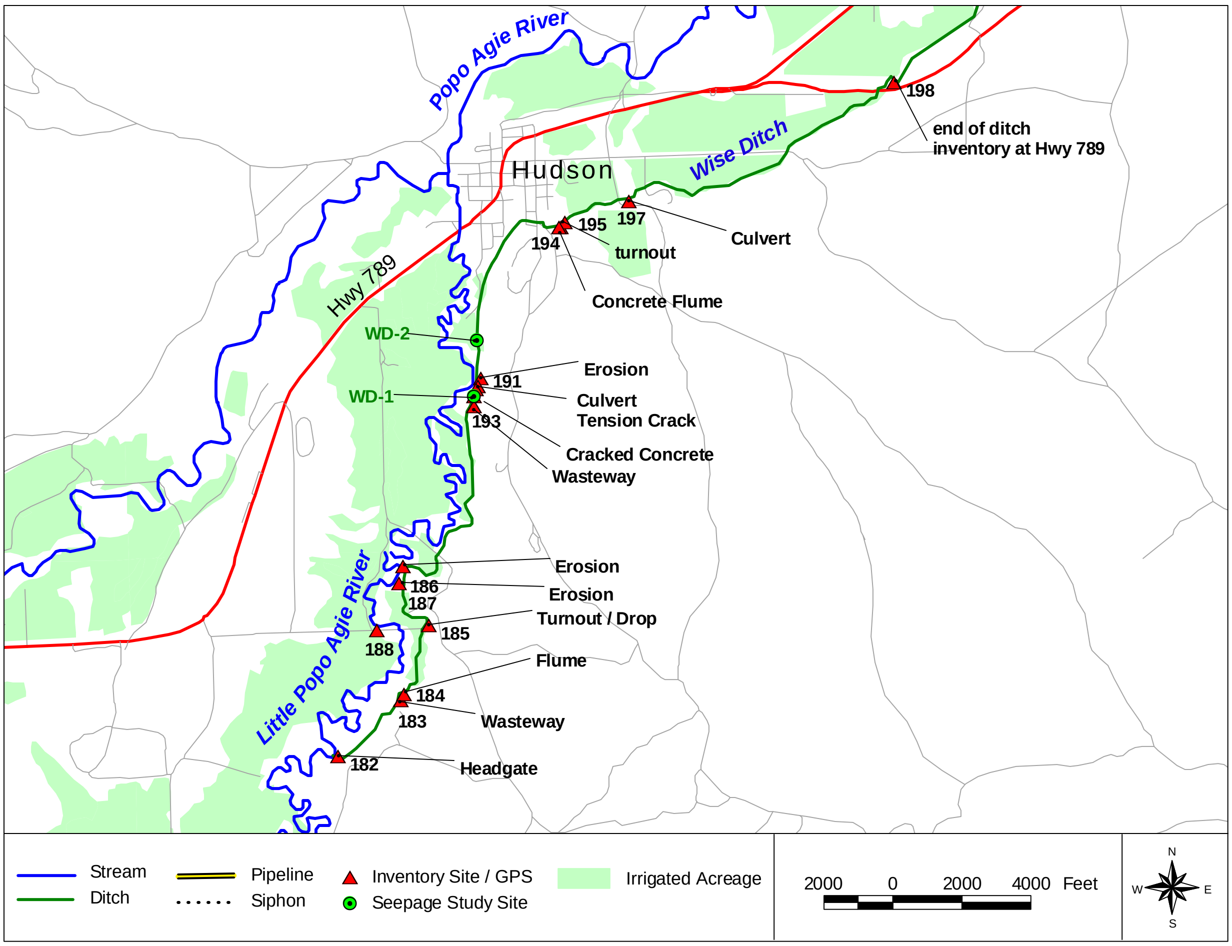


Figure 5.30 Location Map of the Wise Ditch Inventory Sites.

- The Wise Ditch headgate is in generally good condition. There is no diversion structure across the Little Popo Agie River to facilitate diversion, however, it appears that the headgate and alignment of the river allow diversions during all but the lowest of streamflows. The region was in the midst of severe drought during the field inventory. At that time, a cobble berm had been placed in the Little Popo Agie River streambed to enhance diversion capability.

- A wasteway is located approximately 2,400 feet downstream of the headgate/diversion structure. The wasteway spills flows back to the Little Popo Agie River. It is currently in fair condition but there is some visible cracking of concrete which should be repaired.

- A Parshall flume is located on the ditch approximately 200 feet downstream of the wasteway. The flume is in good condition but the ditch banks downstream are eroding and threaten the stability of the flume.

- At GPS point 185, erosion of the right bank of the ditch has undermined a hillslope that appears unstable. The toe of the slope has been protected with haybales and fencing (Figure 5.31). A drop structure at this location is in poor condition.

- Near the mouth of the Lyons Valley (GPS location 191), the Little Popo Agie River impinges on the hillslope below the Wise Ditch. Efforts to reduce seepage and failure of the slope have been completed in the past by lining the reach with plastic. The plastic appears discontinuous. Tension cracks were evident in the ditch embankment (Figure 5.32).

- Portions of concrete lined sections of the ditch have failed resulting in discontinuous protection of the ditch.

- The concrete flume spanning Hudson Draw is in poor condition and in need of replacement.

- No measurement devices were observed on any of the farm turnout structures inventoried.

Figure 5.31 Unstable Ditch Conditions on Wise Ditch.

Figure 5.32 Tension Cracks in Wise Ditch Embankment.

5.4 Seepage Study

5.4.1 Site Selection

The purpose of the seepage study was to identify and evaluate areas of significant water loss, thereby flagging those locations for potential improvement measures. During the inventory phase of the study, the field crew noted indications of ditch seepage. Seepage indicators included:

- the presence of phreatic vegetation and wetlands along the ditches;
- changes in the health and vigor of existing vegetation along the ditches;
- presence of fractured and jointed bedrock in ditch beds and banks;
- evidence of hillslope instability including sloughing, hummocks, and rotational failures;
- the existence of standing water adjacent to the ditch; and
- review of color infrared aerial photographs (taken in 1983 and 1984) provided by WWDC.

This information was supplemented by interviews with ditch representatives and personnel. The interviews provided site-specific insight related to areas of potential seepage losses.

Following the initial field investigation, maps were prepared showing the locations of seepage indicators and the locations the ditch representatives indicated as being "suspect". It must be recognized that all ditches lose water to seepage to a certain degree. The purpose of the seepage study was to identify those locations where seepage appears to be significant and where tangible benefits could be gained if the seepage were eliminated.

With this philosophy in mind, seepage reaches were selected for further analysis. For each reach presented in Table 5.1, paired measurements were collected spanning the locations where seepage was suspected.

Table 5.1 Number of Reaches Evaluated in Seepage Study.

Ditch	Basin	Number of Reaches
Enterprise	Middle Popo Agie River	4
Cemetery	Middle Popo Agie River	3
Taylor	Middle Popo Agie River	1
Nichol-Table Mountain	Middle Popo Agie River	2
North Fork	North Fork Popo Agie River	0
Big Cottonwood	North Fork Popo Agie River	0
Lyons	Little Popo Agie River	0
Wise	Little Popo Agie River	1
Gaylor Warnock	Middle Popo Agie River	3
Snavely / Grant Young	Big Popo Agie River	1

Those sites identified for seepage analysis were selected based upon the perceived magnitude of the losses and the potential conservation savings associated with them. Three of the ditches evaluated during the inventory phase of the project were not evaluated further during this phase of the project because evidence of significant seepage was not observed or ditch representatives provided information indicating that it was not a significant issue.

5.4.2 Methods of Measurement

Ditch seepage losses (and gains) were estimated using a water budget approach. This approach relies on measuring the ditch discharge upstream and downstream of the reach suspected of losing water to seepage. In larger ditch systems, evapotranspiration (ET) may be a significant portion of the water budget, however, in the relatively short reaches evaluated and the minimal surface area, Et was assumed to be insignificant (Figure 5.33).

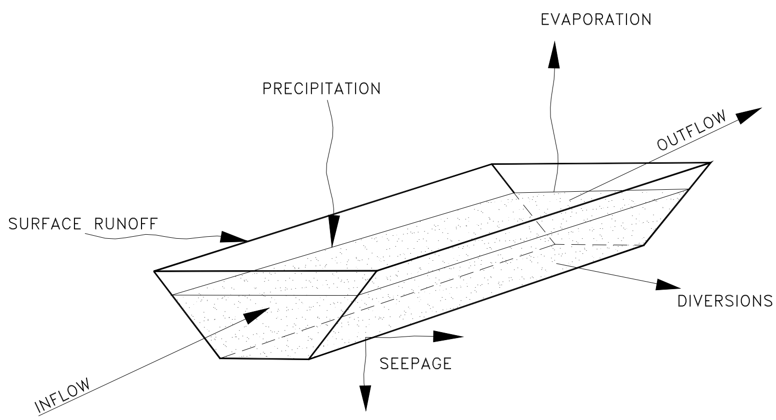


Figure 5. 33 Components of the Water Budget Analyses.

Discharge was measured using methods outlined by the United States Geological Survey (Buchanon, T.J., and W.P. Somers, 1969). Briefly, the ditch cross section was divided horizontally into approximately 15-20 sections. At each section, the water depth was measured by sounding with a graduated staff. A bottom plate was attached to the staff to prevent penetration into bottom sediments thereby providing accurate measurement of flow depth. Flow velocity was measured using a Marsh-McBirney electromagnetic current meter at depths of 0.2 and 0.8 times the water depth when depth was greater than 2.5 feet and at depths of 0.6 times the water depth when less than 2.5 feet deep. A minimum of three velocity measurements, each integrated over a period of 20-seconds, were taken at each point. The average velocity at each location was then multiplied by the section area to obtain the incremental discharge. Total ditch discharge was computed as the sum of these incremental section values.

To reduce the likelihood of an erroneous measurement or inaccuracies in the data obtained during this task, several steps were taken:

- Discharge measurements were made at each seepage site by first gaging the upstream limit of the suspect reach followed by the downstream. This convention was employed in an effort to measure the same “bucket of water” as it passes each location. Consequently, potential errors related to changes in diversions and turnouts are reduced.

- Intervening turnouts were observed during the measurement process. If water was being turned out to a field, it was measured and incorporated into the water budget equation.

- Return flows from upslope irrigation were also noted. Although they are more difficult, and often impossible to measure directly, observation of their locations allowed subjective corrections to the water budget equation. Where quantification of irrigation returns was possible, they were measured.

- All cross sections were gaged by wading the ditch.

- Each reach was walked prior to gaging to observe the presence of ditch inflow (surface runoff, springs, etc.) and/or outflow (turnouts, wasteways, etc.).

5.4.3 Measurement Results

Results of any seepage study must be viewed with respect to the accuracy of the measurement method. According to The Bureau of Reclamation's Water Measurement Manual (1984), measurements rated as "excellent" would be assumed to be accurate within 2 percent, "good" within 5 percent and "poor" within 8 percent. Channel conditions in an irrigation ditch typically lend themselves to the “good” to “excellent” ranges of measurements. Flow distributions are uniform across a ditch cross section, channel irregularities encountered in natural streams are typically absent, and given the nature of ditch diversions, a steady state flow condition can often be achieved. Measurements made during the seepage study went very smoothly, data were reproducible, sites possessing good measurement characteristics were located, and weather conditions were very good. Consequently, results of the seepage study are assumed to be accurate within 5 percent.

Our experience with ditch seepage studies has also shown that the results are not always intuitive; gains are often measured where water is obviously lost from the ditch. Flow in an irrigation ditch represents a balance between ditch inflows and outflows. If inflow exceeds outflow, a gain will be measured despite the fact that seepage is occurring.

Due to the limited time period and budget of the study, repetitive measurements were not collected. The results of this study represent a "snapshot" in time of conditions at the specific sites selected for study. During the investigation, the region was in the midst a severe drought. The effects of the drought on the seepage study are not readily apparent. According to local ditch representatives, flows in many of the ditches were lower than normal.

Also, this Level I investigation did not include evaluation of seepage losses throughout the entire length of each ditch. As noted in the previous section and in the pertinent NRCS reports, seepage is suspected at several locations on ditches such as the Nicol-Table Mountain and the Enterprise Ditches. The sites evaluated in this investigation give an indication of the magnitude of losses which are occurring and will help to focus future, more detailed efforts.

With this information in mind, Table 5.2 is presented which summarizes the results of the seepage investigation. Several of the ditches evaluated stand out in terms of the shear magnitude of losses measured. The Nicol-Table Mountain, Gaylor Warnock, and Enterprise all exhibited losses exceeding 25 percent of their diverted flows. It must be noted that losses are suspected in additional reaches of these ditches, particularly on the Nicol-Table Mountain Ditch. Previous studies by the NRCS suggest total seepage on that ditch may approach 40 percent.

Table 5.2 Summary of Popo Agie River Watershed Study Seepage Investigation.

Ditch	Reach	Site Number	Length (ft)	Discharge (cfs)	Turnouts (cfs)	Reach Loss / (Gain) (cfs)	Reach Loss / (Gain) (%)	Seasonal Loss (af)
Cemetery	CD-a	CD-1 CD-2	795	12.9 13.2	0.0	-0.3	-2%	-78
	CD-b	CD-2 CD-3	645	13.2 13.9	0.0	-0.8	-6%	-195
	CD-c	CD-4 CD-5	1130	17.9 14.7	0.0	3.2	18%	832
Dutch Flat / Taylor	TD-a	TD-1 TD-2	1360	46.0 43.1	0.0	2.9	6%	754
Enterprise	ED-a	ED-1 ED-2	5060	34.8 30.7	0.0	4.1	12%	1066
	ED-b	ED-2 ED-3	5890	32.2 30.2	0.0	2.0	6%	520
	ED-c	ED-4 ED-5	9317	32.1 28.1	1.0	3.0	9%	780
	ED-d	ED-5 ED-6	6870	28.1 23.6	0.0	4.5	16%	1170
Gaylor Warnock	GW-a	GW-1 GW-2	500	21.2 18.1	0.0	3.1	15%	806
	GW-b	GW-3 GW-4	2700	15.1 13.9	0.0	1.2	8%	312
	GW-c	GW-4 GW-5	2900	13.9 12.3	0.0	1.6	12%	416
Nicol - Table Mountain	NTM-a	NTM-1 NTM-2	740	65.9 66.1	0.0	-0.2	0%	-52
	NTM-b	NTM-2 NTM-3	3570	66.1 63.8	0.5	1.8	3%	468
Snavely / Grant Young	SD-a	SGY-1 SGY-2	760	14.2 13.5	0.0	0.7	5%	182
Wise Ditch	WD-a	WD-1 WD-2	1660	43.4 41.0	0.0	2.4	6%	624

Some reaches showed no change or slight gains despite the fact that wetland vegetation, presumably fed from the ditch, was visible and thriving. These reaches may be experiencing seepage losses; however, the losses are likely masked by inflow from irrigation return flows from lands located above the ditch or by releases from bank storage.

Seepage associated with the ditches located lower in the watershed (i.e., Snavely /Grant Young, Taylor/Dutch Flat) appears to be less in magnitude compared to those ditches located higher in the watershed. This relationship is likely a result of several factors including soils, bedrock type, and topography.

5.4.4 Summary of Seepage Study

Results of the seepage study document that seepage is occurring at locations along most of the ditches investigated. At several locations, losses can be considered significant. The magnitude of these losses ranges widely. Ditch improvements targeting mitigation of these losses can provide several benefits to the watershed, including: (a) increase in available water supply to all irrigators, (b) reduced instability of ditch reaches impacted by seepage, and (c) potentially greater streamflow in the water sources affected by the diversions.

It must be remembered that these measurements represent a single "snapshot" in time and additional data are required to further refine the seepage data and to "pinpoint" seepage locations. The numbers do, however, indicate locations and potential quantities of losses. During the course of an irrigation season, ditch seepage can be expected to be highly variable. Changes in water surface elevations resulting from different discharges and channel conditions (e.g., densities of aquatic vegetation) will wet different portions of the ditch banks. Consequently, different seepage estimates could be computed dependent upon when the measurements were taken.

More detailed seepage studies are recommended to refine the location of significant seepage losses and certainly, prior to design of ditch improvements. Measurements should be taken several times during the irrigation season in order to determine the magnitude of the losses that occur annually. The approach taken should incorporate entire ditch systems as opposed to evaluation of individual sites as this Level I investigation accomplished. The density of gaging sites should also be increased to specifically define those reaches that are experiencing significant seepage losses. Gaging locations as well as turnouts should be measured along the entire ditch delivery system to enable a water budget accounting evaluation of any reach of the ditch.

5.5 Irrigation System Rehabilitation Plans

5.5.1 General

In this section, conceptual rehabilitation plans are presented for each of the ditches inventoried. The rehabilitation plans represent the integration of individual measures to mitigate problems identified in the inventory and seepage evaluation phases of the project. Specifically, the improvements that compose each rehabilitation plan focus on:

- Rehabilitation / replacement of existing structures
- Mitigation of seepage losses
- Enhanced delivery of water
- Mitigation of problems associated with aquatic vegetation
- Reduction in annual operation and maintenance costs
- Improvement in ditch management and efficiency through water measurement
- Economic practicality
- Physical feasibility

The alternatives were developed based upon information obtained from: (a) the project meetings, (b) discussions with ditch representatives, (c) the evaluation field inventory data, and (d) the seepage investigation. The improvements discussed in this section also include recommendations from previous investigations conducted by the NRCS where appropriate.

For each of the ten irrigation systems inventoried, an individual rehabilitation plan was developed. These plans are intended to provide the PACD and the ditch companies, an overall assessment of conditions associated with the ditches and their associated hydraulic structures. They are not all-inclusive as the entire extent of each ditch was not examined. For the purposes of this Level I investigation, the rehabilitation plans offer potential salutations to the primary issues and problems associated with each system. The PACD and the ditch companies can use these plans as a "resource or wish list" from which they can select projects for future Level II investigations and ultimately Level III design and construction, if they desire to follow through with WWDC funding.

5.5.2 Ditch Rehabilitation Plans

Based upon the results of the field inventories and seepage studies, the conceptual rehabilitation plans presented in Figures 5.34 through 5.43 were developed. The improvements recommended in these plans are summarized in Tables 5.3 to 5.12. These tables include the general description of the improvement and the estimated cost of construction. In an effort to assist the PACD and the ditch representatives in prioritizing potential improvements to each ditch. Relative priorities were defined as follows:

- Priority 1: These improvements replace or rehabilitate a potential failure in ditch operation, provide improved water management by providing measurement capabilities; or mitigate significant seepage losses.

- Priority 2: These improvements improve the overall condition of the ditch system by replacing or rehabilitating aging structures.

- Priority 3: These improvements provide for reduced operation and maintenance costs and provide additional long-term improvements to ditch infrastructure.

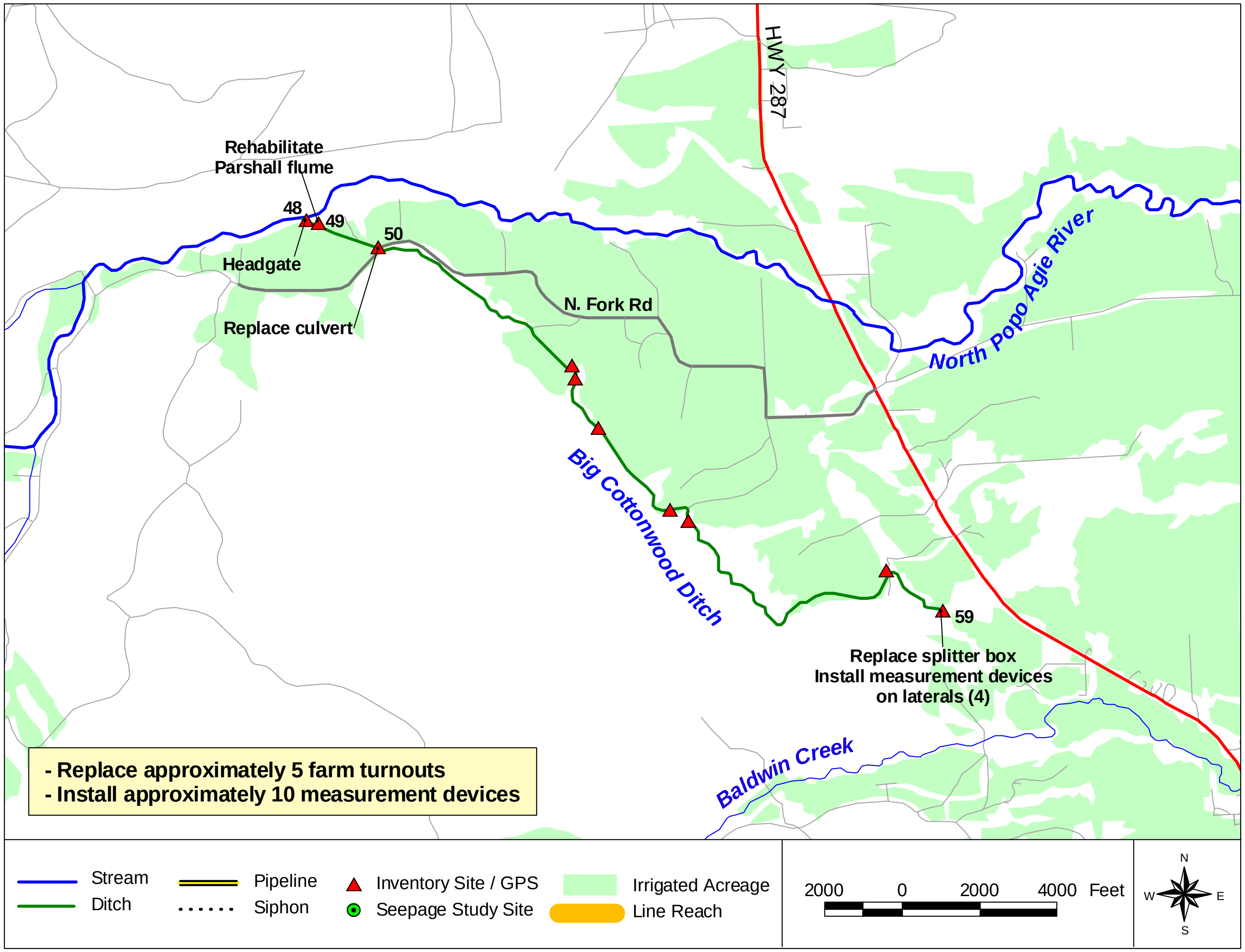


Figure 5.34 Big Cottonwood Ditch Conceptual Rehabilitation Plan.

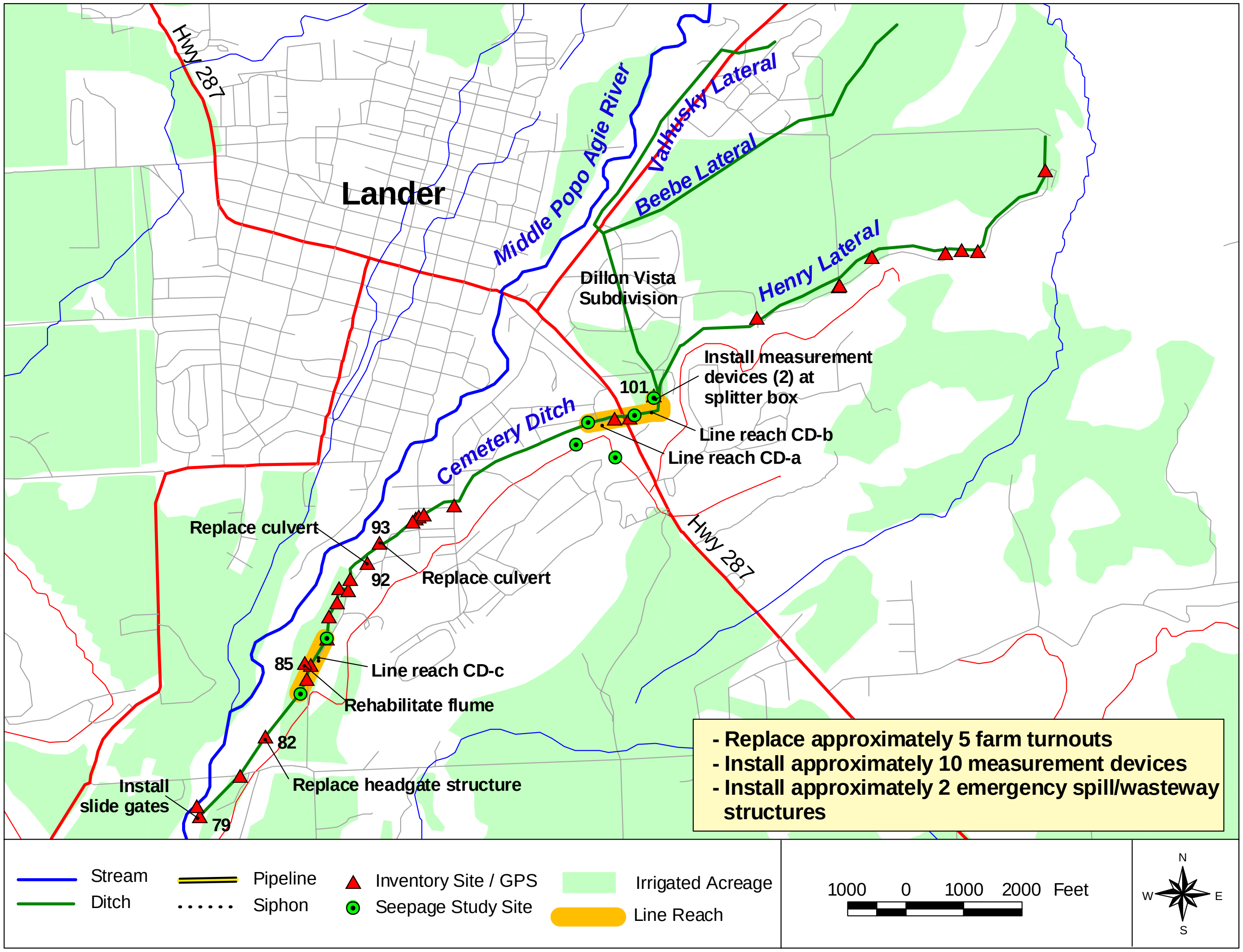


Figure 5.35 Cemetery Ditch Conceptual Rehabilitation Plan.

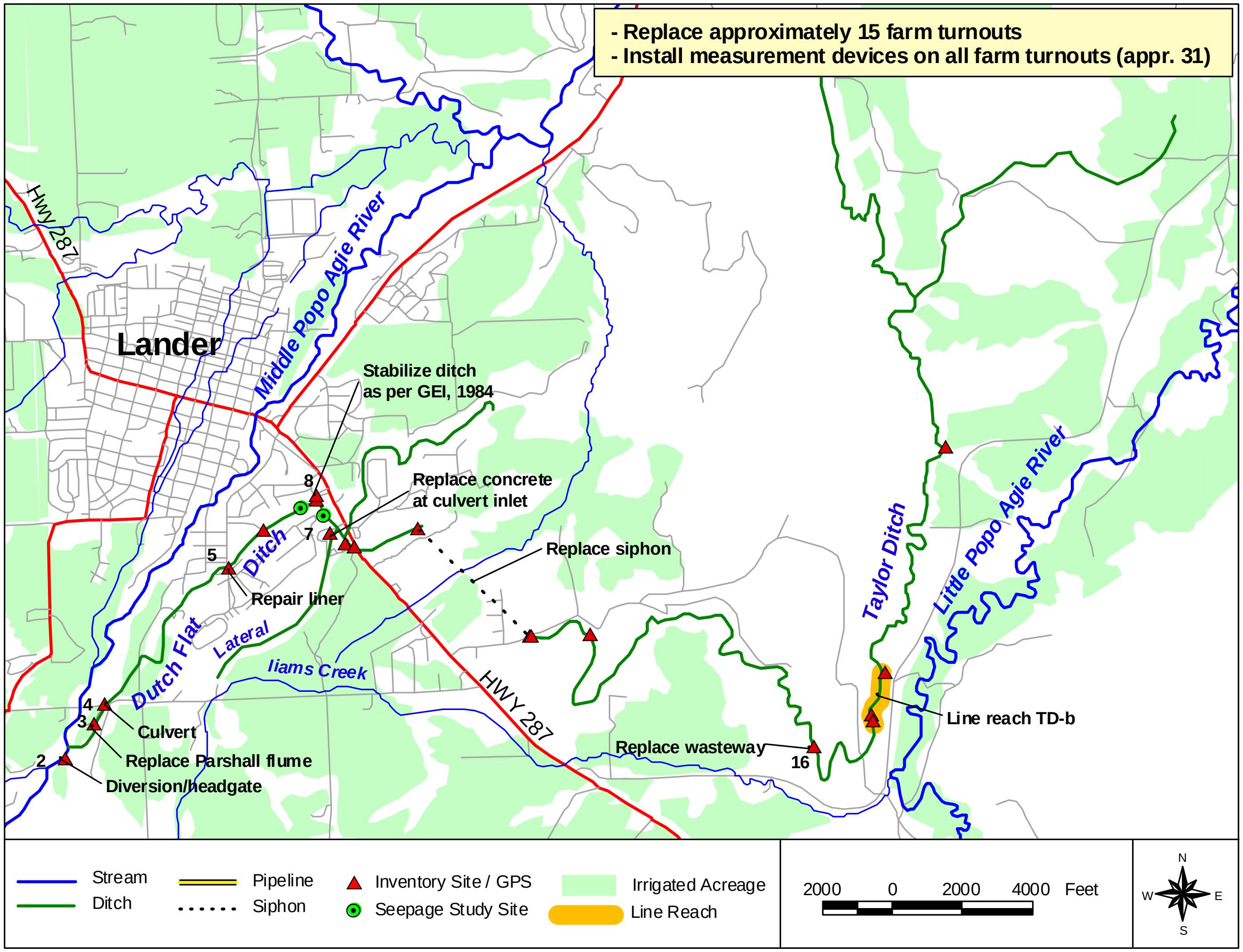


Figure 5.36 Dutch Flat / Taylor Ditch Conceptual Rehabilitation Plan.

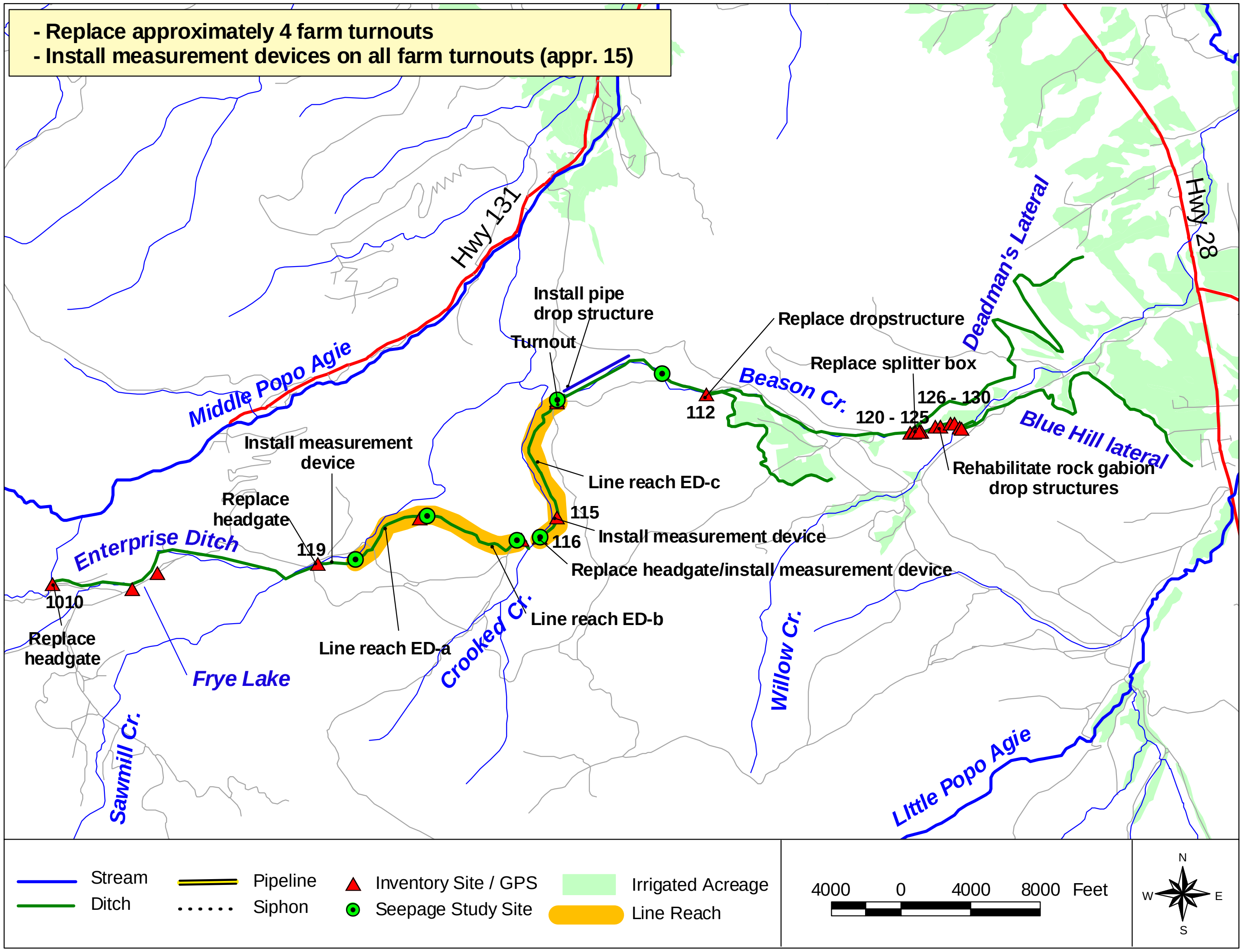


Figure 5.37 Enterprise Ditch Conceptual Rehabilitation Plan.

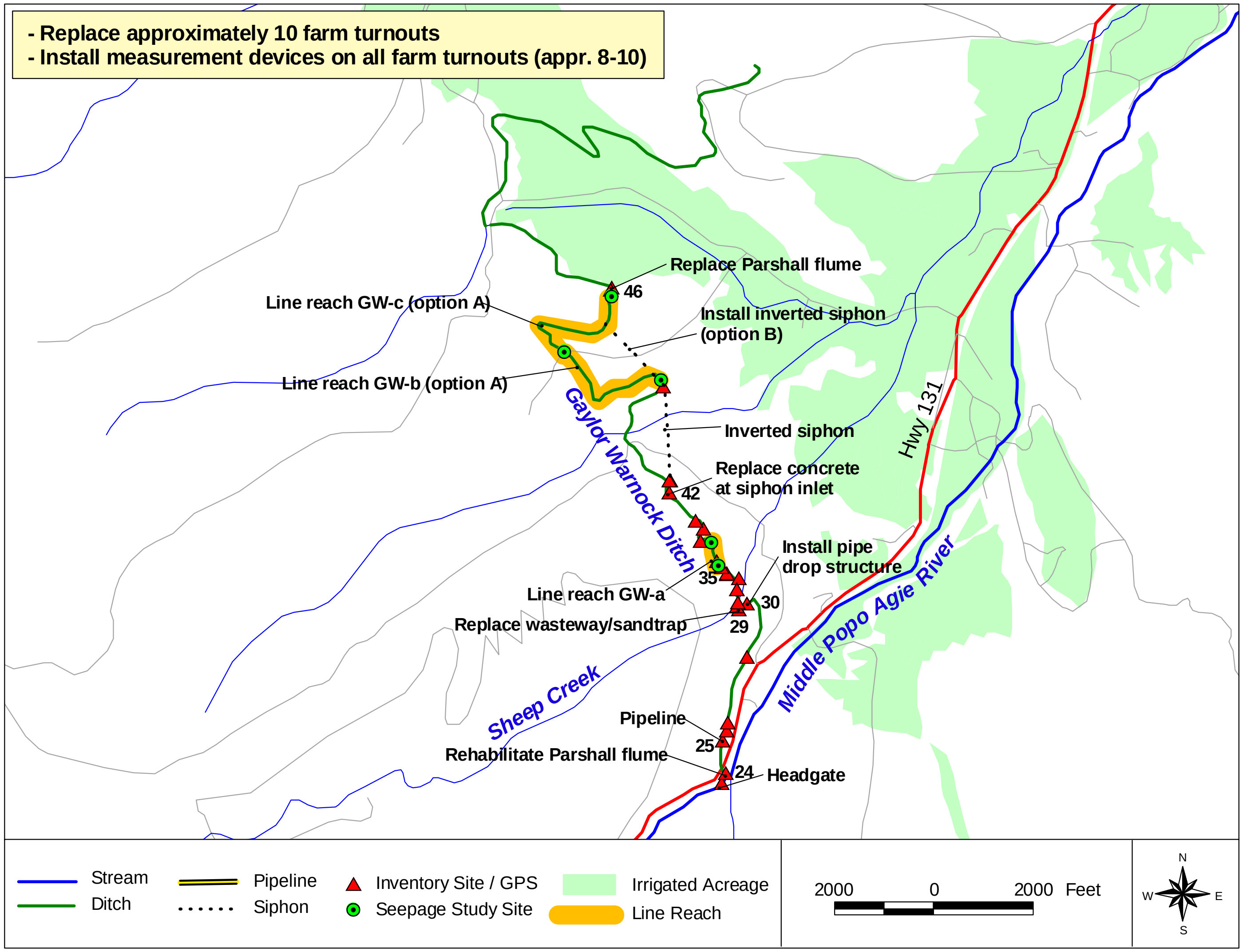


Figure 5.38 Gaylor Warnock Ditch Conceptual Rehabilitation Plan.

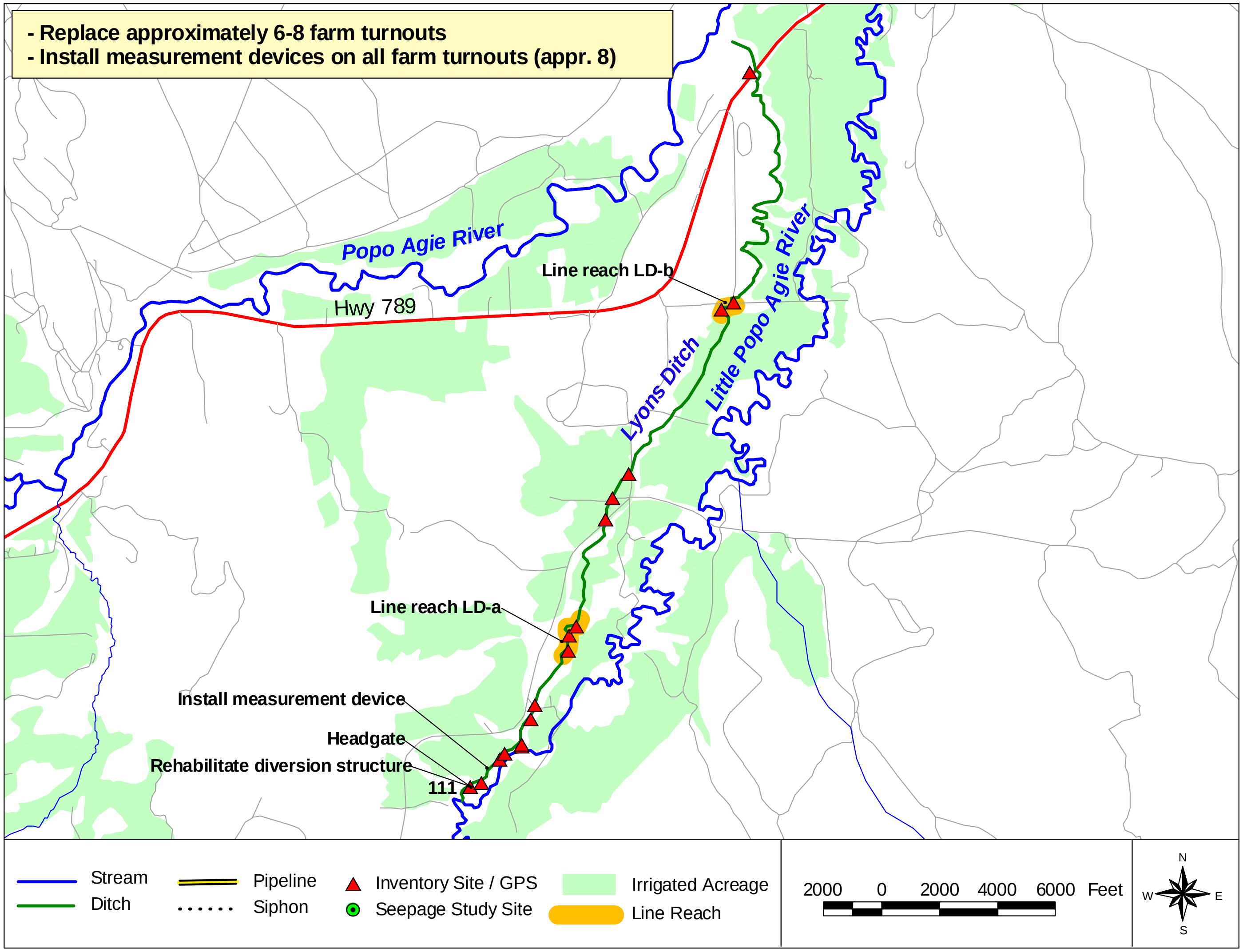


Figure 5.39 Lyons Ditch Conceptual Rehabilitation Plan.

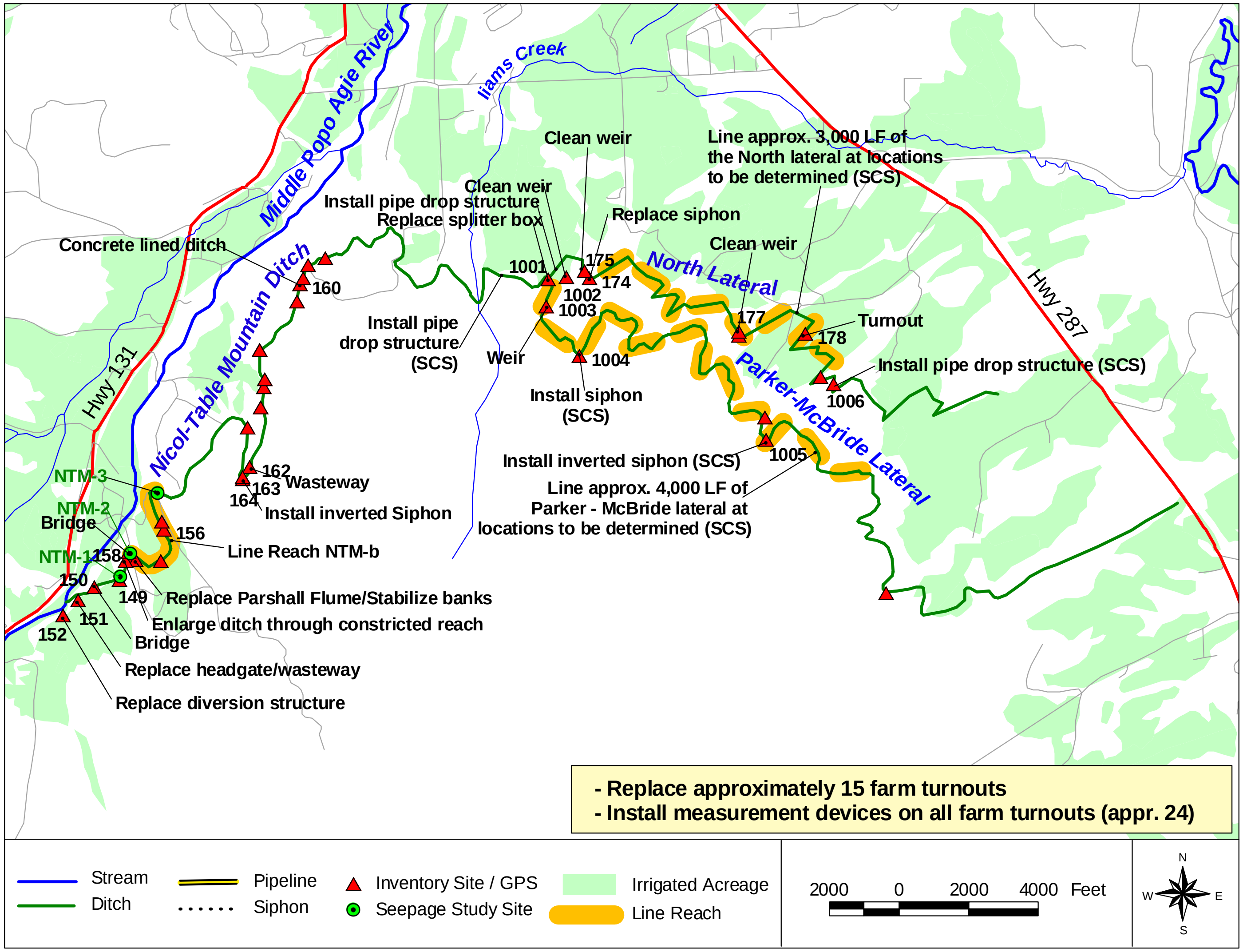


Figure 5.40 Nicol – Table Mountain Ditch Conceptual Rehabilitation Plan.

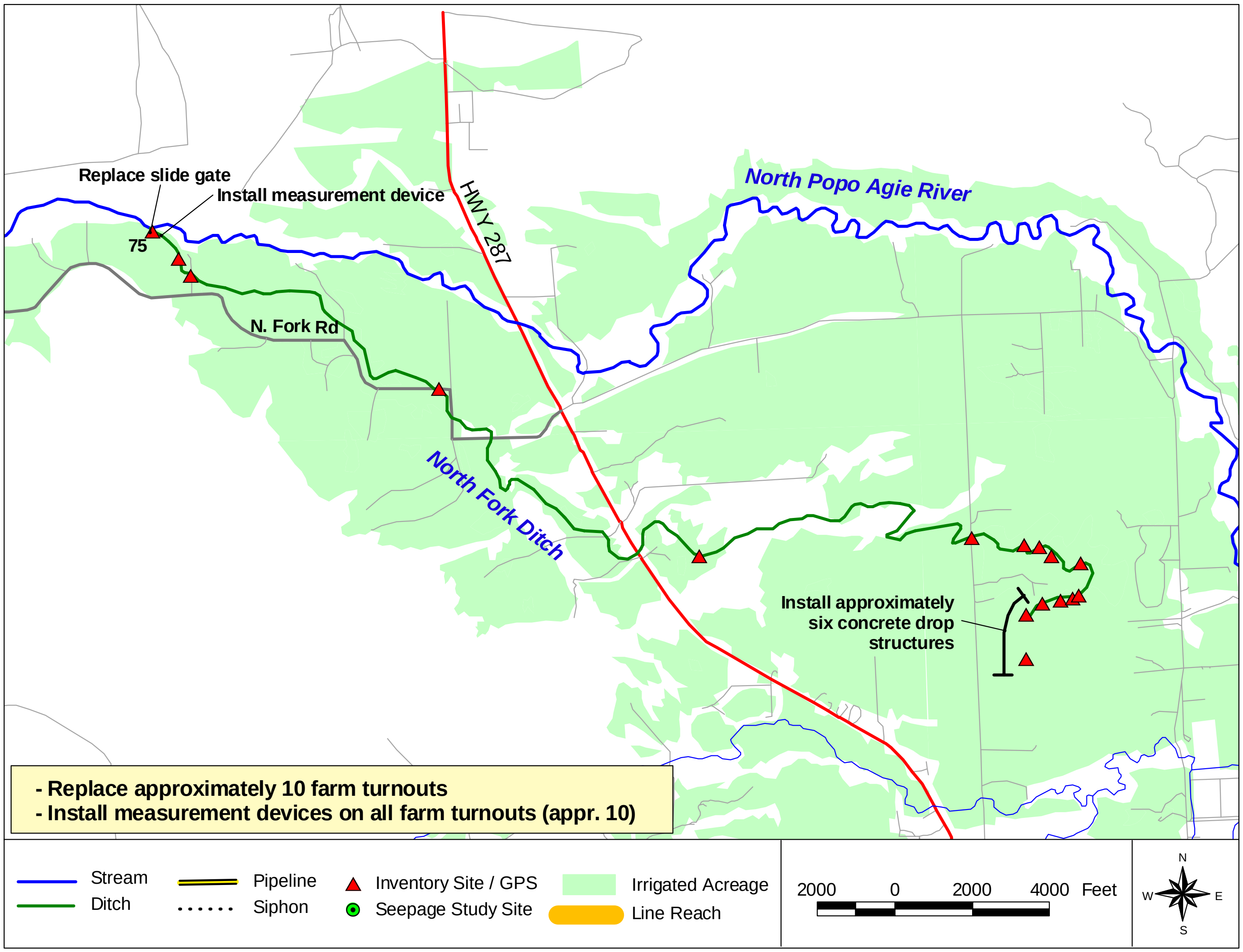


Figure 5.41 North Fork Ditch Conceptual Rehabilitation Plan.

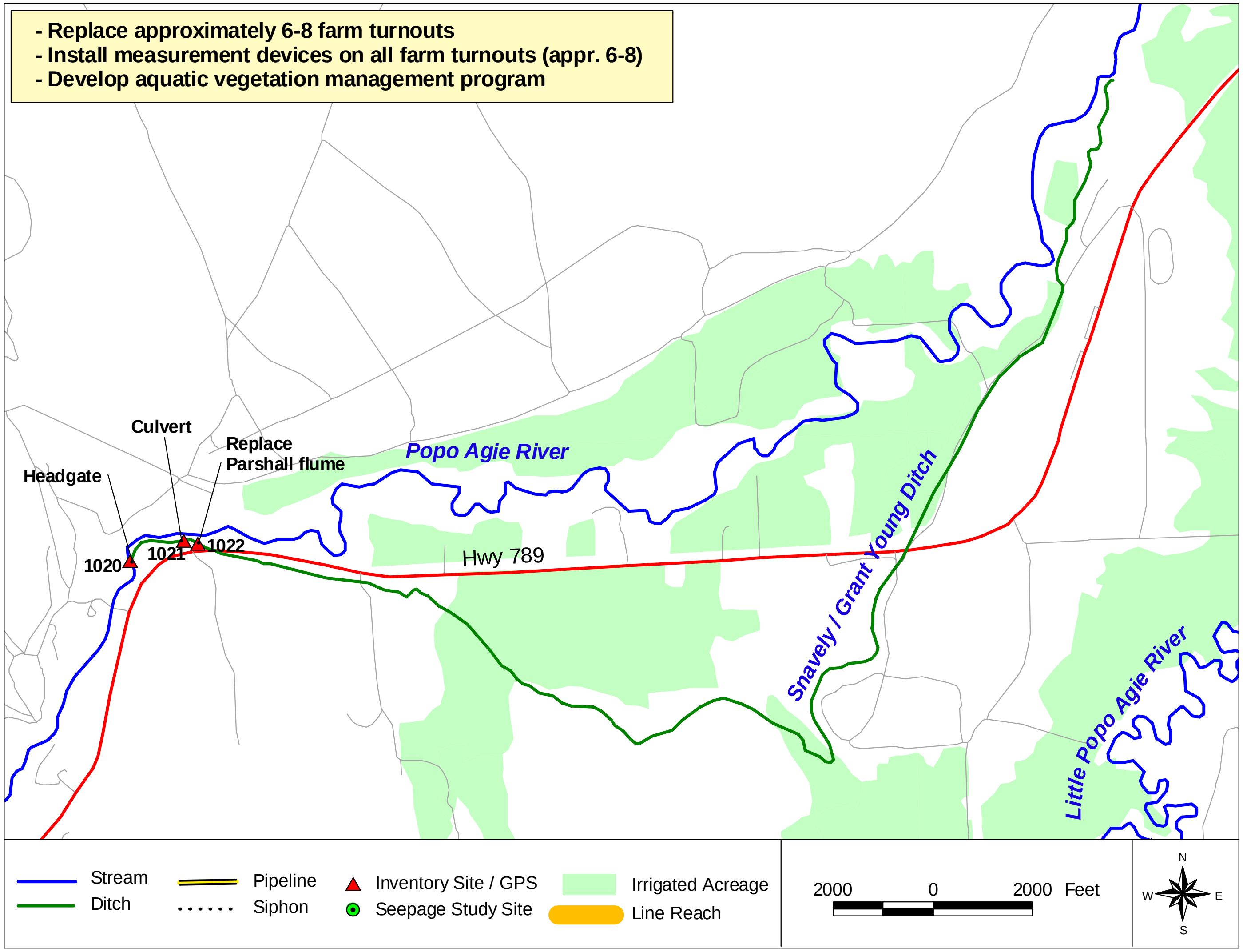


Figure 5.42 Snavely / Grant Young Ditch Conceptual Rehabilitation Plan.

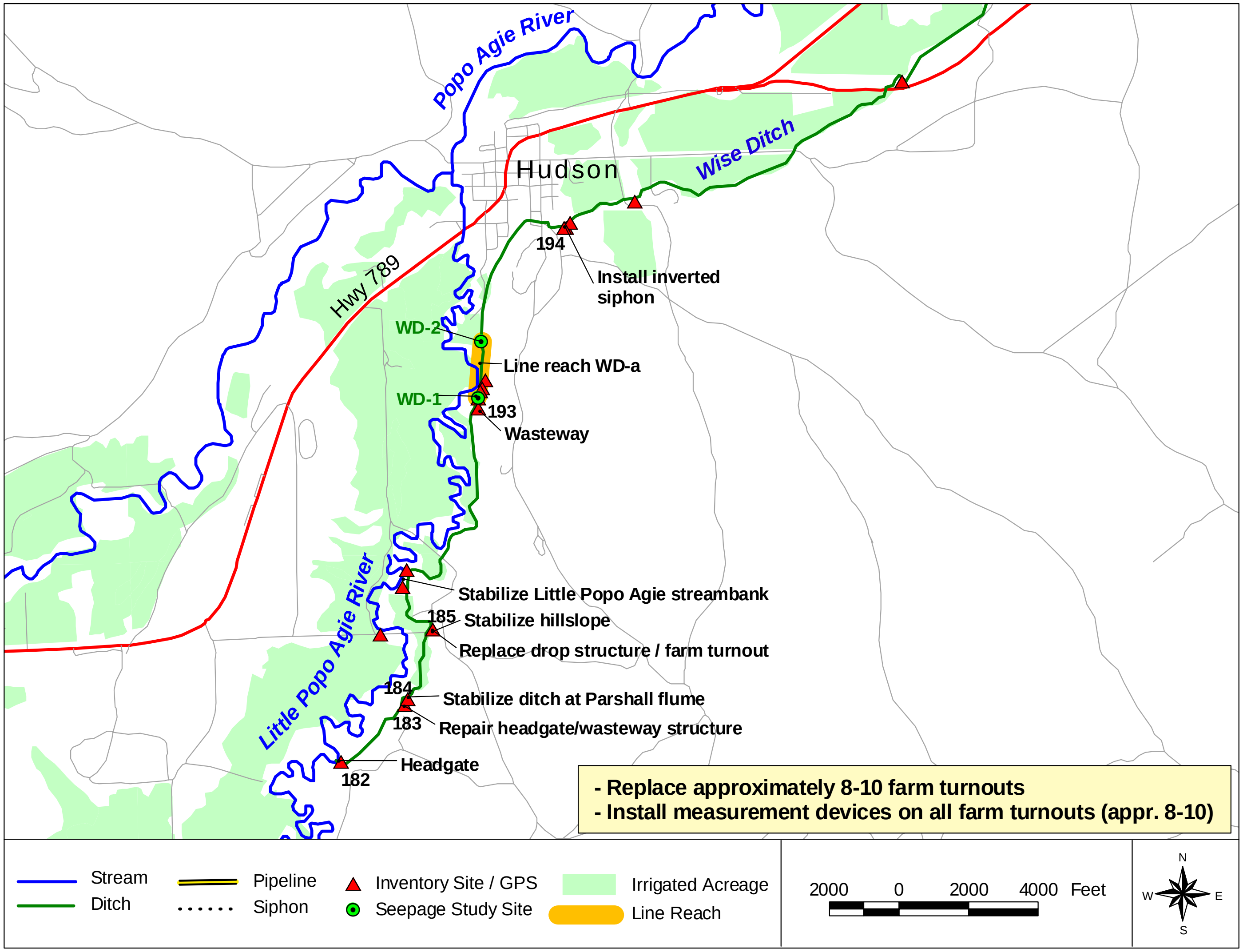


Figure 5.43 Wise Ditch Conceptual Rehabilitation Plan.

Table 5.3 Big Cottonwood Ditch System Improvements.

GPS	Description	Priority	Cost
49	Rehabilitate Parshall Flume	1	$500
50	Replace culvert	2	$3,000
59	Replace splitter box/install measurement devices	1	$7,000
NA	Replace/Rehabilitate farm turnouts / install slide gates (approx. 5)	1	$10,000
NA	Install measurement devices (approx. 10)	1	$10,000

Table 5.4 Cemetery Ditch System Improvements.

GPS	Description	Priority	Cost
79	Install slide gate at existing diversion	2	$16,000
82	Replace headgate and winter bypass	3	$12,000
84	Rehabilitate Parshall Flume	1	$500
92	Replace culvert	2	$2,000
93	Replace Culvert	2	$2,000
101	Install measurement devices at lateral split (2)	1	$4,000
NA	Replace approximately 5 farm turnouts/install slide gates	2	$10,000
NA	Install measurement devices on 10 turnouts	1	$10,000
099	Line reach CD-a	3	$24,000
100-11	Line reach CD-b	3	$21,000
83-85	Line reach CD-c	1	$31,000
NA	Install 2 wasteways / slide gates	1	$10,000

Table 5.5 Dutch Flat - Taylor Ditch System Improvements

GPS	Description	Priority	Cost
3	Replace Parshall Flume	1	$5,000
5	Repair geotextile liner	1	$2,000
7	Rehabilitate unstable ditch (GEI, 1984)	1	$200,000
9	Repair culvert inlet / concrete	3	$3,000
10	Replace inverted siphon	2	$150,000
16	Repair concrete invert in wasteway	2	$2,000
NA	Replace farm turnouts (approximately 15) / install slide gates	2	$30,000
NA	Install measurement devices at approximately 31 farm turnouts	1	$31,000
017	Line reach along Lyons Valley (NRCS, assume approx. 1500 LF)	3	$67,500

Table 5.6 Enterprise Ditch System Improvements

GPS	Description	Priority	Cost
1010	Replace Roaring Fork headgate	3	$20,000
119	Replace Sawmill Creek headgate	3	$60,000
119	Install measurement device at Sawmill Creek headgate	1	$5,000
116	Replace Crooked Creek headgate / install slide gate	3	$51,000
116	Install measurement device at Crooked Creek headgate	1	$5,000
114	Install pipe drop structure	1	$250,000
1121	Install drop structure - Beason Creek (NRCS)	2	$108,000
112	Replace drop structure/turnout	1	$69,000
120	Replace splitter box	1	$20,000
126-130	Rehabilitate Gabion drop structures (5)	1	$20,000
NA	Rehabilitate/replace farm turnouts / install slide gates (approx. 4)	2	$8,000
NA	Install approximately 15 measurement devices at farm turnouts	1	$15,000
1011	Line Reach ED-a (approx. 2,500 LF)	1	$124,000
1011-1016	Line Reach ED-b (approx. 2,500 LF)	2	$151,000
118 - 114	Line Reach ED-c (approx. 4,000 LF)	2	$238,000

Table 5.7 Gaylor Warnock Ditch System Improvements

GPS	Description	Priority	Cost
29	Replace sediment trap/wasteway / install slide gate	3	$6,000
42	Rehabilitate siphon inlet	3	$2,000
46	Rehabilitate Parshall Flume	1	$2,000
NA	Replace approximately 10 farm turnouts / install slide gates	2	$20,000
NA	Install approximately 10 measurement devices at farm turnouts	1	$10,000
030	Install pipe drop structure	2	$45,000
273-274	Line Reach GW-a (approx. 500 LF)	1	$18,000
276-278	Install inverted siphon - Option A	1	$45,000
276-277	Line Reach GW-b (approx. 1500 LF) - Option B	2	$46,000
277-278	Line Reach GW-c (approx. 1500 LF) - Option B	2	$46,000

Table 5.8 Lyons Ditch System Improvements

GPS	Description	Priority	Cost
111	Rehabilitate structure/stop logs	3	$2,000
NA	Replace approximately 8 farm turnouts / install slide gates	2	$16,000
NA	Install measurement devices at approximately 8 farm turnouts	1	$8,000
111	Install weir on ditch	1	$4,000
NA	Line Reach LD-a (~500 l.f.)	1	$18,000
NA	Line Reach LD-b (~500 l.f.)	1	$18,000

Table 5.9 Nicol-Table Mountain Ditch System Improvements

GPS	Description	Priority	Cost
	Nicol-Table Mountain Ditch		
152	Replace diversion structure	1	$38,000
151	Replace headgate bypass	1	$37,000
153	Replace Parshall Flume	1	$5,000
149	Enlarge ditch through rock section	2	$8,000
162	Install inverted siphon at Frye Gulch	1	$50,000
1001	Replace splitter box at lateral split	3	$25,000
159-268	Line Reach NTM-b (approx. 1800 LF)	2	$106,000
NA	Replace approximately 8 farm turnouts / install slide gates	2	$16,000
NA	Install approximately 12 measurement devices at farm turnouts	1	$12,000
	North Lateral		
1002	Rehabilitate weir	1	$2,000
1001	Install pipe drop structure (NRCS)	1	$65,000
174	Rehabilitate inverted siphon	2	$40,000
1006	Install pipe drop structure (NRCS)	3	$65,000
NA	Replace approximately 11 farm turnouts / install slide gates	2	$22,000
NA	Install measurement devices (21)	1	$21,000
NA	Line reaches of North Lateral (NRCS) (approx. 3000 LF)	1	$135,000
	Parker - McBride Lateral		
1004	Replace flume with inverted siphon (NRCS)	1	$50,000
1005	Install inverted siphon (NRCS)	2	$43,000
NA	Replace approximately 6 farm turnouts / install slide gates	2	$12,000
NA	Install measurement devices (12)	1	$12,000
NA	Line ten reaches on Parker McBride lateral as per NRCS (approx. 4000 LF)	1	$180,000

Table 5.10 North Fork Ditch System Improvements

GPS	Description	Priority	Cost
75	Replace slidegate at headgate/diversion structure	2	$45,000
75	Install measurement device	1	$5,000
NA	Replace approximately farm turnouts (10) / install slide gates	2	$20,000
NA	Install approximately measurement devices (10)	1	$10,000
061	Install drop structures (approximately 6)	3	$30,000

Table 5.11 Snavely / Grant Young Ditch System Improvements

GPS	Description	Priority	Cost
1020	Install Parshall Flume	1	$5,000
NA	Replace approximately 8 farm turnouts / install slide gates	2	$16,000
NA	Install approximately 8 measurement devices	1	$8,000

Table 5.12 Wise Ditch System Improvements

GPS	Description	Priority	Cost
183	Rehabilitate headgate/wasteway	2	$4,000
184	Rehabilitate Parshall Flume / stabilize banks	1	$5,000
185	Replace drop structure/turnout/hills stabilize ditch/lining	1	$80,000
194	Replace flume with inverted siphon	1	$45,000
NA	Replace approximately 10 farm turnouts / install slide gates	2	$20,000
NA	Install approximately 10 measurement devices at farm turnouts	1	$10,000
193	Line Reach WD-a (approx. 1500 LF)	1	$70,000
186	Little Popo Agie River bank stabilization	2	$20,000

Water Use Modeling

Chapter 6

6.1 The Popo Agie River Watershed Model

The Wyoming Water Development Commission (WWDC) has undertaken statewide water basin planning efforts in selected river basins. The purpose of the statewide planning process is to provide decision makers with current, defensible data to allow them to manage water resources for the benefit of all the state's citizens. At the time of this study, the Wind / Bighorn River Basin system, which incorporates the Popo Agie River basin, was being investigated as part of the WWDC's planning process (Figure 6.1). The Popo Agie River investigation was conducted in coordination with that study. The Popo Agie River model was created using the same infrastructure and formatting as the Wind / Bighorn River Basin model enabling direct interface between them.

The model is a complex water accounting spreadsheet which incorporates multiple diversions, gaging stations, and other water resources within the Popo Agie River basin. It was developed following several months of effort and coordination with various state and local agencies and water officials. The purpose of the model is to provide a planning tool to the Popo Agie Conservation District and the State of Wyoming for use in determining those river reaches in which flows may be available to Wyoming water users for future development.

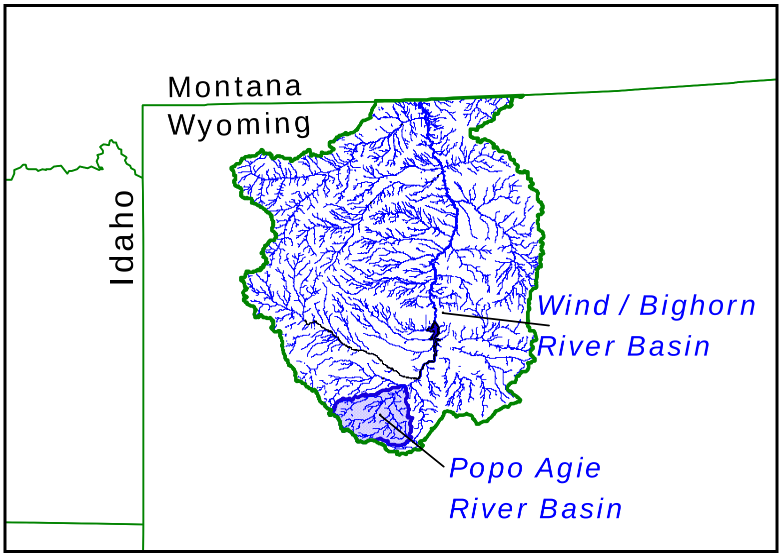


Figure 6.1 Wind / Bighorn River and Popo Agie River Basins.

6.2 Model Overview

Individual spreadsheet models were developed which reflect each of three hydrologic conditions: dry, normal, and wet year water supply. The spreadsheets each represent one calendar year of flows, on a monthly time step. Each relies on historical data from the 1971 to 2000 study period to estimate the hydrologic conditions. Streamflow, consumptive use, diversions, and irrigation return flows are the basic input data to the model. For all of these data, average values drawn from the dry, normal, or wet subset of the study period were computed for use in the spreadsheets. The model does not explicitly account for water rights, appropriations, or compact allocations nor operate the river basin based on these legal constraints. It is assumed that the historic discharge data reflect effects of any limitations that may have been placed upon water users by water rights restrictions.

To mathematically represent the Popo Agie River system, it first had to be divided into sixteen reaches based primarily upon the location of USGS gaging stations. Other key locations, such as confluences with major tributaries, were also used to determine the extent of reaches (Figure 6.2). Each reach was then sub-divided by identifying a series of individual nodes representing locations where diversions occur, basin imports are added, tributaries converge, or other significant water resources features are located. Figure 6.3 presents a node diagram of the model developed for the Popo Agie River.

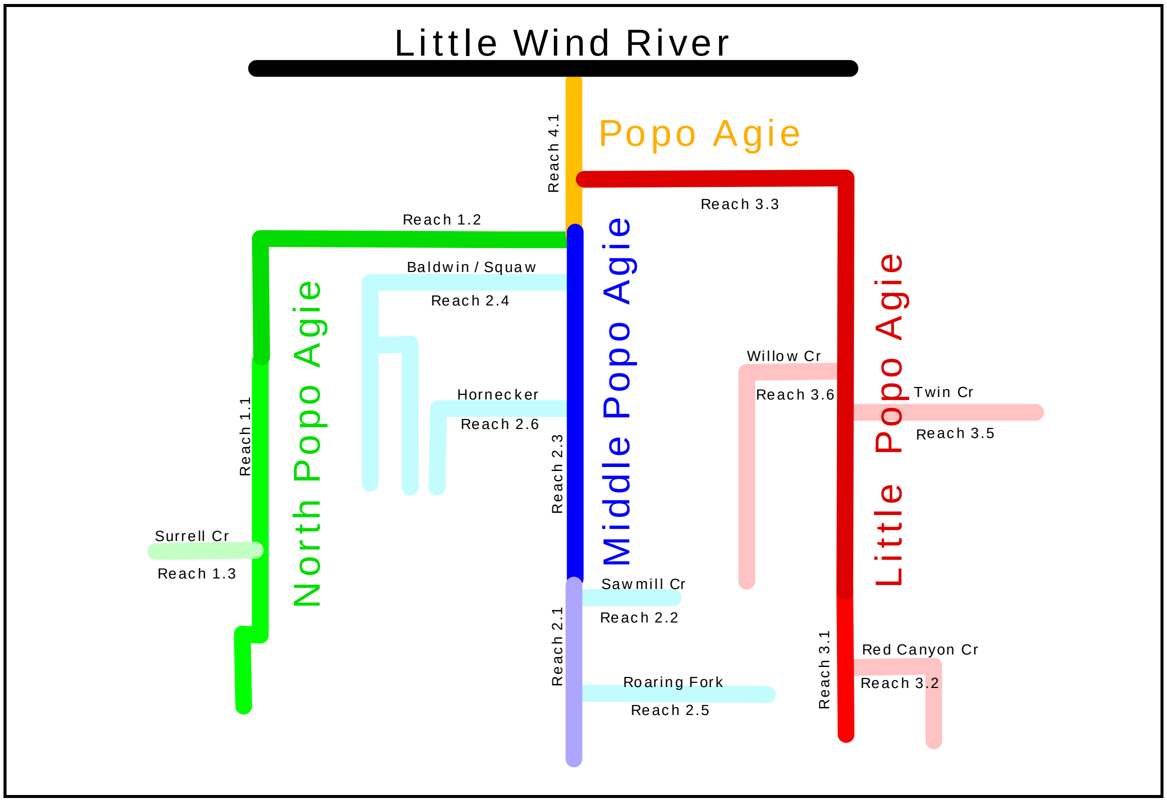


Figure 6.2 Popo Agie River Model Reach Diagrams.

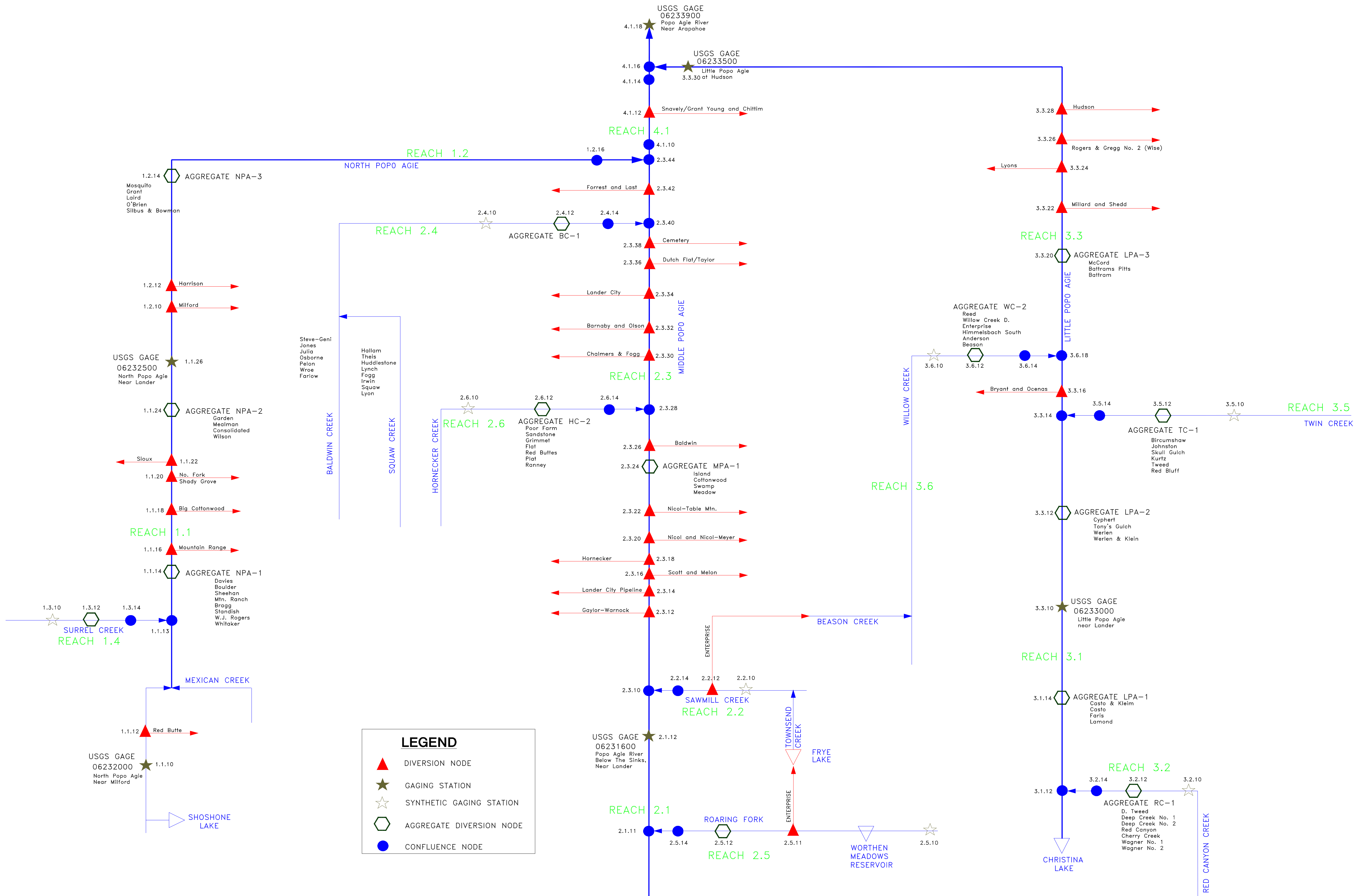


Figure 6.3 Popo Agie River Model Node Diagram.

At each node, a water budget computation is completed to determine the amount of water that flows out of the node. Total flow into the node and diversions or other losses from the node are calculated. The difference between total inflow and diversions is the amount of flow available to the next node downstream. Mass balance, or water budget calculations, are repeated for all nodes in a reach, with the outflow of the last node being the inflow to the top node in the next reach.

Figure 6.4 displays a graphical representation of the water balance approach. For each reach, ungaged stream gains (e.g., ungaged tributaries, groundwater inflow, and return flows from unspecified diversions) and losses (e.g. seepage, evaporation, and unspecified diversions) are computed as the difference between average historical gage flows. Stream gains are input at the top of a reach to be available for diversion throughout the reach and losses are subtracted at the bottom of each reach.

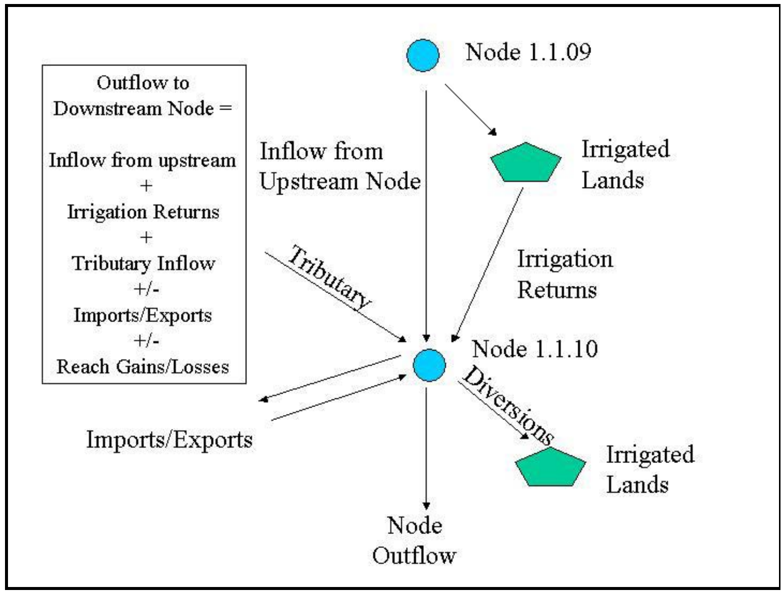


Figure 6.4 Diagram of Model Water Budget Computations.

Model output includes the target and actual diversions at each of the diversion points and streamflow at each of the Popo Agie River Basin nodes. Estimates of impacts associated with various water projects can be analyzed by changing input data. New storage projects that alter the timing of streamflows or shortages may also be evaluated.

6.3 Model Input

Primary input to the model consists of streamflow data for gages within the watershed, estimated monthly diversion at each diversion node, consumptive use estimates, and irrigation return locations/patterns. Detailed descriptions of methods associated with the development of each are provided in the technical memoranda included in the project notebook. Brief summaries of the processes are included below.

6.3.1 Surface Streamflow Data and Hydrologic Condition

Monthly stream gage data were obtained from the USGS and the Wyoming SEO for each of the stream gages used in the model. Missing data or incomplete records were filled using standard regression techniques. A 1971 through 2000 study period was selected based largely upon review of the available data, the objectives of the model, and the historical development of the basin. Determination of dry, normal, and wet years was accomplished by plotting graphs of the ranked total annual streamflow at each gage. Based upon a combination of using natural breaks in the measured data and use of simple statistics, that is, the upper and lower 20% of the data; dry, normal, and wet years were selected for each gage. The filled data record for each gage was evaluated in this manner. Figure 6.5 provides the results of this analysis for USGS Gaging Station 06231600 - Popo Agie River below the Sinks, near Lander, Wyoming. At this gage, the DRY years were determined to be 1977, 1981, 1985, 1989, 1992, and 1994. WET years were 1971, 1980, 1983, 1986, 1995, and 1999. The remaining 18 years were determined to be NORMAL. Table 6.1 presents the results of this evaluation and the determination of basin-wide hydrologic conditions. Average monthly streamflow was then computed for each of the three hydrologic conditions using the appropriate years as indicated in Table 6.1.

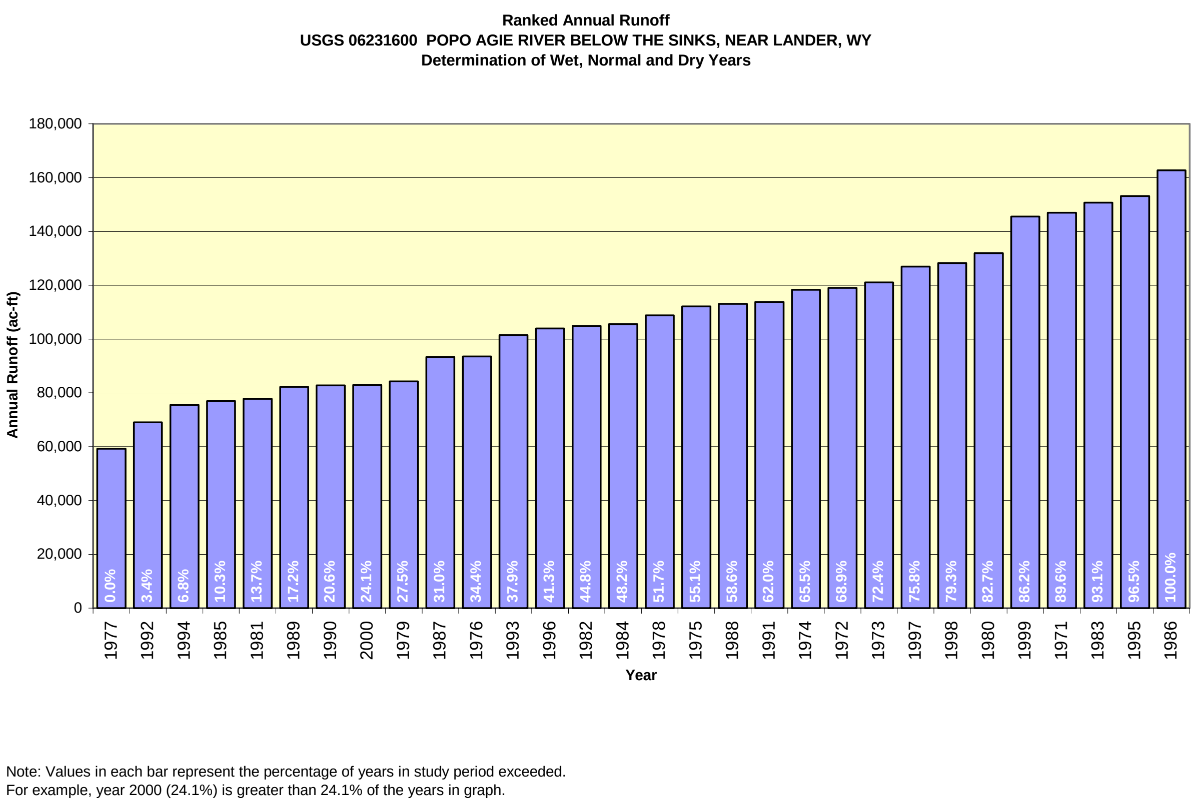


Figure 6.5 Ranked Annual Runoff for USGS Gaging Station 06231600
Popo Agie River below the Sinks, near Lander, Wyoming.

Table 6.1 Determination of Hydrologic Condition at Key Gaging Stations.

Year	LITTLE POPO AGIE RIVER NEAR LANDER, WYO. USGS 6233000	NORTH POPO AGIE RIVER NEAR LANDER, WY USGS 6232500	POPO AGIE RIVER BELOW THE SINKS, NEAR LANDER, WY USGS 6231600	Basin Wide Condition
1971	Wet	Wet	Wet	Wet
1972	Normal	Normal	Normal	Normal
1973	Normal	Wet	Normal	Normal
1974	Normal	Normal	Normal	Normal
1975	Normal	Normal	Normal	Normal
1976	Normal	Normal	Normal	Normal
1977	Dry	Dry	Dry	Dry
1978	Normal	Normal	Normal	Normal
1979	Normal	Normal	Normal	Normal
1980	Wet	Normal	Wet	Wet
1981	Dry	Normal	Dry	Dry
1982	Normal	Normal	Normal	Normal
1983	Wet	Wet	Wet	Wet
1984	Normal	Normal	Normal	Normal
1985	Dry	Dry	Dry	Dry
1986	Wet	Wet	Wet	Wet
1987	Normal	Normal	Normal	Normal
1988	Dry	Dry	Normal	Dry
1989	Dry	Normal	Dry	Dry
1990	Normal	Dry	Normal	Normal
1991	Normal	Normal	Normal	Normal
1992	Dry	Dry	Dry	Dry
1993	Normal	Normal	Normal	Normal
1994	Normal	Dry	Dry	Dry
1995	Wet	Wet	Wet	Wet
1996	Normal	Normal	Normal	Normal
1997	Normal	Normal	Normal	Normal
1998	Normal	Normal	Normal	Normal
1999	Wet	Wet	Wet	Wet
2000	Normal	Normal	Normal	Normal

6.3.2 Water Rights Considerations

In addition to the existing adjudicated water rights, there are several water rights which have been awarded by the Courts which must be considered. These are:

1. Reserved water rights - This class of water rights is a judicial creation derived from "Winters v. United States" (207 U.S. 564, 1907) and subsequent federal case law, which collectively hold that when the federal government withdraws land from general use and reserves it for a specific purpose, the federal government by implication reserves the minimum amount of water unappropriated at the time the land was withdrawn or reserved to accomplish the primary purpose of the reservation. Federal reserved water rights may be claimed when Congress has by statute withdrawn lands from the public domain for a particular federal purpose or where the President has withdrawn lands from the public domain for a particular federal purpose pursuant to congressional authorization. Examples are Indian reservations, national forests, national parks/monuments (P.Tyrrell, 2002).

2. Walton Rights - Reserved water rights for non-Indian successors on Indian reservations.

3. Remand Rights – It is our understanding that these rights are still undecided within the courts and that the areas involved are inconsequential.

Table 6.2 summarizes the number of acres associated with the Reserved and Walton rights, the diversions associated with them, and the number of acres which fall within the Popo Agie River watershed.

Table 6.2 Tabulation of Future Water Rights within the Popo Agie River Basin.

Type	Unit / Ditch	Diversion (cfs)	Acres
Reserved	Arapahoe	16,720	3,808
Reserved	McDowell	28.3	6
Reserved	Reynolds	116.4	25
Reserved	Sioux	1,641.8	347
Reserved	Schneider	116.4	24.5
Walton	McDowell	365.8	77.5
Walton	Oliver Lamoureaux	217.12	46
Walton	Reynolds	609.07	128.3
Walton	Sioux	1,030.85	218.4

A "Future Projects" version of the spreadsheet model was developed. The future project diversions represent demands upon the system *in addition* to those addressed by the tabulation of state water rights. *Therefore, the only difference between the "Future Projects" version of the Popo Agie River model and the Baseline Model is the addition of these future diversions to existing diversions.* Irrigation returns are incorporated only for those irrigated acres that lie within the boundaries of the Popo Agie River watershed. Consequently, the majority of water diverted via the Arapahoe Ditch is lost to the Popo Agie River system because those irrigated lands lie outside of the watershed.

The Reserved and Walton rights are granted on an "acre-foot" basis; they are not granted on the basis of 1cfs per 70 acres as other water rights in Wyoming are. A determination of how to distribute these diversions throughout the irrigation season was required. To be consistent with the estimation of the state water rights, the distribution was based upon the Consumptive Use distribution throughout the season. The amount diverted per month is equivalent to that month's relative share of annual crop consumptive use. These diversions were then added to the Futures models (wet / normal / dry).

6.3.3 Diversion Estimates

Estimates of monthly diversions at each of 32 key diversion nodes were computed for each of the three hydrologic conditions based upon the annual condition presented in Table 6.1. Key diversions were defined as those locations where generally greater than 5 cfs are diverted from the river. Eleven aggregated diversions for all other diversions were added to complete the water balance for the basin

The Wyoming State Engineer's Office publishes diversion records in its annual hydrographers reports. These reports present periodic discharge measurements or estimates and do not represent comprehensive data series for the ditches. That is, there were insufficient data to take these sources as a historic record of diversions for inclusion to the model. However, the reports do provide a valuable source of information to verify the magnitude of the estimated diversion data qualitatively.

Due to the general lack of diversion data, estimates of monthly diversions for the basin's irrigation ditches must be estimated. Detailed discussion of this task is provided in the technical memoranda. This effort required evaluation of the following irrigation components:

- irrigated lands mapping;
- water rights tabulations;
- Crop Irrigation Requirement (CIR): the quantity of water needed to meet the evapotranspiration (ET) requirement of a given crop;

- On-farm Delivery Requirement: the amount of water that must be applied to satisfy the CIR for the crop following efficiency losses associated with irrigation practices in place; and
- Ditch Diversion Requirement: the amount of water that must be diverted to meet the on-farm delivery requirement after conveyance losses are accounted for.

Mapping of irrigated lands in the Popo Agie River watershed was incorporated in the project GIS (Figure 6.6). The database of existing water rights attributes for the GIS theme was used to estimate the irrigated acreage under each ditch.

Previous investigations conducted by the NRCS regarding small delivery systems in the Wind River Basin provided valuable information which was incorporated into the modeling effort. The NRCS study estimated average ditch efficiency for various ditch systems. These values were used as default parameters for ditches where site-specific information was not available.

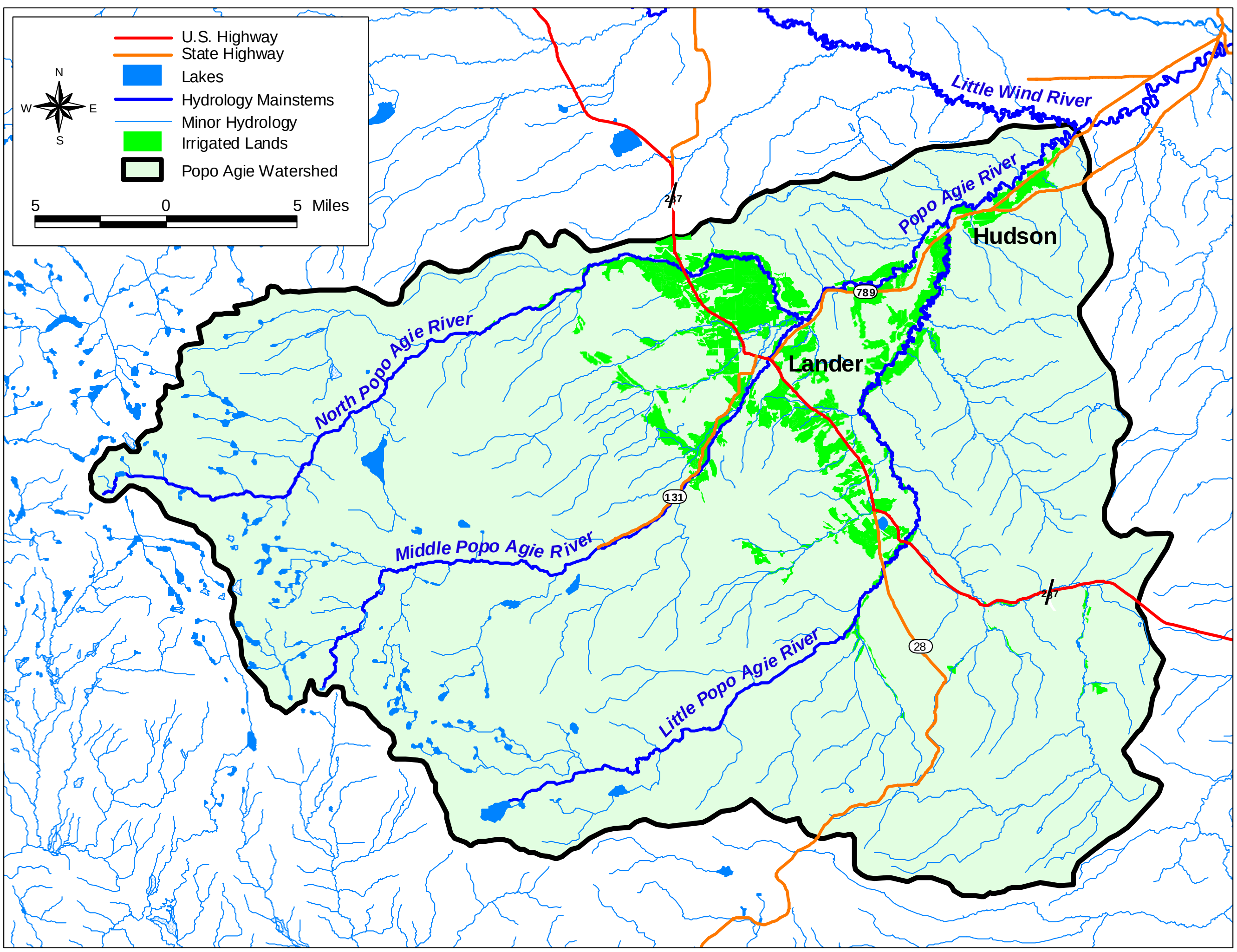


Figure 6.6 Irrigated Lands within the Popo Agie River Basin.

Crop Irrigation Requirement (CIR)

Quantification of CIR is an integral part of the Popo Agie River watershed water use model. This quantity of water drives estimates of monthly diversions and represents the amount of diverted water that is essentially lost from the river system. Blaney-Criddle approaches to determining crop evapotranspiration (ET) are widely used due to limited climate data requirements. Blaney-Criddle methods require average monthly temperature and total monthly precipitation, whereas other methods may require daily parameters including temperature, precipitation, wind speed, vapor pressure, and solar radiation. One of the most widely used approaches is the NRCS method, published in Irrigation Water Requirements Technical Release No. 21 (TR-21) (NRCS 1970). This methodology can be adapted to better represent known local conditions by calibrating the climatic coefficient (kt) and the crop coefficients (kc) so empirically calculated ET estimates represent measured ET.

Monthly crop coefficients (kc) and average growing season data were obtained from information published by Dr. Pochop of the University of Wyoming: "Consumptive Use and Consumptive Irrigation Requirements in Wyoming" (1992). In that report, Pochop presented calibrated crop coefficients for several regions of Wyoming, including the Lander area. Consumptive use quantities were determined for both alfalfa and grass hay using the Lander climate station.

On-Farm Delivery Requirement

The On-Farm Delivery Requirement (ODR) is defined as the amount of water that must be delivered to satisfy the CIR for the crop following efficiency losses associated with the irrigation practices in place. To estimate the ODR, the CIR for a given crop on a given parcel of irrigated land is divided by the efficiency associated with the irrigation method.

Irrigation methods/practices that are currently used within the Popo Agie River Basin were identified with the assistance ditch representatives, existing NRCS studies, and field observation. A literature review was conducted to obtain estimates of typical application efficiencies associated with these methods. Table 6.3 summarizes application efficiencies for various irrigation methods as presented in the literature and the values used in this investigation. This table includes the estimated application efficiencies for the existing irrigation methods as well as alternative methods that may be used during the evaluation of water saving alternatives.

Table 6.3 Summary of Irrigation Efficiencies (Literature Values).

Irrigation Method						
Conventional Furrow	**Side Roll**	**Center Pivot**	**Furrow with Surge**	**LEPA**	**Drip**	**Source**
65 - 75 [1]	65 – 75	75 - 90	-	80 - 95	-	Solomon, 1988
25 - 60 Mean 40	-	60 - 95 Mean 75	30 – 80 Mean 60	-	80 - 95 Mean 90	Waskom, et al., 1994
50	-	50 - 95[2]	-	85 - 95	70 - 90	Fipps, undated
50 - 85 [3]	-	-	-	-	-	Buller, et al, 1988
40 - 60	-	75 - 80	80 – 90	96 - 98	96 - 98	New, 1995
70 - 75	65 – 85	65 - 85	-	-	75 - 90	Merriam and Keller, 1978
40 - 60	60 – 70	75 - 85	70 – 90	80 - 90	85 - 95	Soltanpour, et al., 1999
60	85	80	85	85	-	Klamm and Brenner, 1995
Values Used in the Popo Agie River Model						
50	75	80	N/A	N/A	N/A	

Notes:
1. Runoff return flow systems may be required to achieve high water use efficiencies (Solomon, 1988)
2. Range of efficiencies based on options center pivot is equipped with.
3. "Average system, no treatment" (i.e., no land leveling, delivery pipeline, etc)

The predominant irrigation method in the basin is conventional flood irrigation. This study recognizes that there are several different means of conveyance to the field that will influence the overall efficiency of the furrow irrigation method. Most irrigators rely on earthen ditches to convey water and control the flow through a series of gates; others have installed more efficient gated-pipe systems that convey water to the edge of the field. Each method, or combination of methods, will have a different overall application efficiency. Those using pipes will obviously incur lower overall losses than those using open ditches. The value used in estimation of On-Farm Delivery Requirement represents an estimated average of the published values for the various forms of furrow irrigation. Consequently, this value was applied to the entire acreage under furrow irrigation methods to compute that portion of the on-farm water requirement.

Based upon the application efficiencies identified in Table 6.3, the water delivery necessary to satisfy the On-farm Delivery Requirement was determined. This quantity of water is the amount needed to satisfy the CIR plus the amount needed to satisfy efficiency losses associated with the irrigation methods.

Ditch Diversion Requirement

Ditch Diversion Requirement represents the amount of water actually diverted at the headgate. These values were computed by dividing the estimated On-Farm Delivery Requirement by ditch conveyance efficiency. Estimates of ditch losses were made following review of existing information including ditch-specific reports and general reports by the NRCS, discussions with ditch representatives, and field observations. The resulting data were compared qualitatively to data presented in the State Engineers Office Hydrographer's Reports. Generally, the results compared favorably; agreement was improved by adjusting coefficients. Mean monthly diversion requirements were computed for individual larger ditches and for aggregated smaller ditches.

6.3.4 Irrigation Return Flows

The unused portion of a headgate diversion either returns to the river as surface runoff during the month it is diverted, or "deep percolates" into the alluvial aquifer. The deep percolation portion returns to the river through the aquifer but generally lags the time of diversion by several months, or even years. It is important for the model to simulate both the percent of headgate diversions that return to the river, and the timing of which this unused portion returns.

Diversion efficiency is the common measure of the portion of headgate diversion that is consumed, and therefore not returned to the river. Diversion efficiency for municipal and industrial use is the percent of headgate diversion that makes it to the treatment plant or industrial site. The remaining percent is lost during conveyance, and returns to the river as surface runoff or deep percolation. Diversions for agricultural use experience both conveyance losses and application losses, and both these loss percentages return to the river as surface runoff or deep percolation. Additional discussion of the consumptive use analysis and return flow study is contained in "Popo Agie River Model: Diversion Estimates" memorandum.

The locations at which the unused portion of the diversions, or "return flows" were identified through evaluation of the location of the irrigated lands with respect to model nodes. Mapping provided by the NRCS proved valuable in this effort.

6.4 Available Flow Determination

The Popo Agie River basin model is divided into a number of reaches, each composed of several nodes, or water balance points. Reaches are typically defined by gages or confluences, and represent tributary basins or subsections of the mainstem. An output worksheet in each spreadsheet model summarizes monthly flow at the downstream end of each reach, and provides the basis of this analysis.

While simulated flow at the reach terminus provides an estimate of the amount of water physically present, it does not fully reflect availability. Estimation of “available” water required consideration of impact to downstream users and instream flow considerations.

6.4.1 Instream Flow Considerations

In 1986, the State of Wyoming passed legislation defining "instream flow" as a beneficial use of water, and stipulated how instream flow water rights are filed, evaluated and ultimately regulated. The legislation is codified under Wyoming statutes 41-3-1001 to 1014.

The law allows for instream flow water rights to be filed or granted on unappropriated water originating as natural flow or from storage in existing or new reservoirs. The use of natural flow sources is defined as the minimum needed to maintain or improve existing fisheries. The use of stored water is defined as the minimum needed to establish or maintain new or existing fisheries.

The law requires that the Game and Fish Commission identify stream segments for instream flow filings and the minimum flows required. The Wyoming Water Development Commission (WWDC) then files the application with the State Engineer's Office in the name of the State of Wyoming. According to the law, the State of Wyoming is the only entity allowed to hold an instream flow permit. WWDC then performs the hydrologic analyses necessary to determine feasibility of providing the flows requested. The findings of the hydrologic analyses are then submitted to the Game and Fish Commission and the State Engineer for the use in evaluating the application for approval. The instream flow application is then subject to a public hearing, which is administered by the State Engineer. The law provides protection for senior rights and compact allocation water.

Within the Popo Agie River watershed, there is only one pending instream flow right. This segment, located on the Little Popo Agie River, extends form the south boundary of the E ½ NE ¼ of Section 4, downstream to the north boundary of the NE ¼ SW ¼ of Section 34, T32N, R99W, a length of approximately 1.4 miles. This reach is located downstream of the confluence of the Little Popo Agie River and Red Canyon Creek and upstream of Highway 28. The requested flows range from a minimum of 21 cfs to a maximum of 45 cfs. This right has not yet been adjudicated.

6.4.2 Out-of-Basin Considerations

The Popo Agie River is a sub-basin of the Wind River/Bighorn River system. In turn, the Bighorn River is a sub-basin within the Yellowstone River. Consequently, availability of streamflow within the Popo Agie River system may be governed in part by downstream obligations. The spreadsheet models effectively terminate at the confluence of the Popo Agie River and the Little Wind River. To be complete, evaluation of surface water availability within the Popo Agie watershed must include consideration of Wind River/Bighorn River rights.

In addition, the spreadsheet models do not contain logic to evaluate impacts upon the state's obligations under the Yellowstone River Compact (Compact). The Yellowstone River Compact between Montana, North Dakota and Wyoming was signed in 1950. The compact outlines allocations for several rivers in northern Wyoming, including the Bighorn River. On the Bighorn River, water is to be allocated 80% to Wyoming and 20% to Montana. Pre-1950 water rights are guaranteed. Native American rights to Yellowstone River water are not effected by the Compact.

6.4.3 Available Water

To determine how much of the physical supply is actually available to future uses, "available water" at a reach terminus was defined as the minimum of the physically available flow at that point, and "available water" at all downstream reaches. In lieu of “drying up” the river by computing total availability, minimum streamflows were left in the rivers. It is our understanding that the Popo Agie Conservation District wishes to develop water resources in a multi-use manner and that maintenance of flows within the channels is an important goal. Therefore, a minimum of 25 cfs was left in the Popo Agie River mainstems when available. This value was determined from review of the Lander 2020 report and is assumed to represent an average minimum streamflow for support of aquatic biota. A minimum of 5 cfs was left in tributaries incorporated in the model as a typical average minimum streamflow.

Tables 6.4 through 6.6 summarize total annual water availability for all reaches modeled within the Popo Agie River basin for both the Existing and Future water rights scenarios. Available water supply is a function of timing and location, however, and Tables 6.7 through 6.9 provide additional information on availability on a monthly basis, in specific reaches.

Table 6.4 Total Available Flow for the Popo Agie River Basin Under Dry Hydrologic Conditions.

Reach Name	Reach Number	Existing	Future
Upper North	Reach 1.1	16,035	3,397
Lower North	Reach 1.2	20,093	8,607
Surrel Creek	Reach 1.3	1,494	888
Upper Middle	Reach 2.1	39,066	39,066
Sawmill Creek	Reach 2.2	13,651	13,651
Lower Middle	Reach 2.3	61,457	61,649
Baldwin/Squaw Creeks	Reach 2.4	9,826	9,950
Roaring Fork Creek	Reach 2.5	3,188	3,188
Hornecker Creek	Reach 2.6	461	461
Upper Little	Reach 3.1	22,634	22,634
Red Canyon Creek	Reach 3.2	3,989	3,989
Lower Little	Reach 3.3	4,458	4,458
Twin Creek	Reach 3.5	685	685
Willow Creek	Reach 3.6	416	416
Popo Agie Outflow	Reach 4.1	124,130	123,006

Table 6.5 Total Available Flow for the Popo Agie River Basin Under Normal Hydrologic Conditions.

Reach Name	Reach Number	Existing	Future
Upper North	Reach 1.1	58,419	42,050
Lower North	Reach 1.2	64,078	46,209
Surrel Creek	Reach 1.3	5,478	5,478
Upper Middle	Reach 2.1	74,827	74,827
Sawmill Creek	Reach 2.2	19,736	19,736
Lower Middle	Reach 2.3	107,762	107,953
Baldwin/Squaw Creeks	Reach 2.4	15,180	15,325
Roaring Fork Creek	Reach 2.5	7,816	7,816
Hornecker Creek	Reach 2.6	3,100	3,100
Upper Little	Reach 3.1	48,067	48,067
Red Canyon Creek	Reach 3.2	10,576	10,576
Lower Little	Reach 3.3	55,733	55,733
Twin Creek	Reach 3.5	697	697
Willow Creek	Reach 3.6	1,892	1,892
Popo Agie Outflow	Reach 4.1	243,350	236,225

Table 6.6 Total Available Flow for the Popo Agie River Basin Under Wet Hydrologic Conditions.

Reach Name	Reach Number	Existing	Future
Upper North	Reach 1.1	104,127	89,090
Lower North	Reach 1.2	109,656	93,417
Surrel Creek	Reach 1.3	10,074	9,939
Upper Middle	Reach 2.1	119,095	119,095
Sawmill Creek	Reach 2.2	32,844	32,844
Lower Middle	Reach 2.3	165,838	165,838
Baldwin/Squaw Creeks	Reach 2.4	23,393	23,393
Roaring Fork Creek	Reach 2.5	14,413	14,413
Hornecker Creek	Reach 2.6	3,472	3,472
Upper Little	Reach 3.1	79,138	79,138
Red Canyon Creek	Reach 3.2	20,903	20,903
Lower Little	Reach 3.3	85,608	85,608
Twin Creek	Reach 3.5	673	673
Willow Creek	Reach 3.6	3,779	3,779
Popo Agie Outflow	Reach 4.1	365,211	355,112

Table 6.7 Available Flow for the Popo Agie River Basin under Dry Hydrologic Conditions.

"Futures" Water Rights Condition													
Reach Name	**Reach Number**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Upper North	Reach 1.1	0	0	550	0	1,971	0	0	0	0	291	553	32
Lower North	Reach 1.2	0	0	550	28	2,587	4,017	0	0	0	708	670	47
Surrel Creek	Reach 1.3	0	0	0	0	290	598	0	0	0	0	0	0
Upper Middle	Reach 2.1	2,123	1,899	2,968	21	9,164	10,358	4,342	0	0	2,925	2,815	2,451
Sawmill Creek	Reach 2.2	890	817	1,169	21	2,717	3,155	1,781	0	0	985	1,118	998
Lower Middle	Reach 2.3	3,732	3,437	5,044	843	11,568	14,105	7,431	914	194	5,044	5,069	4,268
Baldwin/Squaw Creeks	Reach 2.4	78	85	236	511	2,060	3,353	2,647	0	0	606	251	123
Roaring Fork Creek	Reach 2.5	326	287	472	0	561	421	0	0	0	294	445	382
Hornecker Creek	Reach 2.6	0	0	0	0	1	268	153	0	0	39	0	0
Upper Little	Reach 3.1	744	604	1,253	1,685	5,130	6,898	2,103	836	513	1,027	990	851
Red Canyon Creek	Reach 3.2	0	0	66	202	1,759	1,610	321	0	0	0	31	0
Lower Little	Reach 3.3	510	419	441	257	0	259	1,044	67	228	392	404	437
Twin Creek	Reach 3.5	0	0	0	0	0	240	404	41	0	0	0	0
Willow Creek	Reach 3.6	0	0	0	0	99	298	19	0	0	0	0	0
Popo Agie Outflow	Reach 4.1	4,714	4,554	7,214	9,134	23,852	28,723	13,315	6,504	5,396	7,447	6,576	5,577
Existing Water Rights Condition													
Reach Name	**Reach Number**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Upper North	Reach 1.1	0	0	550	916	4,838	7,551	1,178	0	0	506	475	21
Lower North	Reach 1.2	0	0	550	1,094	5,418	8,593	2,566	0	125	1,038	663	46
Surrel Creek	Reach 1.3	0	0	0	37	490	798	169	0	0	0	0	0
Upper Middle	Reach 2.1	2,123	1,899	2,968	21	9,164	10,358	4,342	0	0	2,925	2,815	2,451
Sawmill Creek	Reach 2.2	890	817	1,169	21	2,717	3,155	1,781	0	0	985	1,118	998
Lower Middle	Reach 2.3	3,732	3,437	5,044	836	11,548	14,068	7,384	872	168	5,034	5,067	4,267
Baldwin/Squaw Creeks	Reach 2.4	78	85	236	504	2,039	3,317	2,600	0	0	596	249	122
Roaring Fork Creek	Reach 2.5	326	287	472	0	561	421	0	0	0	294	445	382
Hornecker Creek	Reach 2.6	0	0	0	0	1	268	153	0	0	39	0	0
Upper Little	Reach 3.1	744	604	1,253	1,685	5,130	6,898	2,103	836	513	1,027	990	851
Red Canyon Creek	Reach 3.2	0	0	66	202	1,759	1,610	321	0	0	0	31	0
Lower Little	Reach 3.3	510	419	441	257	0	259	1,044	67	228	392	404	437
Twin Creek	Reach 3.5	0	0	0	0	0	240	404	41	0	0	0	0
Willow Creek	Reach 3.6	0	0	0	0	99	298	19	0	0	0	0	0
Popo Agie Outflow	Reach 4.1	4,714	4,554	7,214	9,802	25,513	31,230	13,230	4,030	4,613	7,245	6,428	5,557

Table 6.8 Available Flow for the Popo Agie River Basin Under Normal Hydrologic Conditions.

"Futures" Water Rights Condition													
Reach Name	**Reach Number**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Upper North	Reach 1.1	108	161	1,392	1,367	9,193	22,077	3,561	0	0	2,164	1,443	584
Lower North	Reach 1.2	108	161	1,392	1,496	9,685	22,992	4,889	0	702	2,575	1,608	601
Surrel Creek	Reach 1.3	0	0	53	148	1,188	2,697	1,000	94	96	145	57	0
Upper Middle	Reach 2.1	2,535	2,389	3,792	555	13,896	31,208	7,906	0	1,107	4,675	3,763	3,001
Sawmill Creek	Reach 2.2	726	678	1,140	0	3,411	8,199	2,221	0	37	1,316	1,129	879
Lower Middle	Reach 2.3	4,438	4,239	6,339	1,433	16,828	39,062	11,800	1,109	3,040	7,979	6,525	5,161
Baldwin/Squaw Creeks	Reach 2.4	130	129	306	570	2,596	5,335	3,466	0	1,498	773	341	181
Roaring Fork Creek	Reach 2.5	404	379	624	0	1,212	3,431	0	0	0	663	618	485
Hornecker Creek	Reach 2.6	0	0	0	0	478	1,338	685	0	394	205	0	0
Upper Little	Reach 3.1	753	659	1,556	1,481	9,610	18,598	6,882	2,003	1,794	2,072	1,591	1,068
Red Canyon Creek	Reach 3.2	0	0	191	143	2,864	4,702	1,581	293	247	311	189	55
Lower Little	Reach 3.3	1,240	1,133	2,076	2,716	9,610	19,393	8,520	2,544	2,311	2,611	2,035	1,544
Twin Creek	Reach 3.5	0	0	0	0	0	263	402	32	0	0	0	0
Willow Creek	Reach 3.6	0	0	0	0	406	1,117	369	0	0	0	0	0
Popo Agie Outflow	Reach 4.1	6,509	6,209	9,688	12,351	40,044	77,389	32,119	12,200	10,423	12,112	9,542	7,639
Existing Water Rights Condition													
Reach Name	**Reach Number**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Upper North	Reach 1.1	108	161	1,392	2,109	11,839	26,442	9,414	895	1,737	2,295	1,443	584
Lower North	Reach 1.2	108	161	1,392	2,237	12,324	27,338	10,708	2,195	2,599	2,816	1,599	601
Surrel Creek	Reach 1.3	0	0	53	148	1,188	2,697	1,000	94	96	145	57	0
Upper Middle	Reach 2.1	2,535	2,389	3,792	555	13,896	31,208	7,906	0	1,107	4,675	3,763	3,001
Sawmill Creek	Reach 2.2	726	678	1,140	0	3,411	8,199	2,221	0	37	1,316	1,129	879
Lower Middle	Reach 2.3	4,438	4,239	6,339	1,428	16,809	39,028	11,751	1,063	3,013	7,969	6,523	5,161
Baldwin/Squaw Creeks	Reach 2.4	130	129	306	565	2,577	5,301	3,417	0	1,471	764	339	181
Roaring Fork Creek	Reach 2.5	404	379	624	0	1,212	3,431	0	0	0	663	618	485
Hornecker Creek	Reach 2.6	0	0	0	0	478	1,338	685	0	394	205	0	0
Upper Little	Reach 3.1	753	659	1,556	1,481	9,610	18,598	6,882	2,003	1,794	2,072	1,591	1,068
Red Canyon Creek	Reach 3.2	0	0	191	143	2,864	4,702	1,581	293	247	311	189	55
Lower Little	Reach 3.3	1,240	1,133	2,076	2,716	9,610	19,393	8,520	2,544	2,311	2,611	2,035	1,544
Twin Creek	Reach 3.5	0	0	0	0	0	263	402	32	0	0	0	0
Willow Creek	Reach 3.6	0	0	0	0	406	1,117	369	0	0	0	0	0
Popo Agie Outflow	Reach 4.1	6,509	6,209	9,688	12,817	41,621	79,790	35,156	11,940	10,794	11,798	9,404	7,625

Table 6.9 Available Flow for the Popo Agie River Basin Under Wet Hydrologic Conditions.

"Futures" Water Rights Condition													
Reach Name	**Reach Number**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Upper North	Reach 1.1	209	301	1,111	2,921	15,045	47,312	16,673	0	863	2,475	1,536	644
Lower North	Reach 1.2	209	301	1,111	3,036	15,480	48,202	17,995	0	1,807	2,905	1,708	663
Surrel Creek	Reach 1.3	0	0	25	287	1,733	5,272	2,332	0	45	179	66	0
Upper Middle	Reach 2.1	2,634	2,502	3,517	3,481	16,201	53,769	25,079	0	0	4,999	3,853	3,060
Sawmill Creek	Reach 2.2	759	715	1,049	705	4,082	15,603	6,462	0	0	1,412	1,159	898
Lower Middle	Reach 2.3	4,440	4,256	5,757	4,504	20,489	72,622	30,464	1,230	1,948	8,353	6,605	5,170
Baldwin/Squaw Creeks	Reach 2.4	95	91	213	716	3,422	8,700	4,959	2,272	1,510	844	376	195
Roaring Fork Creek	Reach 2.5	414	391	567	215	1,608	7,255	2,153	0	0	697	625	488
Hornecker Creek	Reach 2.6	0	0	0	0	430	1,685	751	229	259	118	0	0
Upper Little	Reach 3.1	858	805	1,444	2,174	13,112	36,040	14,647	2,828	1,983	2,427	1,680	1,140
Red Canyon Creek	Reach 3.2	4	0	161	329	4,384	10,434	3,626	666	412	500	312	75
Lower Little	Reach 3.3	1,300	1,209	1,892	3,606	13,112	36,040	17,135	2,828	1,983	2,826	2,094	1,583
Twin Creek	Reach 3.5	0	0	0	0	0	256	399	18	0	0	0	0
Willow Creek	Reach 3.6	0	0	0	0	646	2,202	931	0	0	0	0	0
Popo Agie Outflow	Reach 4.1	5,784	5,420	7,770	15,519	57,717	147,359	62,481	11,922	10,492	12,734	10,001	7,913
Existing Water Rights Condition													
Reach Name	**Reach Number**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Upper North	Reach 1.1	209	301	1,111	3,502	17,290	51,747	22,575	1,207	1,218	2,787	1,536	644
Lower North	Reach 1.2	209	301	1,111	3,616	17,720	52,619	23,864	2,555	2,120	3,177	1,702	662
Surrel Creek	Reach 1.3	0	0	25	287	1,733	5,272	2,332	135	45	179	66	0
Upper Middle	Reach 2.1	2,634	2,502	3,517	3,481	16,201	53,769	25,079	0	0	4,999	3,853	3,060
Sawmill Creek	Reach 2.2	759	715	1,049	705	4,082	15,603	6,462	0	0	1,412	1,159	898
Lower Middle	Reach 2.3	4,440	4,256	5,757	4,504	20,489	72,622	30,464	1,230	1,948	8,353	6,605	5,170
Baldwin/Squaw Creeks	Reach 2.4	95	91	213	716	3,422	8,700	4,959	2,272	1,510	844	376	195
Roaring Fork Creek	Reach 2.5	414	391	567	215	1,608	7,255	2,153	0	0	697	625	488
Hornecker Creek	Reach 2.6	0	0	0	0	430	1,685	751	229	259	118	0	0
Upper Little	Reach 3.1	858	805	1,444	2,174	13,112	36,040	14,647	2,828	1,983	2,427	1,680	1,140
Red Canyon Creek	Reach 3.2	4	0	161	329	4,384	10,434	3,626	666	412	500	312	75
Lower Little	Reach 3.3	1,300	1,209	1,892	3,606	13,112	36,040	17,135	2,828	1,983	2,826	2,094	1,583
Twin Creek	Reach 3.5	0	0	0	0	0	256	399	18	0	0	0	0
Willow Creek	Reach 3.6	0	0	0	0	646	2,202	931	0	0	0	0	0
Popo Agie Outflow	Reach 4.1	5,784	5,420	7,770	15,983	59,412	150,526	66,506	12,762	10,366	12,789	9,991	7,902

6.5 Summary

Review of these tables shows what those familiar with the Popo Agie River watershed have already known and understood: *it's not a question of IF water is available for development or storage, it's a matter of WHEN it is available.* As previously discussed, the annual hydrographs associated with streams in the study area are driven by the snowmelt process. Consequently, during the spring snowmelt period, flow is ample and flooding is a concern in certain reaches. For the majority of reaches in the model, water is available for storage during this period. As the hydrograph recedes, availability drops correspondingly. During the summer months, irrigation demands increase while streamflow levels drop. Demand increases in relation to the supply and availability drops in all reaches. Figure 6.7 shows the relative distribution of flow availability on selected reaches of each of the three mainstems in the study area under normal year conditions. Approximately 70 to 80 percent of the total annual available flows arrive during the months of May, June, and July.

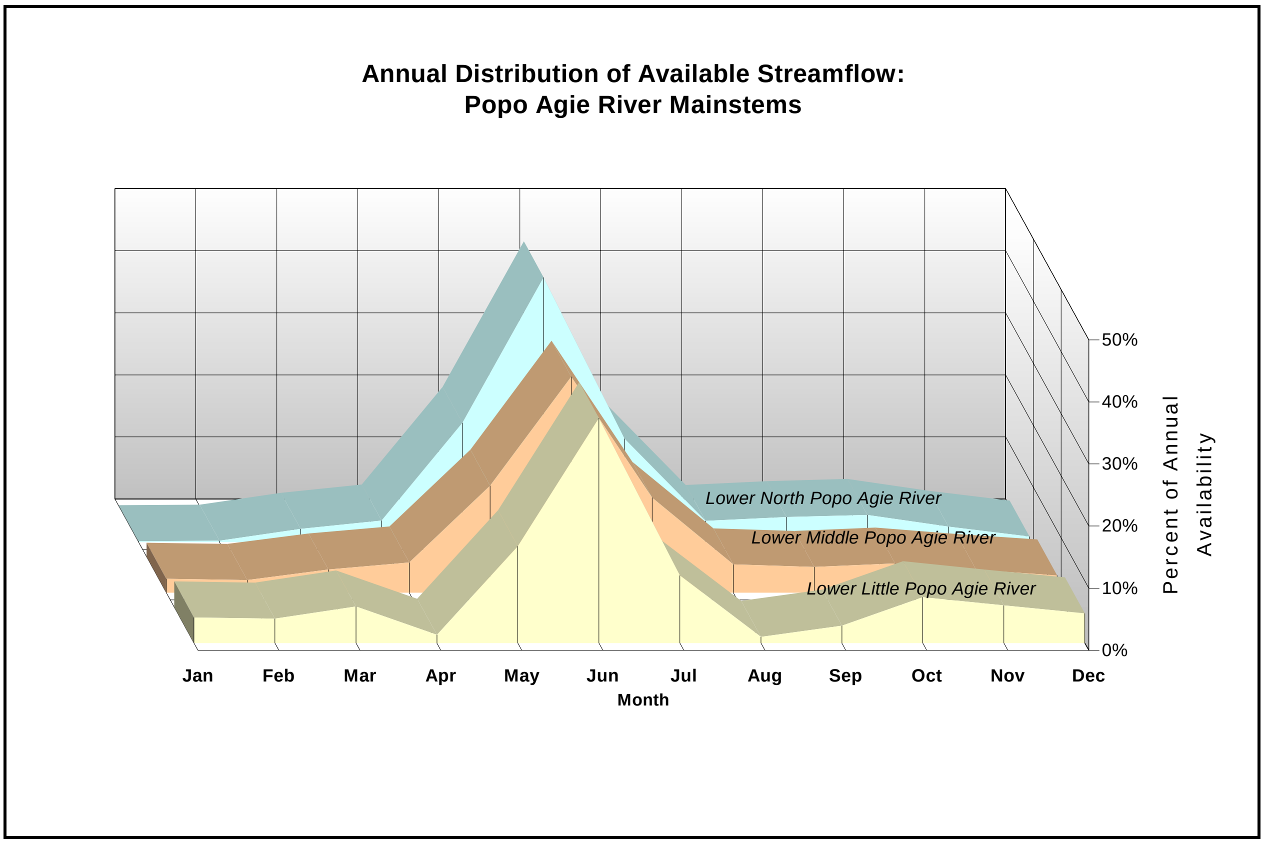


Figure 6.7 Annual Distribution of Available Flows in the Popo Agie River Mainstems.

On the North and the Little Popo Agie Rivers, supply exceeds demands throughout the irrigation season in normal years. Availability drops to minimum levels in these reaches, but the stream "holds its own" in comparison to demand. Streamflows in the model never drop to zero under existing water rights conditions. On the Little Popo Agie, this is likely due in part to irrigation returns derived from lands irrigated by Middle Popo Agie diversions. On the Middle Popo Agie River, however, demand exceeds supply during the months of August and September and flows in the model drop to zero at certain nodes. This relationship was evident during the field investigation when the Middle Popo Agie River was dry downstream of the Cemetery Ditch headgate. This occurred during a very dry year; the model indicates it occurs in Normal and Wet years as well. *Simply put, the Middle Popo Agie River appears to be over-allocated.*

Under "Future Project" conditions, the North Popo Agie River experiences similar conditions. As increased demand pressures are put upon the system by the irrigation of approximately 4,680 additional acres, the model indicates the North Popo Agie River may experience shortages during dry and normal years.

Storage Opportunities

Chapter 7

7.1 Introduction

Development of additional storage has been identified as a potential objective within the Popo Agie River Basin. The PACD Board and Steering Committee have expressed the desire to explore the opportunity for additional storage. At each of the public meetings, various individuals also expressed this opinion. The objective of this task was to determine the feasibility and location of potential storage sites within the Popo Agie River watershed. With respect to this study, additional storage provide the benefits of:

- relief from flooding,
- storage for irrigation uses, and
- augmentation of late season low-flow conditions.

7.1.1 Existing Storage Locations

The following existing reservoir sites were identified and incorporated into the project GIS and included for further evaluation in this task (Figure 7.1):

- Worthen Meadows Reservoir: This reservoir is located on Roaring Fork Creek within the Middle Popo Agie River basin. It is located with the Shoshsone National Forest and serves as a source of municipal storage for the Town of Lander.

- Louis Lake: This reservoir is located on Louis Creek within the Little Popo Agie River watershed. It is located along the Loop Road within the Shoshone National Forest. It serves as a source of irrigation storage for irrigators on the Little Popo Agie River.

- Shoshone Lake: This reservoir is located within the North Popo Agie River basin. It is located within the Shoshsone National Forest and serves as a source of irrigation supply for irrigators on the North Popo Agie River.

- Frye Lake: This reservoir is located on Sawmill Creek within the Middle Popo Agie River basin. It stores water diverted from Roaring Fork Creek for diversion to the Little Popo River basin by means of the Enterprise Ditch system.

- <u>Christina Lake</u>: This reservoir is located within the headwaters of the Little Popo Agie River within the Shoshone National Forest just outside of the Popo Agie Wilderness area. It serves as a source of irrigation storage for irrigators on the Little Popo Agie River.

- <u>Carr Reservoir</u>: Carr Reservoir is located on Twin Creek on private land. Carr Reservoir is also referred to as Johnson Reservoir.

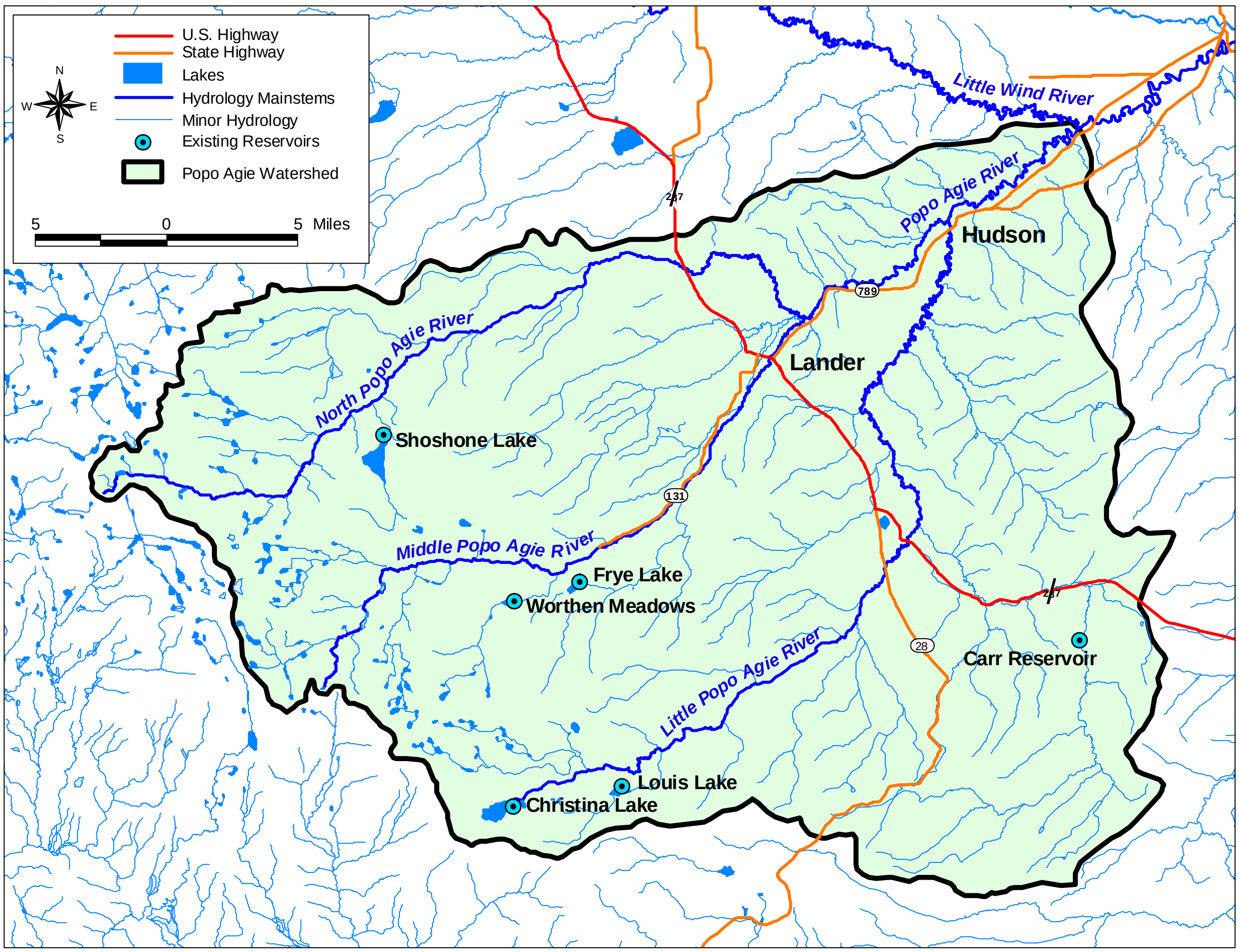


Figure 7.1 Existing Reservoir Storage Sites Within the Popo Agie River Watershed.

7.1.2 Previous Investigations

Several studies have been completed previously pertaining to development of storage in the study area. Reports of these investigations were reviewed and results incorporated herein. None of these studies focused primarily on the Popo Agie River watershed; their primary objective was development of storage within the Wind River basin of which the Popo Agie River watershed is a sub-basin. Consequently, although these reports identify numerous potential reservoir sites, those located within the Popo Agie River basin are relatively limited in number. The primary reports reviewed during this effort were:

- Bishop & Spurlock, 1962. *"Report on Water Resources in the Wind River Basin"*, submitted to the Wyoming Natural Resource Board.
- James M. Montgomery, 1993. *"Wind River Indian Reservation Joint Business Council: Alternative Storage Site Study"*.
- Short Elliott Hendrickson, Inc., 2001. *"Upper Wind River Storage Project – Level 1 Study, Final Report"*, prepared for the Wyoming Water Development Commission.

Potential reservoir site locations identified in these reports that fell within the Popo Agie River watershed were incorporated into the project GIS and included in further evaluations (Figure 7.2).

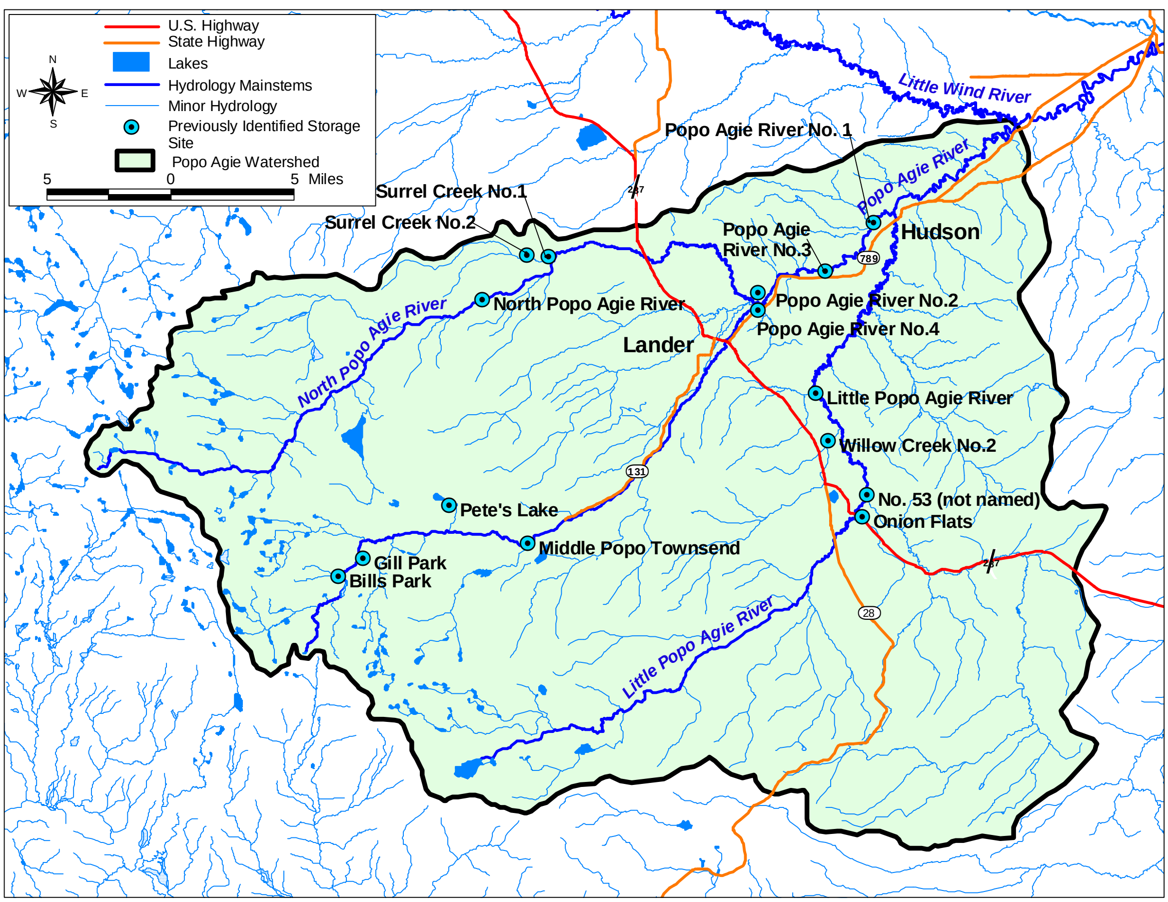


Figure 7.2 Previously Identified Potential Storage Sites.

7.1.3 Identification of New Potential Storage Sites

Additional storage sites (i.e., in addition to those identified in previous investigations) were identified through:

- Interviews with local representatives; and
- detailed review of existing topography / GIS data.

In this effort, the knowledge gained from discussing the project with local residents was used during the review of existing topography. The project GIS was utilized as a resource containing all USGS topographic mapping available. In addition, the digital elevation model incorporated within the GIS was used to determine certain basin characteristics such as basin area, perimeter, relief, etc. The additional storage sites are presented in Figure 7.3.

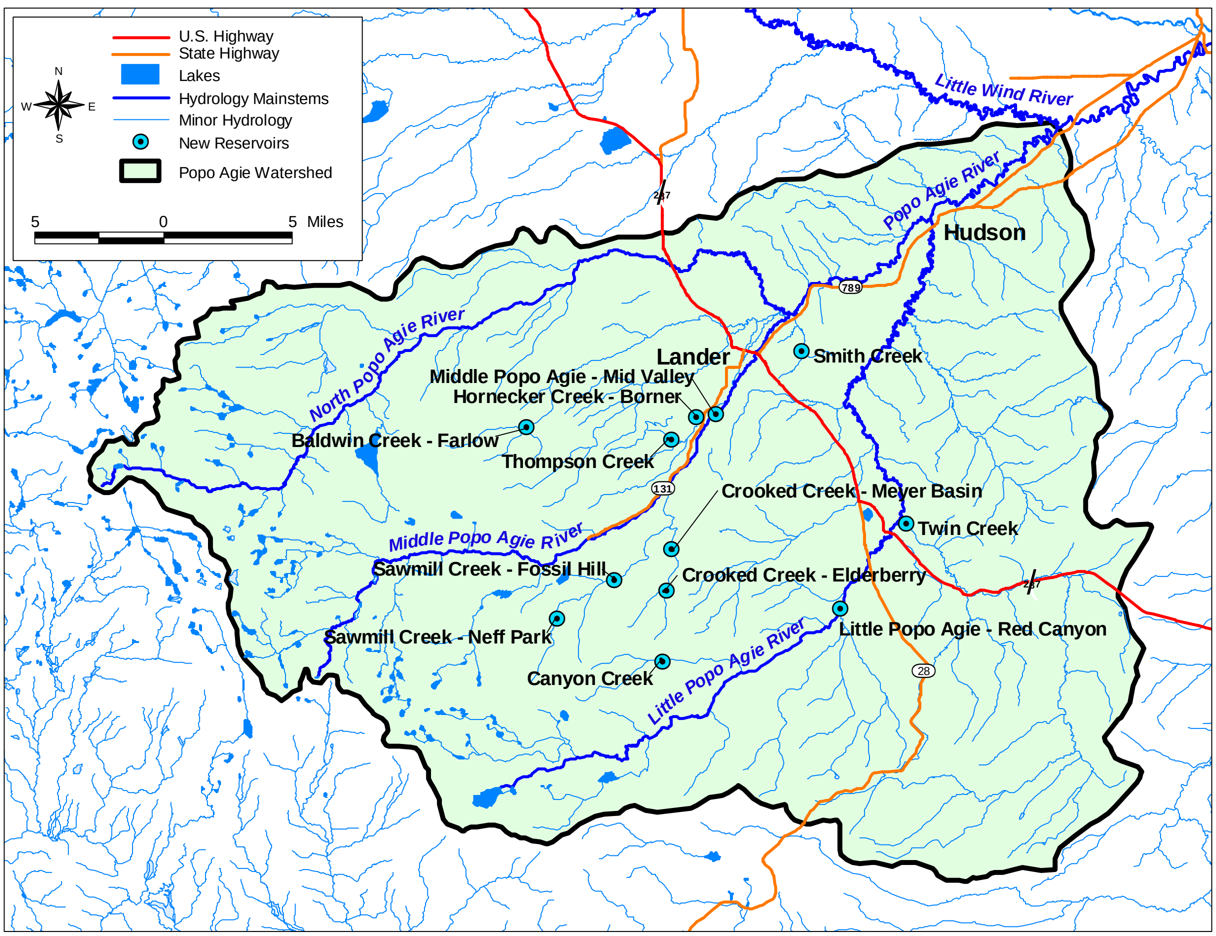


Figure 7.3 Newly Identified Potential Storage Sites.

During the modeling effort, it was determined that the three major sub-basins have differing limitations hydrologically. It was observed that the Middle Popo Agie River suffers the greatest from limited supply in relation to demand. The river bed was observed to be dry during the field investigation due to irrigation diversions. It is our understanding that this was a relatively common occurrence. The Little Popo Agie River basin was second in priority in terms of supply versus demand followed by the North Popo Agie River. The North Popo Agie River exhibits fewer water shortages than both the Middle Popo Agie and Little Popo Agie Rivers. However, should diversions associated with future projects be completed, the North Popo Agie River can be expected to experience shortages similar to the Middle Popo Agie River. Table 7.1 presents a summary list of all sites.

Table 7.1 Summary of Potential Storage Locations in the Popo Agie River Basin.

Site Number	Site Name	Site Source	Source	Basin
1	Baldwin - Farlow	New	Baldwin Creek	Middle Popo Agie
2	Bills Park	Previous Studies	Middle Popo Agie	Middle Popo Agie
3	Canyon Creek	New	Canyon Creek	Little Popo Agie
4	Christina Lake	Existing	Little Popo Agie	Little Popo Agie
5	Crooked Creek - Elderberry	New	Crooked Creek	Middle Popo Agie
6	Crooked Creek - Meyer Basin	New	Crooked Creek	Middle Popo Agie
7	Frye	Existing	Townsend Creek	Middle Popo Agie
8	Gill Park	Previous Studies	Middle Popo Agie	Middle Popo Agie
9	Hornecker - Borner	New	Middle Popo Agie	Middle Popo Agie
10	Carr (Johnson) Reservoir	Existing	Twin Creek	Little Popo Agie
11	Little Popo Agie - Onion Flats	Previous Studies	Little Popo Agie	Little Popo Agie
12	Little Popo Agie - Red Canyon	New	Little Popo Agie	Little Popo Agie
13	Little Popo Agie - Twin (No. 53)	Previous Studies	Little Popo Agie	Little Popo Agie
14	Little Popo Agie - Lyons	Previous Studies	Little Popo Agie	Little Popo Agie
15	Louis Lake	Existing	Louis Creek	Little Popo Agie
16	Middle Popo Agie - Mid Valley	New	Middle Popo Agie	Middle Popo Agie
17	Middle Popo Agie - Roaring Fork	Previous Studies	Middle Popo Agie	Middle Popo Agie
18	North Popo Agie	Previous Studies	North Popo Agie	North Popo Agie
19	Pete's Lake	Previous Studies	Un-named	Middle Popo Agie
20	Popo Agie River No. 1	Previous Studies	Popo Agie	Popo Agie
21	Popo Agie River No. 2	Previous Studies	North Popo Agie	North Popo Agie
22	Popo Agie River No. 3	Previous Studies	Popo Agie	Popo Agie
23	Popo Agie River No. 4	Previous Studies	Middle Popo Agie	Middle Popo Agie
24	Sawmill Creek - Neff Park	New	Sawmill Creek	Middle Popo Agie
25	Sawmill Creek - Fossil Hill	New	Sawmill Creek	Middle Popo Agie
26	Shoshone Lake	Existing	Shoshone Creek	North Popo Agie
27	Smith Creek	New	Middle Popo Agie	Middle Popo Agie
28	Surrel Creek No. 1	Previous Studies	North Popo Agie	North Popo Agie
29	Surrel Creek No. 2	Previous Studies	North Popo Agie	North Popo Agie
30	Thompson Creek	New	Middle Popo Agie	Middle Popo Agie
31	Twin Creek	New	Little Popo Agie	Little Popo Agie
32	Willow Creek No. 2	Previous Studies	Willow Creek	Little Popo Agie
33	Worthen Meadows Reservoir	Existing	Roaring Fork	Middle Popo Agie

7.2 Initial Screening of Storage Sites

Table 7.1 presents a summary of the identification of potential storage sites within the Popo Agie River Basin. This table includes the source of water for the potential reservoir and the main subbasin in which it is located. This list was initially screened using the following criteria:

- Location of site in relation to objectives: Several of the potential sites identified in the previous investigations were located downstream of the Town of Lander. While these sites would have met the objectives of the previous investigations (i.e. Wind River Basin studies), their location provides minimal benefits to the needs of the Popo Agie River Basin. That is, these sites would provide limited flood relief, low-flow augmentation or additional irrigation supplies.

- Contributing Area vs Storage Capacity: Several of the sites identified were located relatively high in the watersheds and consequently did not have sufficient contributing area to generate the runoff necessary to make a reservoir viable.

- Wilderness Area: The upper reaches of the Popo Agie River watershed are located within the Popo Agie Wilderness Area. Due to land use and activity constraints posed by this designation, these sites were removed from further evaluation.

Based upon these criteria, several sites were eliminated form further analysis (Figure 7.4).

Relative feasibility due to location of the site on or off the Shoshone National Forest must also be considered. Although construction of reservoirs within the national forests is not prohibitive, it can certainly be more problematic than construction on private lands. Also, it was assumed that enlargement of an existing reservoir would, in the long run, be more feasible in terms of permitting and public acceptance than construction of new reservoirs. Given this reasoning, one of four categories shown in Figure 7.5 was assigned to each site. The results of this analysis are presented in Table 7.2.

Finally, the following limitations to the site selection are noted:

- Site specific geologic or geotechnical investigations were not performed.

- The sites presented in this report were selected without significant consideration of land ownership. Other than differences between public and private lands, no distinctions are made. Those sites located on private lands may be, in the end, infeasible due to land owner considerations.

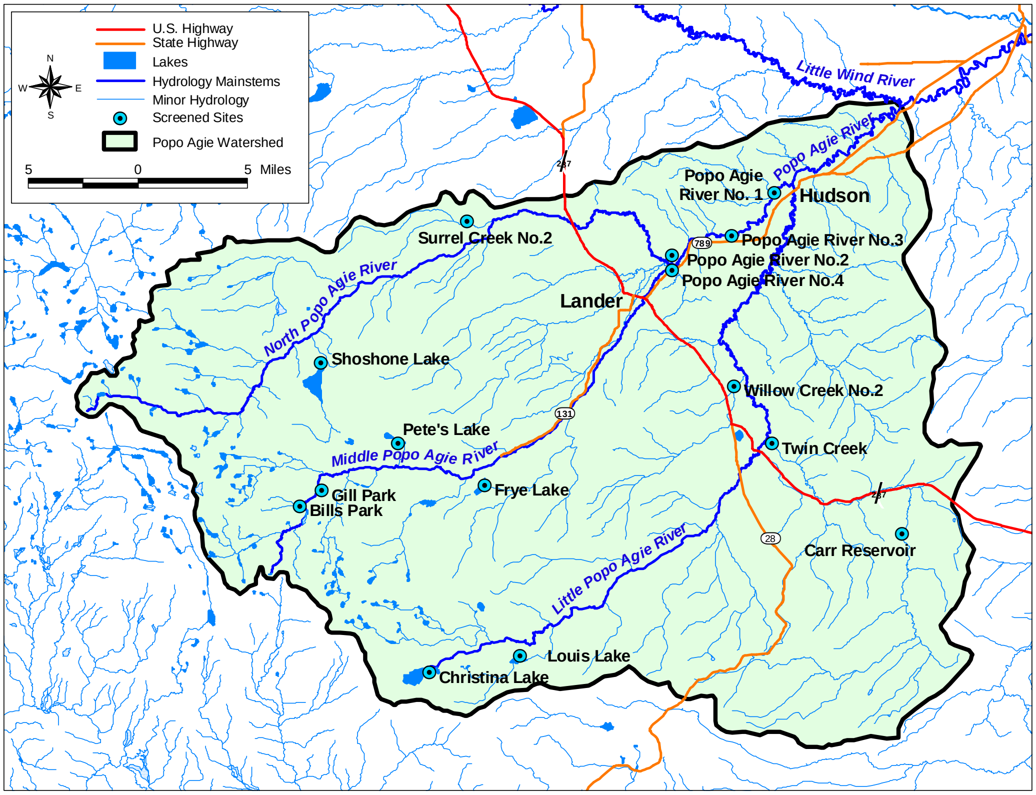


Figure 7.4 Potential Reservoir Sites Screened from Further Analysis.

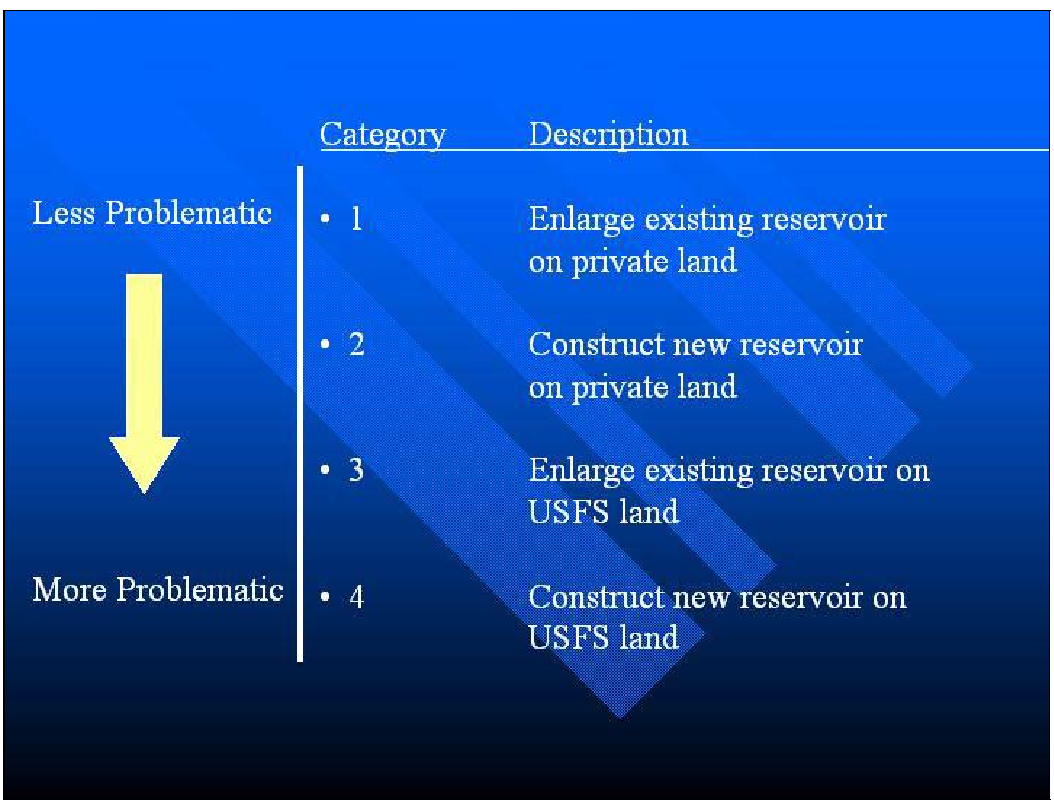


Figure 7.5 Relative Feasibility Associated With USFS Vs Private Lands.

Table 7.2 Summary of Feasibility Categories for Remaining Potential Storage Locations.

Basin	Site Number	Site Name	Category
NORTH	18	North Popo Agie	2
	28	Surrel Creek No. 1	2
MIDDLE	1	Baldwin - Farlow	2
	5	Crooked Creek - Elderberry	4
	6	Crooked Creek - Meyer Basin	2
	9	Hornecker - Borner	2
	16	Middle Popo Agie - Mid Valley	2
	17	Middle Popo Agie - Roaring Fork	4
	24	Sawmill Creek - Neff Park	4
	25	Sawmill Creek - Fossil Hill	4
	27	Smith Creek	2
	30	Thompson Creek	2
	33	Worthen Meadows Reservoir	3
LITTLE	3	Canyon Creek	4
	11	Little Popo Agie - Onion Flats	2
	12	Little Popo Agie - Red Canyon	2
	13	Little Popo Agie - Twin (No. 53)	2
	14	Little Popo Agie - Lyons	2

7.3 Site Evaluation

Figure 7.6 displays the location of the reservoir sites remaining for further analysis after the initial screening was completed. For each of the sites, the following tasks were completed:

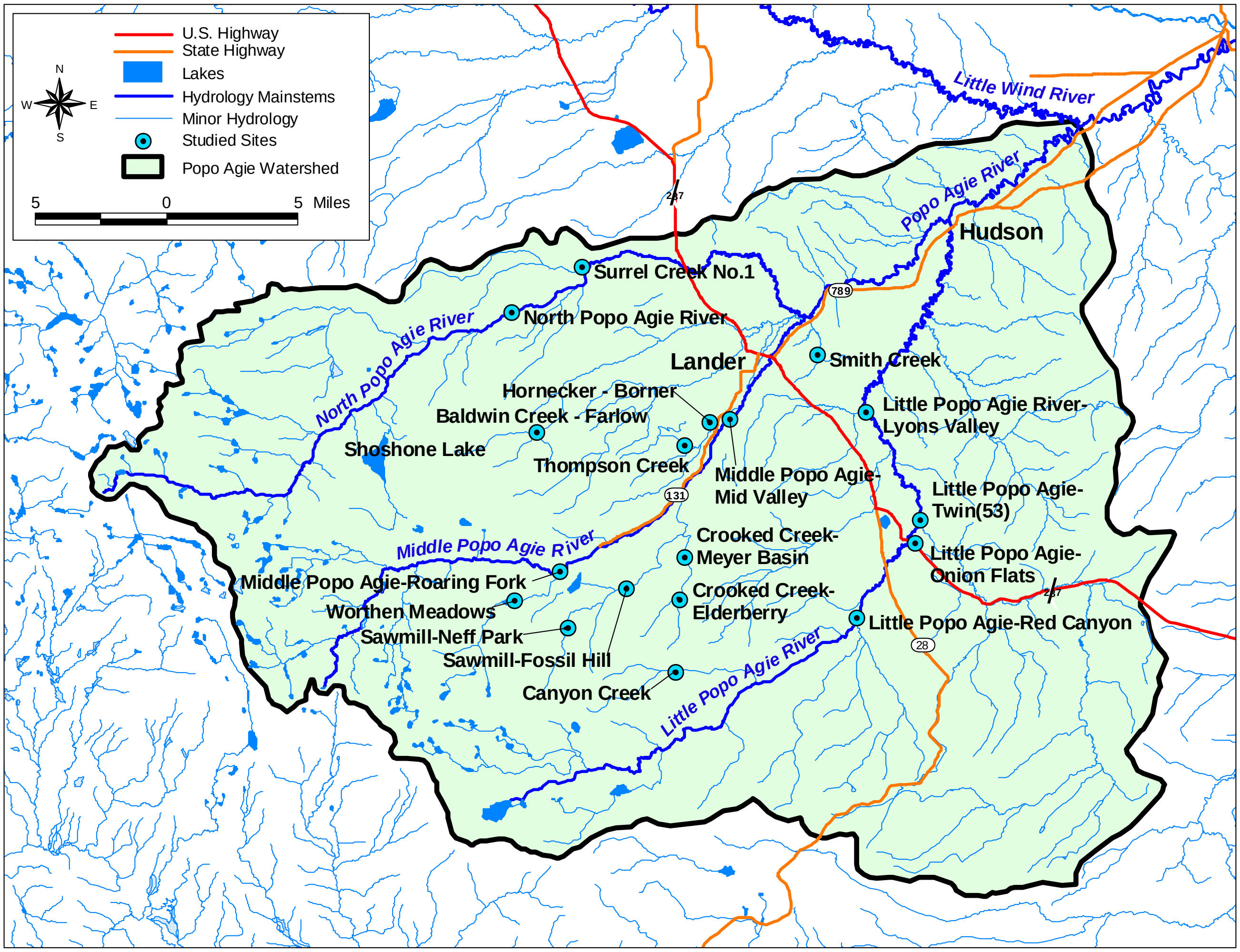


Figure 7.6 Reservoir Sites Included in Popo Agie River Watershed Study.

- <u>Delineation of Contributing Area</u>: Using the DEM within the project GIS, the contributing areas and basin characteristics were determined. The delineated contributing areas were incorporated into the project GIS.

- <u>Determination of Available Flows</u>: Using the spreadsheet water use model, the flow availability was determined for each site for each of the three hydrologic conditions (dry, normal, wet years) and for each of the water rights conditions (existing and future conditions). The purpose of this task was to determine the locations within the watershed potentially "storable" water may exist in an effort to identify potentially viable storage site locations. In other words, even the best reservoir location is not practical if there is no water available to fill it. As discussed in Chapter 6, results of the modeling effort indicated that considerable flow is available for storage at certain times of the year. Peak flows associated with the snowmelt hydrograph occur in May and June followed by a recession in flows through the summer and fall. Irrigation demands begin in the April to

May time frame and continue throughout the growing season into September. As the irrigation season begins, high flows associated with the spring runoff provide sufficient water to meet the irrigation demand as well as providing a surplus. Later in the year as flow levels drop, irrigation demands an increasingly larger portion of the available flow. Available flows decrease to minimal levels in August and September. Consequently, the flood season surplus comprises the bulk of flows typically available for storage. Figure 7.7 displays this relationship in a generalized hydrograph for the Middle Popo Agie River and the estimated irrigation demands.

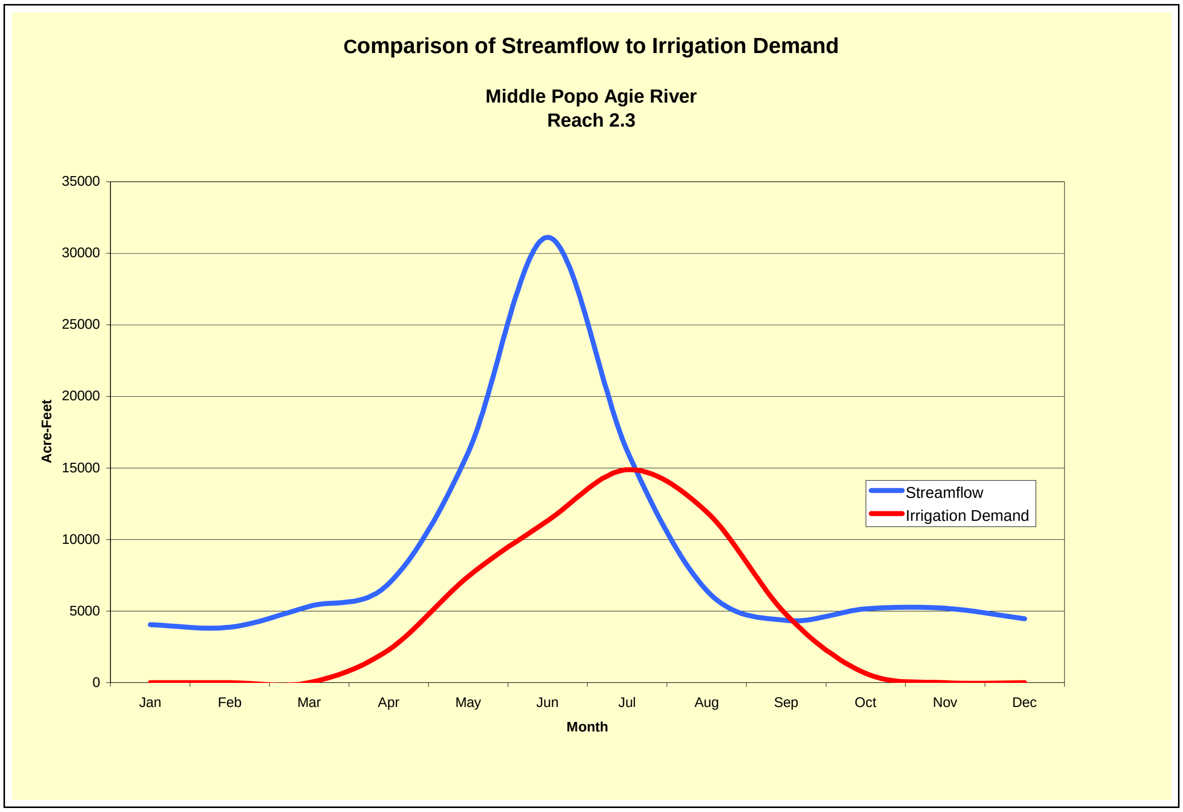


Figure 7.7 Typical Relationship between Streamflow and Irrigation Demand.

- Cost Estimates: Costs of dam construction were estimated using techniques consistent with the previous investigations. The estimates are intended to represent "order of magnitude" costs of the dam and associated infrastructure. They do not include costs associated with land acquisition, permitting, etc. Assuming all dams are earth-fill type structures, a cost of $15 per cubic yard of embankment material was used. These costs were then normalized by computing the cost per acre-foot of storage volume.

Table 7.3 presents a summary of potential storage site characteristics. This table includes quantification of conceptual dam configuration (length, height, and volume), storage volume, and surface area at full capacity. Table 7.4 summarizes the hydrologic aspects of each site. For each potential reservoir location, the available flow is tabulated for the average dry, normal and wet years for both the Existing and Future Conditions scenarios. Location maps of each site are included in Appendix D.

Table 7.3 Summary of Available Flows at Potential Reservoir Sites.

Basin	Site Number	Site Name	Source	Storage Volume (ac-ft)	Available Flow: Existing Water Rights (ac-ft)			Available Flow: Future Projects (ac-ft)		
					Dry	Normal	Wet	Dry	Normal	Wet
NORTH	18	North Popo Agie	North Popo Agie	22,850	17,100	58,400	104,200	6,200	42,200	72,500
	28	Surrel Creek No. 1	North Popo Agie	3,880	17,100	58,400	104,200	6,200	42,200	72,500
MIDDLE	1	Baldwin - Farlow	Baldwin Creek	2,000	1,200	3,000	5,400	1,200	3,000	5,400
	5	Crooked Creek - Elderberry	Crooked Creek	2,600	1,000	2,200	4,000	1,000	2,200	3,900
	6	Crooked Creek - Meyer Basin	Crooked Creek	5,680	2,400	4,300	7,100	2,400	4,100	6,800
	9	Hornecker - Borner	Middle Popo Agie	3,800	46,300	87,900	139,700	46,300	87,900	139,700
	16	Middle Popo Agie - Mid Valley	Middle Popo Agie	29,640	46,300	87,900	139,700	46,300	87,900	139,700
	17	Middle Popo Agie - Roaring Fork	Middle Popo Agie	22,260	46,800	72,300	119,100	39,100	74,800	119,100
	24	Sawmill Creek - Neff Park	Sawmill Creek	6,440	3,000	5,300	8,600	3,000	5,300	8,600
	25	Sawmill Creek - Fossil Hill	Sawmill Creek	4,000	12,500	18,400	26,700	12,500	18,400	26,700
	27	Smith Creek	Middle Popo Agie	9,840	12,500	18,400	26,700	12,500	18,400	26,700
	30	Thompson Creek	Middle Popo Agie	10,260	46,300	87,900	139,700	46,300	87,900	139,700
	33	Worthen Meadows Reservoir	Roaring Fork	450	800	5,400	11,400	800	5,500	11,400
LITTLE	3	Canyon Creek	Canyon Creek	1,395	100	800	2,600	100	800	2,600
	11	Little Popo Agie - Onion Flats	Little Popo Agie	9,000	24,400	50,800	78,800	24,400	50,800	78,800
	12	Little Popo Agie - Red Canyon	Little Popo Agie	5,880	24,400	50,800	78,800	24,400	50,800	78,800
	13	Little Popo Agie - Twin (No. 53)	Little Popo Agie	4,600	24,400	50,800	78,800	24,400	50,800	78,800
	14	Little Popo Agie - Lyons	Little Popo Agie	9,776	26,500	55,400	85,500	26,500	55,400	85,500

Table 7.4 Reservoir Site Evaluation Summary Matrix.

Basin	Site Number	Site Name	Category	Source	Flow Augmentation	Irrigtion Storage	Location	Flood Control	Cost Factor	Storage Volume (ac-ft)	Cost	
											Construction	$/ac-ft
NORTH	18	North Popo Agie	2	North Popo Agie	Yes	Yes	No	No	No	22,850	$ 83,926,000	$ 3,670
	28	Surrel Creek No. 1	2	North Popo Agie	Yes	Yes	No	No	Yes	3,880	$ 3,885,000	$ 1,000
MIDDLE	1	Baldwin - Farlow	2	Baldwin Creek	Yes	Yes	No	No	No	2,000	$ 7,459,000	$ 3,730
	5	Crooked Creek - Elderberry	4	Crooked Creek	Yes	Yes	Yes	No	No	2,600	$ 12,741,000	$ 4,900
	6	Crooked Creek - Meyer Basin	2	Crooked Creek	Yes	Yes	Yes	No	Yes	5,680	$ 6,912,000	$ 1,220
	9	Hornecker - Borner	2	Middle Popo Agie	Yes	Yes	No	No	No	3,800	$ 13,741,000	$ 3,620
	16	Middle Popo Agie - Mid Valley	2	Middle Popo Agie	Yes	Yes	Yes	Yes	Yes	29,640	$ 43,680,000	$ 1,470
	17	Middle Popo Agie - Roaring Fork	4	Middle Popo Agie	Yes	Yes	Yes	Yes	Yes	22,260	$ 36,540,000	$ 1,640
	24	Sawmill Creek - Neff Park	4	Sawmill Creek	Yes	Yes	Yes	No	Yes	6,440	$ 11,696,000	$ 1,820
	25	Sawmill Creek - Fossil Hill	4	Sawmill Creek	Yes	Yes	Yes	No	No	4,000	$ 31,970,000	$ 7,990
	27	Smith Creek	2	Middle Popo Agie	Yes	Yes	No	No	Yes	9,840	$ 5,987,000	$ 610
	30	Thompson Creek	2	Middle Popo Agie	Yes	Yes	Yes	No	No	10,260	$ 32,050,000	$ 3,120
	33	Worthen Meadows Reservoir	3	Roaring Fork	Yes	Yes	Yes	No	Yes	450	$ 800,000	$ 1,780
LITTLE	3	Canyon Creek	4	Canyon Creek	Yes	Yes	Yes	No	No	1,395	$ 3,483,000	$ 2,500
	11	Little Popo Agie - Onion Flats	2	Little Popo Agie	Yes	Yes	Yes	No	Yes	9,000	$ 8,592,000	$ 950
	12	Little Popo Agie - Red Canyon	2	Little Popo Agie	Yes	Yes	Yes	No	Yes	5,880	$ 4,204,000	$ 710
	13	Little Popo Agie - Twin (No. 53)	2	Little Popo Agie	Yes	Yes	Yes	No	Yes	4,600	$ 1,944,000	$ 420
	14	Little Popo Agie - Lyons	2	Little Popo Agie	Yes	Yes	Yes	No	No	9,776	$ 37,659,000	$ 3,850

Chapter 8

ON-FARM IMPROVEMENTS

8.1 Introduction

On-farm water conservation offers significant potential improvement of water use within the Popo Agie River basin. Furthermore, many of the on-farm improvements identified to conserve water may also serve to improve water quality by reducing contamination from nonpoint sources. Both structural and non-structural conservation measures are identified and discussed in the following sections.

As previously discussed, irrigation within the Popo Agie River basin is heavily dominated by conventional flood irrigation methods. When compared with alternative methods, flood irrigation is one of the most inefficient application methods in terms of irrigation efficiency. According to literature values, the application efficiency of flood irrigation is between 40 and 60 percent. Assuming that an average efficiency is approximately 50 percent, twice the amount needed by the crop must be applied just to sustain its growth. This implies that approximately half of the water applied to the crop is lost to deep percolation, runoff, or evaporation. Given the low efficiency in conjunction with the extensive irrigated acreage within the basin, the consideration of on-farm improvements to conserve water merits further investigation.

In the following sections, the various improvements are briefly discussed and their benefits and costs presented. To facilitate a comparative analysis of alternative application methods, a model farm was developed and water requirements computed as if the farm were irrigated using each of the methods. For the purposes of this investigation, the model farm was assumed to consist of a 120-acre parcel and a cropping pattern consisting entirely of alfalfa. The crop consumptive use, on-farm delivery requirement, and ditch diversion requirement were computed using the methods previously presented in Chapter 6.

8.2 Irrigation Methods

There are many irrigation methods, which could be implemented in the basin in an attempt to improve overall efficiency. For the purposes of this investigation, the methods evaluated were:

- center pivot and lateral move sprinkler systems;
- side roll sprinkler systems;
- surge valve furrow systems;
- gated pipe;
- LEPA sprinkler systems; and
- information based irrigation systems.

It should be noted that selection of an irrigation system is dependent upon many factors including field configuration, topography, water source, crop, soils, etc. In this chapter, various irrigation alternatives are discussed under the assumption that conversion to the particular improvement would be feasible. Site-specific evaluations would be required before implementation. Consequently, the various irrigation system improvements discussed herein are provided for the purpose of demonstrating potential conservation savings. Water use on a model farm was computed for each of the irrigation application alternatives. To keep the analysis relatively simple, the farm was assumed to be a 120-acre field of alfalfa supplied by a ditch system experiencing approximately 25 percent conveyance losses. Based upon an annual crop consumptive use of approximately 23 inches, the annual crop irrigation requirement would be approximately 230 acre-feet. Assuming a flood irrigation efficiency of 50 percent, the on-farm delivery requirement becomes 460 acre-feet with conveyance losses of 25 percent, the annual diversion requirement, at the headgate, would be approximately 613 acre-feet.

8.2.1 Center Pivot and Lateral Move Sprinkler Systems

Typical center pivot systems and lateral move systems consist of low-pressure sprinklers with or without end guns (Figure 8.1). The self-propelled sprinkler systems can be equipped with sprinklers either on top of the system or on drop-tubes allowing them to be placed closer to the crop. The center pivots rotate

Figure 8.1 Center Pivot Sprinkler System with End Gun (Photo NRCS).

around a central pivot point as opposed to the lateral move system where all towers move at the same speed and direction, rendering them more practical for rectangular fields. Water application amounts are controlled by the speed of the system.

According to information provided by the NRCS, the cost of implementing a typical center pivot (1/4 mile in length and irrigating approximately 120 acres) would be approximately $65,000. Similarly, the cost of construction for a lateral move system would be approximately $85,000 for a similar area.

There are currently newer and possibly more versatile systems on the market, which may be more applicable for Lander area irrigated acreage than the larger systems discussed above. Smaller systems (mini-pivots) capable of irrigating approximately 40 acres are available which can be towed from one field to another. A mini-pivot capable of irrigating 40 acres would cost approximately $24,000. Assuming three mini-pivots could be required for the model 120-acre forum, the price is commensurate with the larger system. However, the mini-pivots would likely be more applicable to much of the area's irrigated acreage. If irrigation scheduling enabled an irrigator to tow a mini-pivot to multiple fields, the costs associated with this alternative would be reduced accordingly. Conservation savings would be commensurate with the traditional center pivot systems, however, operation and maintenance would require greater labor.

Application efficiencies associated with typical systems typically range from 75 to 90 percent. For the purposes of this study, an average application efficiency of 80 percent was assumed. If the model farm were converted to a center pivot system, the ditch diversion requirement would be approximately 383 acre-feet for the same period. This translates to a conservation savings of approximately 230 acre-feet, as measured at the headgate, at a cost of approximately $252 dollars per acre-foot. Likewise, conversion of the same farm to a lateral move system would result in a similar conservation savings at a cost of approximately $370 per acre-foot.

8.2.2 Gated Pipe

Gated pipe irrigation is a type of surface irrigation in which the conventional main ditch and field lateral ditch are replaced by an above ground pipeline and gated pipe (Figure 8.2). Irrigation water flows from gates that are regularly spaced alone the pipeline. A considerable amount of gated pipe has been installed in recent years within the Popo Agie

Figure 8.2 Gated Pipe Irrigation Application (Photo NRCS).

River watershed. This is partly due to a cost share program sponsored by the Popo Agie Conservation District. Increased efficiency associated with gated pipe is associated with reduced seepage and evaporation losses within the on-farm conveyance and distribution system. Gated pipe also reduces labor associated with field irrigation. According to the NRCS, irrigation efficiency increases with implementation of gated pipe within the study area can be expected to be on the order of five to ten percent.

According to local irrigation supply sources, the cost of installing a typical gated pipe irrigation system on a farm of 120 acres would be approximately $25,000 to $30,000. These figures include consideration of typical topography in the Lander area that generally precludes rectangular fields. Cost of gated pipe varies greatly. At the time of this report, 10-inch diameter gated pipe sold for approximately $2.75 per linear foot. As previously discussed, an existing 120 acre parcel utilizing conventional furrow irrigation methods would require approximately 460 acre-feet at the farm (613 acre-feet at the headgate) to grow alfalfa. If that same farm were converted to flood with gated pipe distribution, the ditch diversion requirement would be approximately 558 acre-feet assuming 55 percent application efficiency. This translates to a conservation savings of 55 acre-feet at a cost of approximately $545 dollars per acre-foot.

8.2.3 LEPA Sprinkler Systems

Low Energy Precision Application (LEPA) combines a mechanical irrigation system (center pivot or lateral move sprinkler system) with soil surface management to promote retention and efficient use of all water received, including rainfall (Rogers, et al., 1994). LEPA systems operate at lower pressures than other types of low-pressure systems and the nozzles minimize spray and drift by producing a highly efficient bubble pattern. True LEPA heads can also produce a horizontal spray and chemigation spray mode. By placing the LEPA nozzles close to the ground, wind drift loss and evaporation are minimized (Figure 8.3).

Figure 8.3 LEPA Sprinkler Irrigation System.

The American Society of Agricultural Engineers has proposed the following definition for LEPA.

"To qualify as LEPA, the system shall:

- Be an overhead tower supported pipeline system capable of either linear of pivotal movement;
- Be capable of conveying and discharging water into a single crop furrow;
- Discharge water very near to, or on, the soil surface to negate evaporation in the air;
- Operate with mainline end pressure no greater than 10 psi when the end tower is at the highest field elevation;
- Position the conveyance and discharge devices so that each plant within a field is approximately equidistant from an applicator and has equal opportunity for irrigation and water delivery; and
- Combine soil surface management and the operation of the mechanical LEPA system so zero runoff occurs from the irrigation water application point and rainfall retention is maximized."

According to information provided by the NRCS, implementation of a LEPA system would require approximately $84,000 for a 120-acre system. This value includes an estimated cost of approximately $75,000 for the sprinkler system and $9,000 for associated land leveling. As discussed in Chapter 6, irrigation application efficiencies for LEPA systems typically range between 80 and 95 percent. For the purposes of this study, an average value of 90 percent was assumed. As previously discussed, the 120-acre model farm utilizing conventional furrow irrigation methods requires approximately 613 acre-feet per season at the ditch headgate. For the purposes of comparison, the same 120-acre farm under LEPA irrigation systems would require approximately 341 acre-feet at the headgate, resulting in a conservation savings of approximately 272 acre-feet at a cost of approximately $309 per acre-foot.

8.2.4 Surge Irrigation Systems

Surge irrigation systems were developed by Utah State University researchers investigating methods of reducing water requirements in furrow systems through automation. Briefly, surge irrigation works by alternating "surges" of water down furrows of irrigation sets until the water reaches the end of the furrow. The time interval is then cut back to shorter intervals to reduce runoff. Once the furrow is wetted, a surge of water can travel farther down the furrow more uniformly. Furrow irrigation efficiencies can be improved from 10 to 40 percent with the use of surge valves (Figure 8.4).

Unit costs of implementing a surge valve into an existing furrow system will vary with the size of the field it will control. To a certain extent, a farmer can irrigate a large range in field sizes with the same surge infrastructure. According to information provided by the NRCS, the cost of integrating a surge valve system into an existing irrigated field, would be approximately $45,000 for a 120-acre field including the gated pipe.

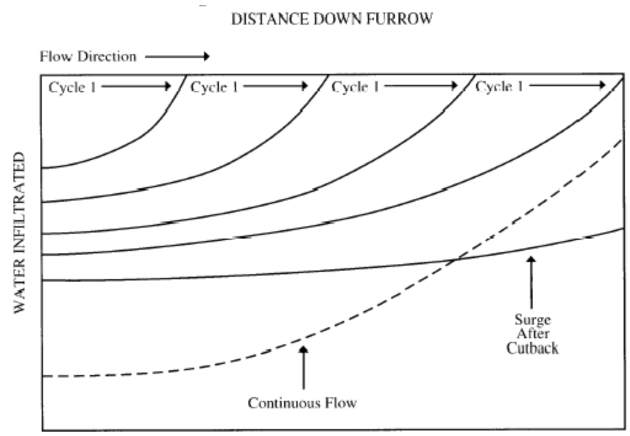


Figure 8.4 Potential Infiltration Patterns for Surge and Continuous Flow Irrigation.

As discussed in Chapter 6, irrigation application efficiencies for surge systems typically range between 70 and 90 percent. For the purposes of this study, an average value of 70 percent was assumed. For the purposes of comparison, if the 120-acre model farm were irrigated under a surge irrigation system, the delivery requirement would be reduced to approximately 329 acre-feet at the farm or 438 acre-feet at the headgate. Consequently, the system yields conservation savings of approximately 175 acre-feet at the headgate a cost of approximately $257 per acre-foot.

8.3 Information-Based Irrigation Scheduling

The determination of the quantity and timing of irrigation deliveries plays a significant role in the conservation of irrigation water supplies. Historically, irrigators have determined their crop water requirements based primarily on their own experience and instinct. Given the programs that presently exist, there is potential for significant water savings by implementation of more precise irrigation scheduling techniques.

Recently, the USDA Agricultural Research Service (ARS) completed a 10-year study on a 4,200-acre farm in Kansas. The study concluded that farmers who use scheduling programs apply about 20 percent less water than those who water when their crops “look thirsty” (DeQuattro, 1997). To obtain information that is more locally applicable, ARS representatives in Fort Collins, Colorado were contacted. According to the ARS, they have conducted extensive research in the area of irrigation scheduling. They have found that the savings, in terms of water conserved and energy reductions, are real but difficult to quantify. One reason for this is that when an irrigator uses an information-based irrigation scheduling system on a demonstration field, his scheduling on other fields is influenced. Another reason savings are difficult to quantify is that they are, in part, a function of the irrigator's previous practices. In a region where water has been limited, savings from information-based irrigation scheduling will not be as great as in areas where water is more plentiful because the irrigator has already been applying water judiciously. According to ARS experience, water conservation savings are typically in the range of 25 to 35 percent when the methods are applied on lands where there were previously no scientifically-based scheduling practices (Dale Heermann, USDA ARS, personal communication).

Information-based irrigation scheduling allows the irrigator to schedule irrigation based upon the measured, or computed needs of the crops. This technique involves monitoring of soil moisture and/or weather-based information (crop evapotranspiration data). Soil moisture can be monitored in many ways. Subsurface soil samples can be taken and visually inspected to estimate the moisture status. Soil moisture can be estimated with mechanical devices such as tensiometers or with electrical resistance devices such as gypsum blocks that rely on the change in electrical conductivity of water in the device. A neutron probe, another moisture-sensing device, measures the amount of neutrons reflected from water molecules in the soil.

Crop ET estimates are developed using either evaporation pans or weather information. Class A evaporation pans are commonly used for measuring evaporation. The pans, constructed of galvanized steel or aluminum, are situated in the center of a large irrigated turf area. The pan station includes devices to measure rainfall, temperature, wind speed, and relative humidity. Evaporation is measured by monitoring the change in height of the water in the pan. The evaporation readings are multiplied by crop coefficients to estimate ET of a specific crop.

The soil moisture and ET data are utilized independently, or in conjunction with each other, in a "checkbook" accounting method. By tracking the daily or weekly crop water use (ET) and precipitation, the irrigator can estimate soil moisture with the "checkbook" through simple addition. If soil moisture is measured, the method is calibrated and more accurate data are provided. Over the course of an irrigation season, the irrigator can become accustomed to his crop's response to irrigation applications, precipitation, etc.

In recent years, a large number of regional automated weather station networks have been established. Weather data are collected daily from network weather stations and automatically transmitted to a central computer. The weather data (solar radiation, temperature, relative humidity, and wind speed) are used in irrigation scheduling to estimate crop evapotranspiration. These networks are currently in use throughout the country, including numerous in the Rocky Mountain Region. Unfortunately, coverage has not been implemented extensively in Wyoming. An existing network that offers potential, however, is the AgriMet system managed by the United States Bureau of Reclamation (BOR). It includes 54 agricultural weather stations located throughout the northwest (Figure 8.5). The system allows the user to obtain daily crop evapotranspiration data from any station via the Internet. According to the AgriMet network administrator, incorporation of additional weather stations is a very simple task. If a weather station (or stations) were established within the basin, the BOR would likely be able to incorporate the data into their Internet-based system, making the data available to the public with only minor expenses (T. Grove, USBR, personal communication).

Figure 8.5 Typical AgriMet Weather Station (Photo USBR).

The potential benefits of using the AgriMet network are numerous. Through the purchase and implementation of a weather station(s), the PACD could take advantage of an existing system, which is already operational. Data would be accessible through the BOR's computer system; consequently, there would be no need for the PACD to purchase a centralized computer to collect and distribute the data. Furthermore, there would be no need to purchase the associated software and programming needed for the system. Although an agreement with the BOR would need to be worked out for use of their system, annual maintenance costs of the system would likely be limited to maintenance of the weather station(s).

Assuming full implementation of an irrigation-scheduling system, the potential to conserve water within the basin could be substantial. As a minimum, two weather stations may be necessary for the basin. The cost associated with installation of two weather stations is estimated to be $15,000 to $20,000.

Assuming information-based irrigation scheduling results in an increase in application efficiency of 10 percent, the on-farm delivery requirement becomes 383 acre-feet and the headgate delivery is reduced to 511 acre-feet or a savings of 102 acre-feet. The cost per acre-foot of savings is $196.

It should be noted, however, that widespread acceptance and utilization of information-based irrigation scheduling may require several years of demonstrated benefits.

8.4 Subsurface Drip Irrigation (SDI)

Subsurface drip irrigation (SDI) is a low-pressure, low-volume irrigation system that uses drip tubes buried below the soil surface. The system facilitates the subsurface application of water aimed directly at the root zone and improves yields by reducing the incidence of disease and weeds. While previously applied primarily to high-value fruit and vegetable crops, current research has shown its applicability to a wider range of crops, including alfalfa. Alfalfa regrowth after a cut may be encouraged by subsurface irrigation without allowing shallow-rooted weeds to emerge. Research shows the yield and quality of produce improves with a buried drip system. Normal life expectancy of a system is 12 to 15 years (Colorado State University Cooperative Extension). Costs of implementing an SDI system will vary greatly depending upon topography, parcel configuration, soil types, water quality and filtration requirements. Installation costs reportedly range from $600 to $1,500 per acre.

For the purposes of comparison, if the 120-acre model farm were irrigated under a SDI system, the annual ditch diversion requirement would be reduced to approximately 323 at the headgate assuming application efficiency of 95 percent. Consequently, the system yields conservation savings of approximately 290 acre-feet at the headgate a cost of approximately $248 to $621 per acre-foot depending upon farm-specific conditions.

8.5 Summary

Given the extent of irrigated lands within the study area and the current domination of irrigation by conventional flood methods, there is a demonstrated potential for conservation savings. Significant improvements in water management have been completed in recent years. Irrigators facing water shortages, even in normal years, are striving to make better use of available flows by improving conveyance systems and irrigation methods. Recent programs sponsored by the PACD have helped drive the implementation of gated pipe throughout the basin. There are relatively few sprinkler irrigation systems, and to our knowledge, there are no surge irrigation systems installed to date.

It is important to keep in mind that this evaluation represents a simple comparison of various irrigation methods. Costs presented herein represent capital costs associated with each system; they do not include costs of operation and maintenance. Consequently, the costs associated with conservation savings are intended to represent potential figures under ideal conditions. Upon evaluation of site-specific farm conditions, costs may increase.

It is also important to recognize that on-farm irrigation measures not only make better use of water available at the farm turnout, but they can also be translated to conservation savings at the ditch headgate. For every acre-foot of water delivered at the turnout, up to 1.3 acre-feet are required to be diverted at the headgate assuming twenty five percent conveyance losses. Table 8.1 summarizes the results of the model farm comparisons presented in this section. In addition to reductions in on-farm delivery requirements, this table also shows the reductions at the ditch headgate, which would be associated with each of the on-farm improvements.

Table 8.1 Comparison of Potential Irrigation Conservation Savings Associated with Various On-Farm Improvements.

Farm Model	Irrigation Efficiency (percent)	Crop Irrigation Requirement (acre-feet)[1]	On-Farm Delivery Requirement (acre-feet)	Ditch Diversion Requirement (acre-feet)[2]	Savings in Relation to Conventional Flood (acre-feet)	Savings in Relation to Conventional Flood (percent)
Flood	50%	230	460	613	N/A	N/A
Gated Pipe	55%	230	418	558	55	9%
Flood w/ IBIS	60%	230	383	511	102	17%
Sprinkler	85%	230	288	383	230	37%
LEPA	90%	230	256	341	272	44%
Surge	70%	230	329	438	175	29%
Subsurface Drip	95%	230	242	323	290	47%

[1] Assumes a model farm of 120 acres, growing Alfalfa with a CIR of 23 inches

[2] Assumes ditch losses of 25 percent

Watershed Management and Irrigation Rehabilitation Plan

Chapter 9

9.1 Introduction

As stated previously, the objective of this study is to generate a watershed management and irrigation rehabilitation plan that is not only technically sound, but also one that is practical and economically feasible. Formulation of the plan also includes providing the Popo Agie Conservation District with the data required to facilitate the planning process and make informed decisions regarding potential mitigation of several key issues/problems that presently exist within the watershed. The key issues/problems that were previously identified are summarized below:

- Augmentation of the low flows within various reaches of the Popo River system.
- Mitigation of flooding within the Popo Agie River watershed.
- Monitoring potential changes in water quality within the watershed.
- Mitigation of impaired reaches within the Popo Agie River watershed that presently experience problems with channel stability/degradation.
- Limited supplies to satisfy the needs of agricultural, municipal and industrial uses within the watershed (i.e., over-appropriation of water supply within the watershed).

In conjunction with the development of a database for the watershed, the investigative phase of this study focused on an assessment of the watershed and the identification and evaluation of improvements to address those issues/problems described above. Potential improvements were developed and categorized into the following:

- Irrigation System Conservation and Rehabilitation. The inventory and evaluation of the existing infrastructure was completed and improvements identified for the rehabilitation of existing structures and the potential conservation of existing irrigation diversions.
- Stream Channel Condition and Stability. Stream channels within the watershed were characterized with respect to their condition and stability. Impaired channels were identified for further evaluation and alternative improvements developed.

- Storage Opportunities. Based on flow availability and site-specific topography, potential storage reservoirs were identified, screened and evaluated. Existing reservoirs were also investigated with respect to flow availability and the potential to increase existing storage capacity.

- On-farm Improvements. An evaluation of the potential conservation benefits associated with the implementation of various on-farm improvements was conducted.

- Water Quality. No specific improvements were identified for water quality. Sources of water quality data were identified and integrated into a GIS database. The database serves and a tool to track the benefits of potential improvements on the water quality within the watershed.

Watershed or irrigation rehabilitation plans have been developed for each category, with the exception of water quality, and have been presented in the previous chapters of this report. These plans have been prepared to provide an overview of potential improvements that can partially or fully address the key issues/problems identified within the watershed.

During the completion of this work effort, it became evident that the most severe problems with respect to the watershed were experienced within the Middle Popo Agie River. Due to the nature of the irrigation systems, the river appears to be over-appropriated with insufficient supplies to meet the needs of its water users. That is, under existing conditions, the demands exceed the supply during a normal year. These conditions exist to a lesser degree on the Little Popo Agie River and assuming a "Futures" condition, similar shortages may be expected on the North Popo Agie River. Flood control needs appear to be greater on the Middle Popo Agie River as well as augmentation of low flows. Consequently, the improvements earmarked for the watershed and irrigation management plan were prioritized to reflect an increased need in the Middle Popo Agie River, followed by the Little Popo Agie River and finally the North Popo Agie River.

In the remainder of this chapter, the individual plans developed and described in previous chapters are screened and further evaluated with respect to providing benefits to flood control and low-flow augmentation, and improving the existing water supply through conservation. The results of the geomorphic assessment are further refined to identify those impaired reaches that merit more immediate attention. With respect to irrigation rehabilitation, the plans prepared for each irrigation entity are further screened to identify those improvements that provide the most benefit considering the overall condition of the watershed. In summary, this chapter provides the PACD with a plan that can be used to guide future efforts to mitigate existing problems and enhance the water resources within the watershed

9.2 Irrigation System Rehabilitation Plan

The results of this work effort confirm information presented in previous reports that indicate the existing water supply from the watershed is not capable of fully meeting the requirements of all water users (irrigation, municipal, industrial, domestic, etc.), especially in the Middle Popo Agie River. Given that the majority of the water use within the watershed is associated with irrigation, it is reasonable to assume that irrigation will play a vital role in meeting the goals of conservation of the existing water supplies as well as augmentation of low flows.

A comprehensive list of irrigation rehabilitation improvements were provided in Chapter 5. While all improvements are worthy of consideration, several criteria and assumptions were developed to determine the improvements that provide the most benefit with respect to the goals and objectives of the study. These criteria and assumptions are itemized below.

- Rehabilitation of Existing Infrastructure. Irrigation plays an important role in the agricultural industry within the watershed. Facilities to divert and convey water for irrigation use must be property maintained and continue to function. Those facilities that have been identified as badly deteriorated or for which failure is imminent (less than 5 years remaining), are earmarked for rehabilitation and are included in the watershed management and irrigation rehabilitation plan.

- Water Measurement. Management of existing diversions is facilitated by accurate water measurement. In addition, quantification of potential conservation benefits will require measurement of diversions. Consequently, it is assumed that improvements to water measurement structures, where appropriate, will be integrated into the watershed management and irrigation rehabilitation plan.

- Conservation. Rehabilitation projects that provide for conservation of the existing water supplies were assumed to provide potential benefits to the watershed and were considered as high priority improvements. Incentives to encourage a reduction in the headgate diversions, commensurate with all or a portion of the conservation savings, would be required.

- Existing Storage. Those ditches that have storage facilities within the watershed were assumed to enhance the potential benefits associated with projects that provide for conservation.

- River Priority. Consistent with the information presented in Section 9.1, the irrigation systems diverting from the Middle Popo Agie River were prioritized first, followed by the Little Popo Agie River and the North Popo Agie River.

- <u>Protection of Reductions in Diversions.</u> To the extent that all or a portion of the conservation savings in irrigation rehabilitation projects result in a reduction in headgate diversions, it was assumed that these diversions could be "shepherded" downstream to the critical reaches where flow augmentation is desired. Due to the number of diversions along the river, cooperative agreements along with incentives will be necessary to provide a mechanism to facilitate the "shepherding" concept.

- <u>Ditch Location.</u> In view of the difficulties that may exist in arriving at system-wide cooperative agreements, the location of the ditch headgates along the river systems was reviewed. A ditch located immediately upstream of a critical reach poses the greatest potential opportunity for flow augmentation within that reach. Consequently, the ditches were ranked in order of their location in relation to the reaches identified for low flow augmentation. The ditch located immediately upstream was rated highest and the most remote (and consequently having the highest number of intervening ditches) was rated lowest. Assuming the critical reach of the Middle Popo Agie River is located immediately upstream of the City of Lander, this criteria would provide the Cemetery Ditch with the highest priority on the river system.

Based on these criteria and assumptions, the individual irrigation rehabilitation plans were evaluated and screened. The results of the screening effort are presented in Table 9.1. As indicated, rehabilitation efforts that provide the most benefit to the watershed appear to be related to the following ditch systems.

- Cemetery Ditch,
- Dutch Flat / Taylor Ditch,
- Enterprise Ditch,
- Gaylor Warnock Ditch.
- Nicol – Table Mountain Ditch, and the
- Wise Ditch

These systems are all located on the Middle Popo Agie River and upstream of the City of Lander with the exception of the Wise Ditch which is located on the lower Little Popo Agie River. Individual irrigation system rehabilitation improvements that meet the criteria and assumptions described above, are presented in Table 9.2. Figures 9.1 to 9.6 present the improvements recommended as part of the watershed management and irrigation rehabilitation plan.

Table 9.1 Irrigation System Screening Matrix.

Mainstem	Ditch System	Infrastructure Condition (1)	Measurement Capabilities (1)	Conservation Potential (1)	Existing Storage (2)	River Priority (3)	Relative Ditch Location (4)	Score (5)
North Popo Agie	Big Cottonwood Ditch	1	2	1	3	1	1	9
Middle Popo Agie	Cemetery Ditch	2	3	2	0	3	3	13
Middle Popo Agie	Dutch Flat - Taylor Ditch	2	3	2	0	3	3	13
Middle Popo Agie	Enterprise Ditch	3	3	3	3	3	1	16
Middle Popo Agie	Gaylor-Warnock Ditch	2	2	3	0	3	3	13
Little Popo Agie	Lyons Ditch	2	2	1	3	2	2	12
Middle Popo Agie	Nicol-Table Mountain Ditch	3	3	3	0	3	2	14
North Popo Agie	North Fork Ditch	1	2	1	3	1	1	9
Big Popo Agie	Snavely/Grant-Young Ditch	1	2	1	0	1	1	6
Little Popo Agie	Wise Ditch	2	2	2	3	2	3	14

Infrastructure / Measurement (1)

1 Lower need for improvement
2 Moderate need for improvement
3 High need for rehabilitation

Existing Storage (2)

0 Lands under ditch with no shares to existing storage
3 Lands under ditch with shares to existing storage

Score (5)

Low Score Less benefit to watershed
High Score Greater benefit to watershed

River Priority (3)

1 North Popo Agie
2 Little Popo Agie
3 Middle Popo Agie

Relative Ditch Location (4)

1 Remote from critical reach
2 Mid-range distance from critical reach
3 Immediately upstream of critical reach

Table 9.2 Irrigation Rehabilitation Plan Components.

Ditch System		Description
Cemetery Ditch		Rehabilitate Parshall Flume
		Install measurement devices at lateral split (2)
		Install measurement devices on 10 turnouts
		Line reach CD-c
		Install 2 wasteways / slide gates
Dutch Flat - Taylor Ditch		Replace Parshall Flume
		Repair geotextile liner
		Rehabilitate unstable ditch (GEI, 1984)
		Install measurement devices at approximately 31 farm turnouts
Enterprise Ditch		Install measurement device at Sawmill Creek headgate
		Install measurement device at Crooked Creek headgate
		Install pipe drop structure
		Replace drop structure/turnout
		Replace splitter box
		Rehabilitate Gabion drop structures (5)
		Install approximately 15 measurement devices at farm turnouts
		Line Reach ED-a (approx. 2,500 LF)
Gaylor Warnock Ditch		Rehabilitate Parshall Flume
		Install approximately 10 measurement devices at farm turnouts
		Line Reach GW-a (approx. 500 LF)
		Install inverted siphon - Option A
Nicol Table Mountain Ditch System	Nicol-Table Mountain Ditch	Replace diversion structure
		Replace headgate bypass
		Replace Parshall Flume
		Install inverted siphon at Frye Gulch
		Install approximately 12 measurement devices at farm turnouts
	North Lateral	Rehabilitate weir
		Install pipe drop structure (SCS)
		Install measurement devices (21)
		Line reaches of North Lateral (SCS) (approx. 3000 LF)
	Parker - McBride Lateral	Replace flume with inverted siphon (SCS)
		Install measurement devices (12)
		Line ten reaches on Parker McBride lateral as per SCS (approx. 4000 LF)
Wise Ditch		Rehabilitate Parshall Flume / stabilize banks
		Replace drop structure/turnout/hills stabilize ditch/lining
		Replace flume with inverted siphon
		Install approximately 10 measurement devices at farm turnouts
		Line Reach WD-a (approx. 1500 LF)

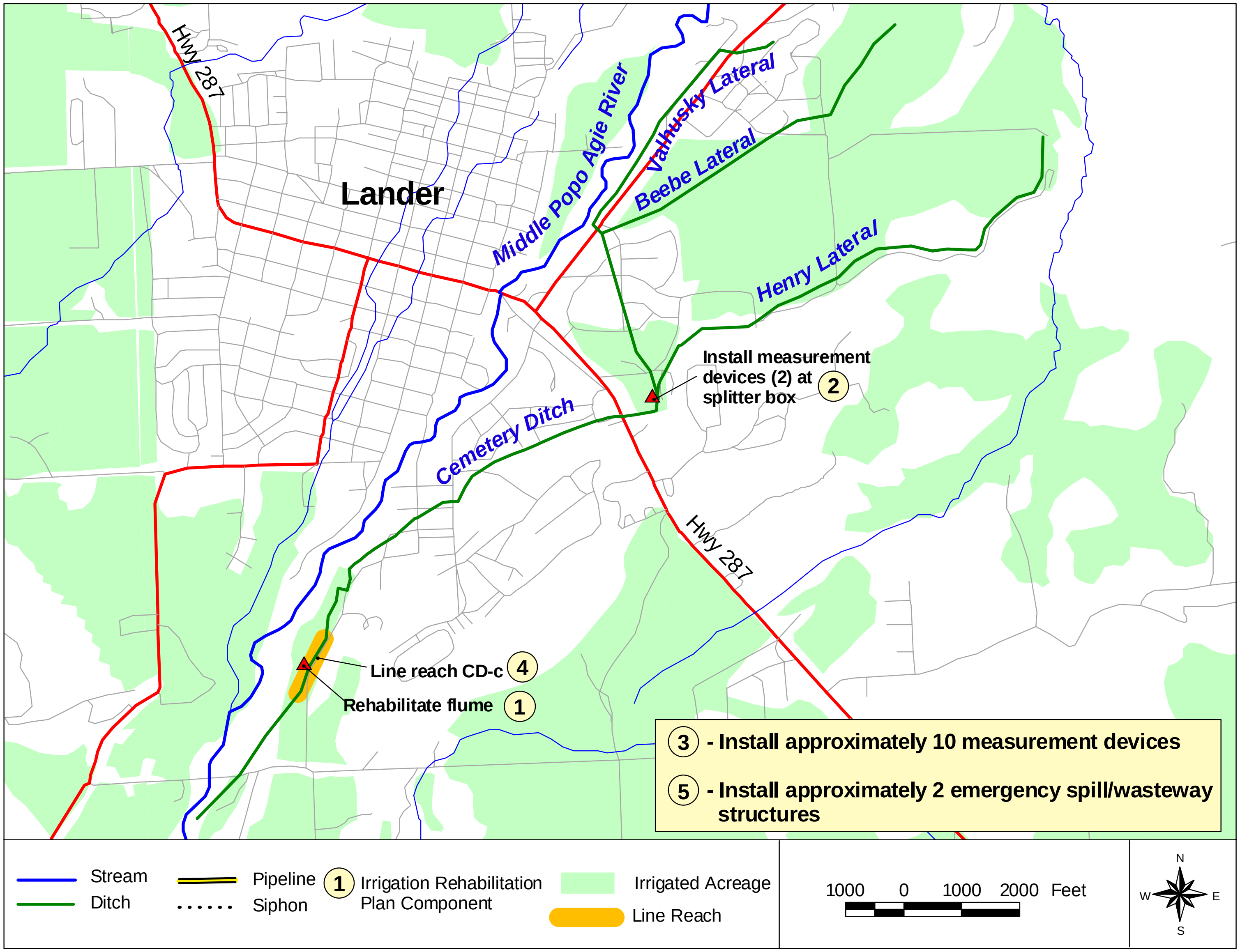


Figure 9.1 Irrigation Rehabilitation Plan: Cemetery Ditch.

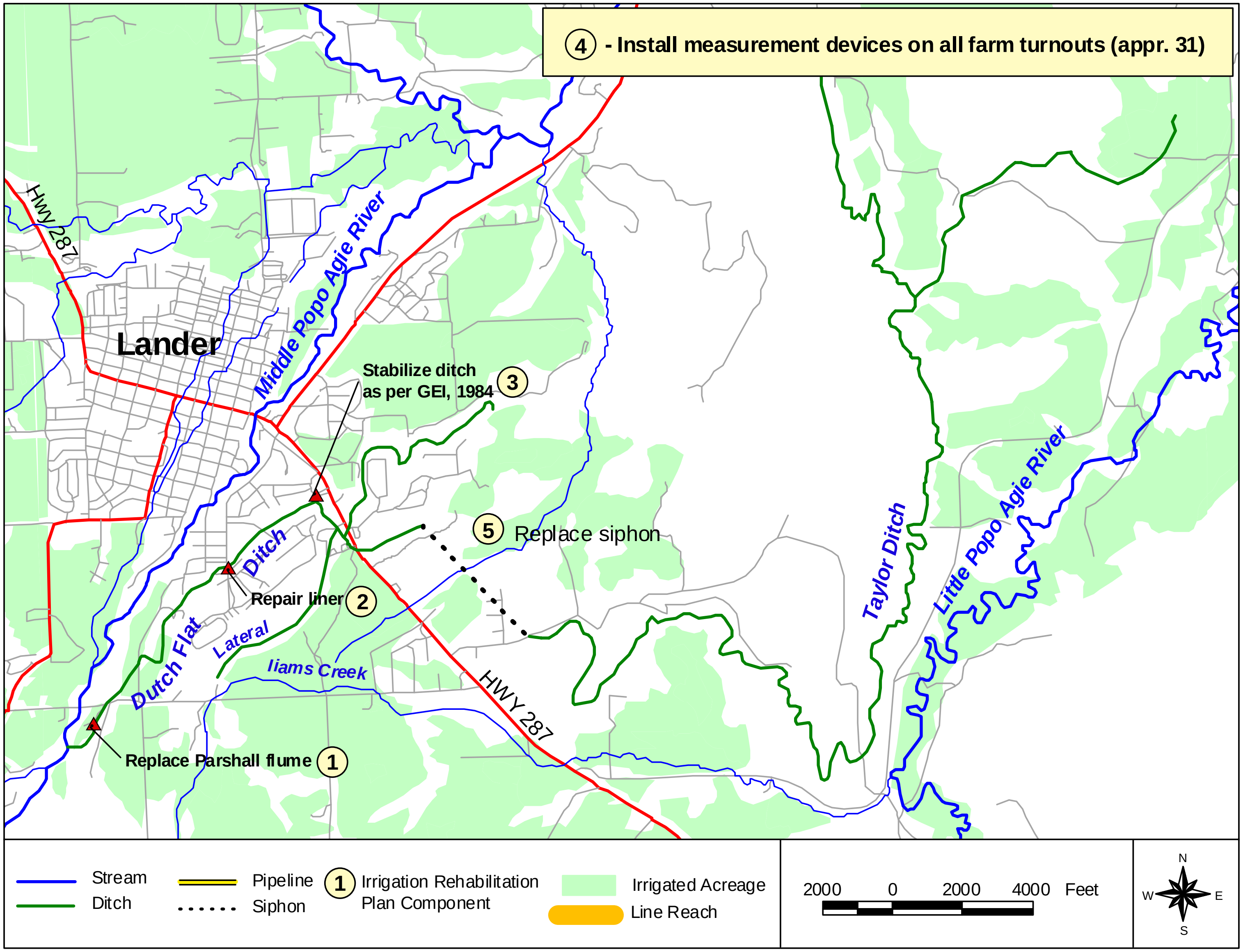


Figure 9.2 Irrigation Rehabilitation Plan: Dutch Flat / Taylor Ditch.

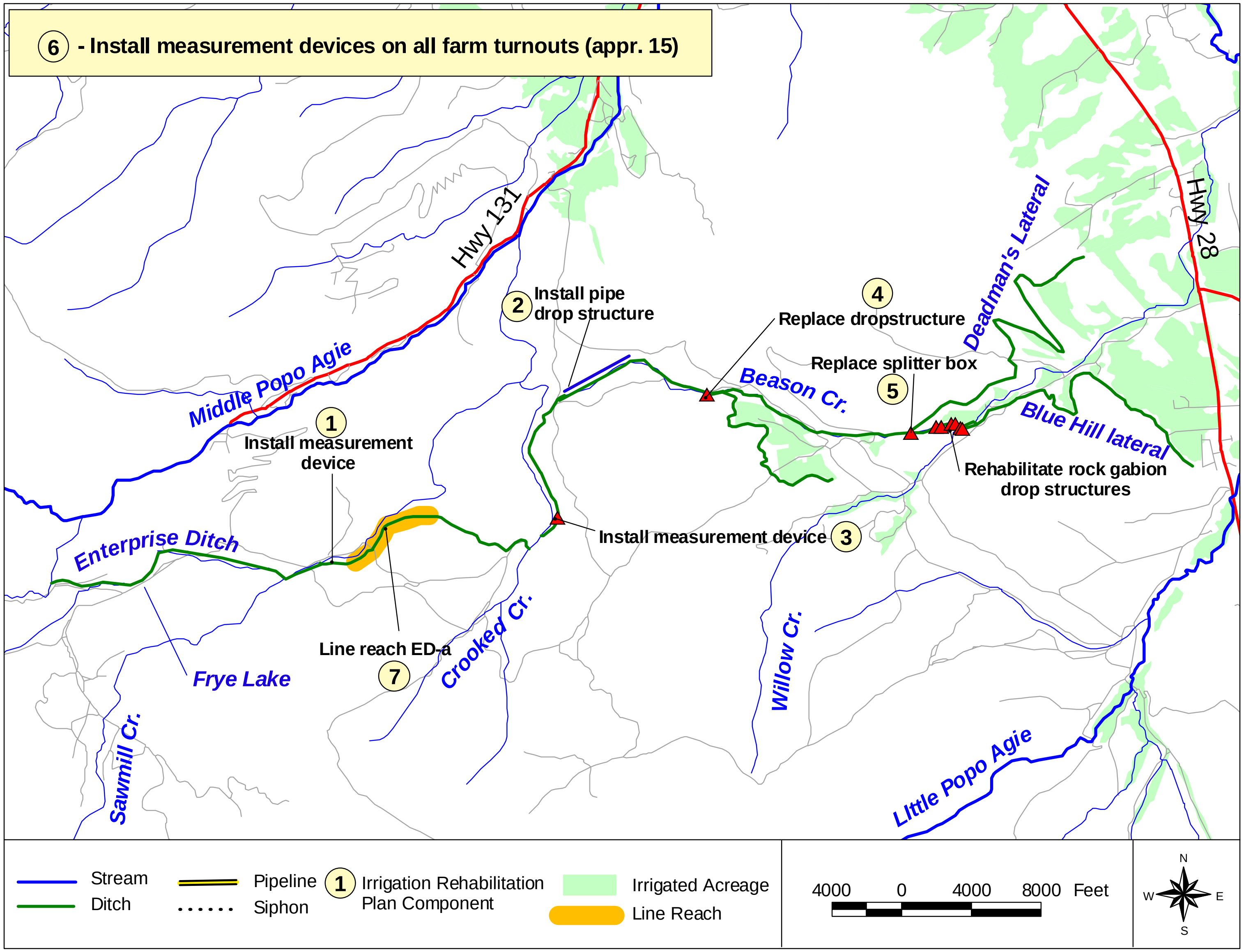


Figure 9.3 Irrigation Rehabilitation Plan: Enterprise Ditch.

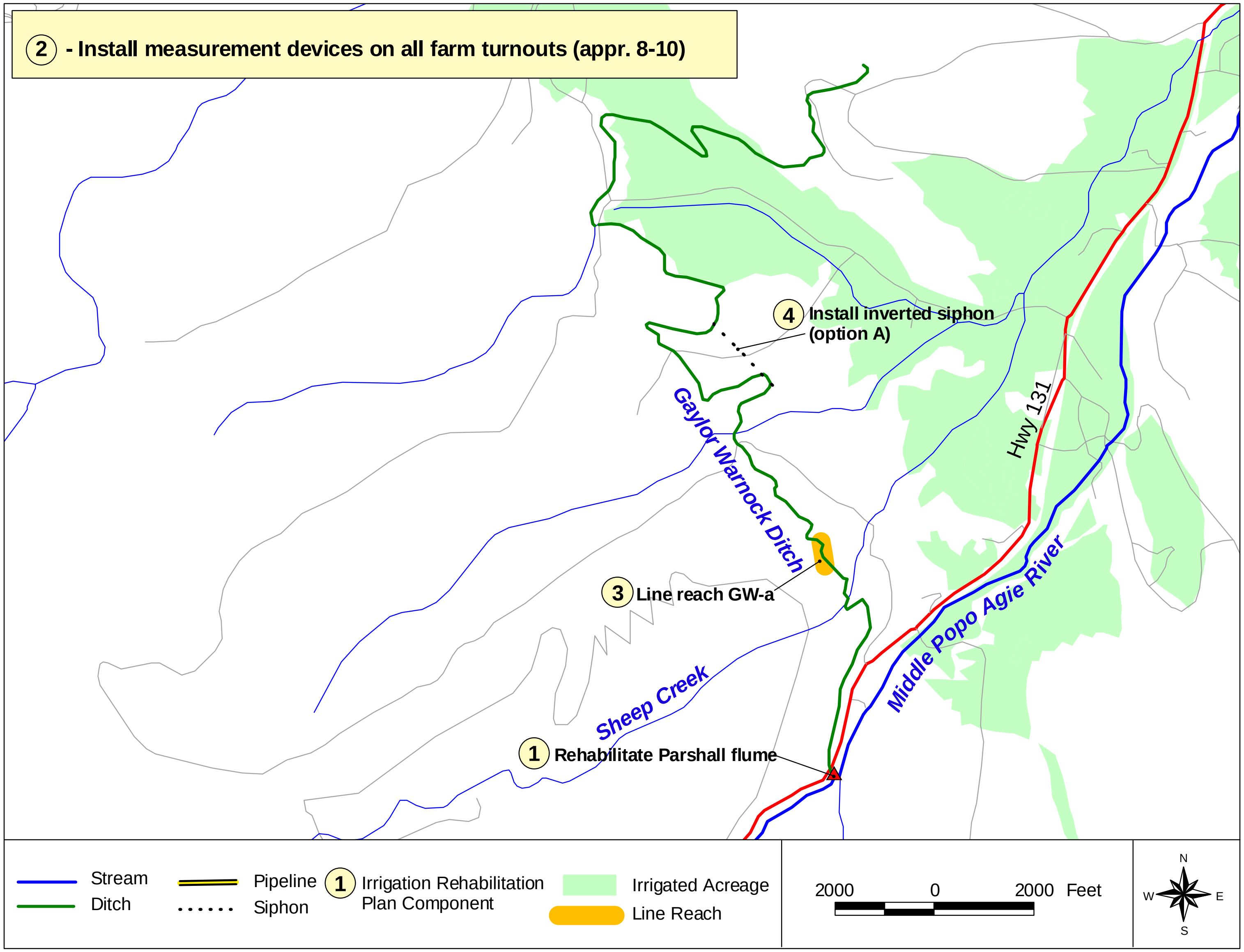


Figure 9.4 Irrigation Rehabilitation Plan: Gaylor Warnock Ditch.

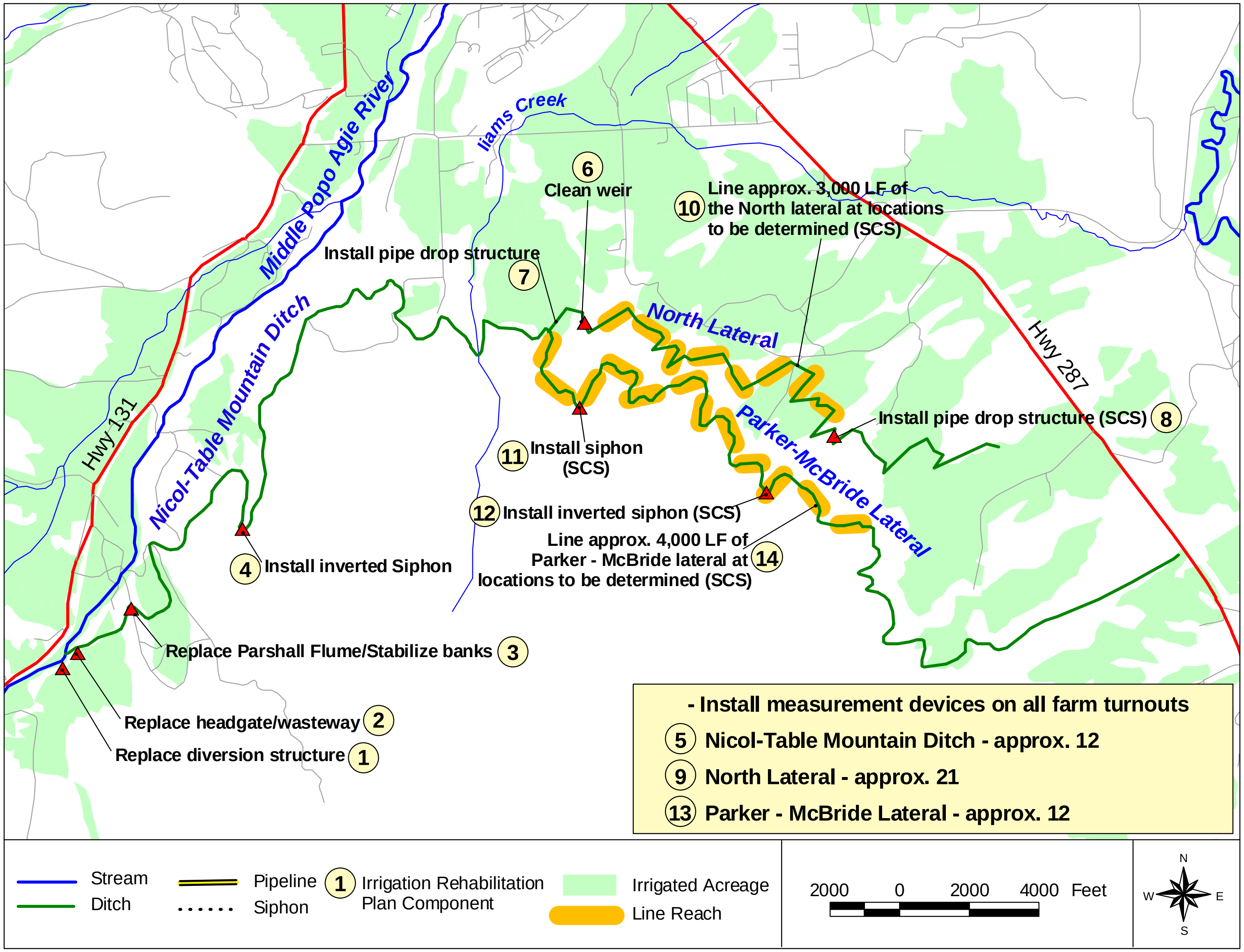


Figure 9.5 Irrigation Rehabilitation Plan: Nicol – Table Mountain Ditch.

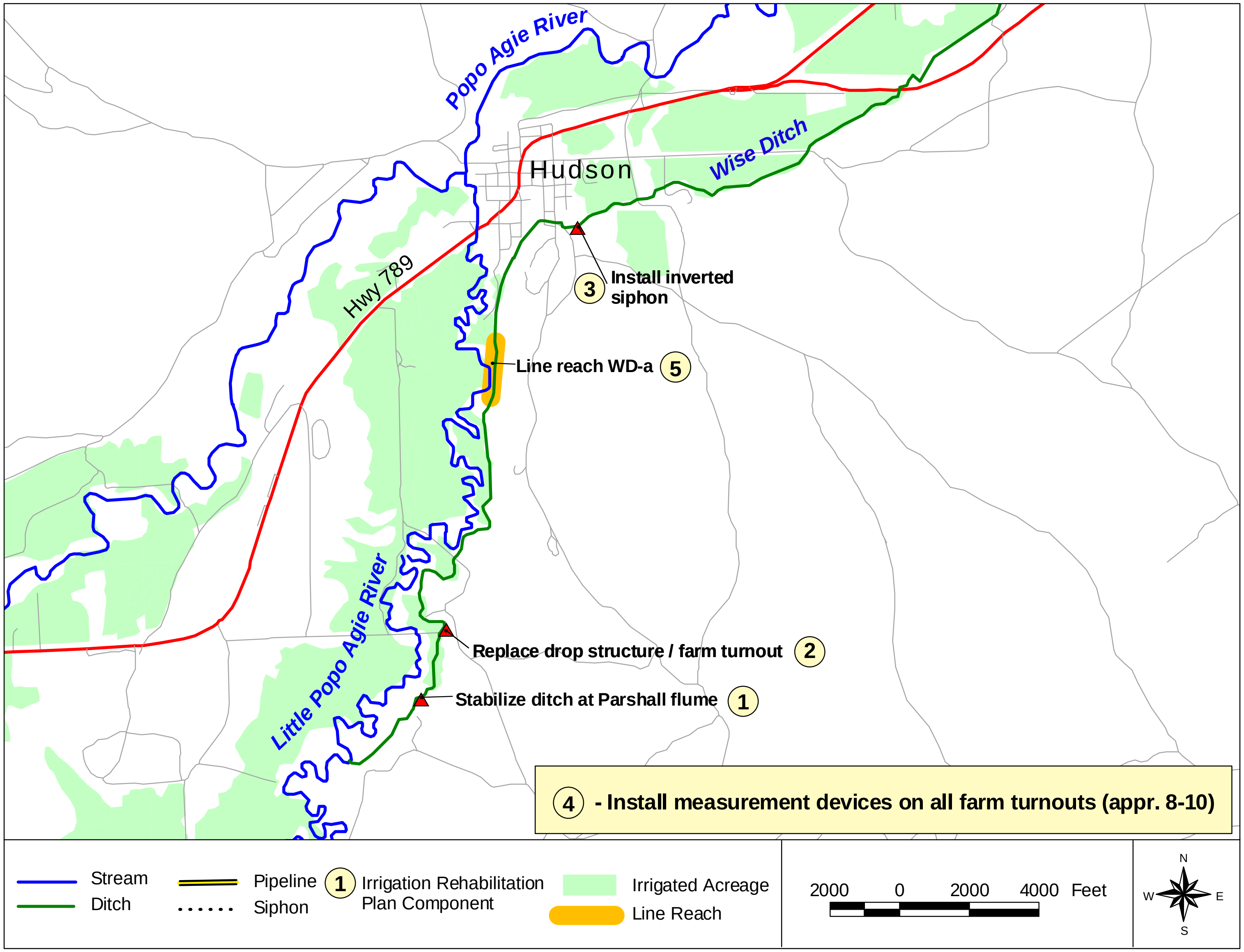


Figure 9.6 Irrigation Rehabilitation Plan: Wise Ditch.

9.3 Stream Channel Condition and Stability

The general condition of the principal river channels and primary tributaries were evaluated during the geomorphic investigation. Results of that study are presented in Chapter 4 of this report. During the evaluation of existing channel conditions, several impaired reaches were identified and four classes of impairments noted. The impairments were classified as indicated below:

- Riparian Vegetation. Loss of riparian condition and habitat due to grazing, crop encroachment, and loss of riparian buffers.
- Riparian Degradation. Bank erosion and channel lowering/downcutting.
- Channel Encroachment. Loss of floodplain access and existence of levees.
- Rigid Planform Control. Loss of meander capability and reduced sinuosity.

A comparative evaluation of the impaired reaches is presented in Table 9.3. Based on the number and relative magnitude of the impairment, the following reaches were identified as priority reaches and are recommended for inclusion in the watershed management plan:

- Middle Popo Agie River – Confluence with North Popo Agie River to Mortimer Lane
- Popo Agie River – Hudson Siding to confluence with North Popo Agie River
- Little Popo Agie River – Lyons Valley to confluence with Popo Agie River.
- Twin Creek – Upper Hwy 287 crossing to confluence with Little Popo Agie River.

Table 9.3 Summary of Geomorphic Impairments.

Stream	Reach	Riparian Vegetation(1)	Riparian Degradation (1)	Channel Encroachment(1)	Rigid Planform(1)
North Popo Agie	Confluence of North Popo Agie River and Surrell Creek to confluence with Middle Popo Agie River	✔			
Middle Popo Agie	Mortimer Lane to confluence with North Popo Agie River	✔		✔	✔
Little Popo Agie	Lyons valley to confluence with Popo Agie River	✔	✔		
	Confluence with Twin Creek to mouth of canyon	✔			
Popo Agie	Confluence North Popo Agie and Middle Popo Agie to Hudson Siding	✔		✔	✔
Twin Creek	Confluence with Little Popo Agie to upstream crossing of Hwy 287	✔	✔		
Baldwin Creek	Confluence with Middle Popo Agie to mouth of canyon	✔			
Squaw Creek	Confluence with Baldwin Creek to mouth of canyon	✔			

(1) Riparian Vegetation: loss of riparian condition and habitat due to grazing, crop encroachment, and loss of riparian buffers
Riparian Degradation: bank erosion, channel downcutting
Channel Encroachment: levees, loss of floodplain access
Rigid Planform Control: loss of meander capacity

Various approaches can be taken during channel restoration and stabilization efforts, including both "hard" engineering and "soft" approaches and combinations of the two. Examples of "hard" approaches would include construction of channel structures or reconstruction of channels themselves. For instance, methods of restoring incised channels may include construction of gradient restoration facilities (i.e., drop structures) within the incised channel. Another option, where there is sufficient space available, could be the design and construction of a new geomorphically stable channel within the existing floodplain and abandoning the previous alignment. Examples of "soft" approaches include a variety of Best Management Practices (BMPs). Examples of BMPs designed for channel restoration activities include prohibition of livestock from accessing designated riparian zones, establishment of riparian buffers, etc. These examples of "hard" and "soft" approaches represent both extremes of the continuum of channel restoration strategies that exist. In practice, it must be kept in mind that it is generally a combination of strategies, integrated into a cohesive plan that provides the most effective solution.

Table 9.4 presents a summary of some of these channel restoration strategies which can be employed during future restoration efforts.

Table 9.4 Potential Channel Restoration Strategies.

Impairment	Restoration Strategy
Riparian Vegetation Degradation:	Grazing management
	Riparian buffer zones
	Revegetation
Riparian Degradation:	Restoration of channel profile
	Structural rehabilitation measures
	Non-structural rehabilitation measures
Levee Confinement and Floodplain Isolation:	Restore floodplain access
	Gradient restoration facility
Rigid Planform Control:	Apply bioengineered erosion control methods
	Establish migration corridors / erosion setback limits where feasible

9.4 Storage Evaluation

Several potential storage site locations were initially identified, screened and evaluated in Chapter 7 of this report. These sites ranged from small off-channel or tributary sites to larger reservoir sites along the principal river channels. In this chapter, those sites that passed the initial screening effort are evaluated in terms of the overall watershed planning objectives and reservoir feasibility.

Storage is recognized as a highly desirable solution with respect to satisfying many of the study objectives. A reservoir ideally located in the watershed and with ample storage capacity could potentially provide the flood protection needed for the City of Lander and the Town of Hudson while providing a means of storing water for irrigation use and augmentation of late season low flows.

To facilitate the evaluation of the reservoir sites, screening criteria were developed. These criteria are briefly described below.

- Flood Control Benefit. Each reservoir site is evaluated with respect to the potential benefit in the reduction of flooding within the watershed, specifically flooding in the City of Lander and the Town of Hudson. Off-channel reservoirs are assumed to provide minimal flood control benefits. Reservoir sites on the Middle Popo Agie River or principal tributaries were assumed to provide moderate flood control benefits depending on the storage capacity of the site. Similarly, sites on the Little Popo Agie River or principal tributaries were assumed to provide moderate flood control benefits depending on the storage capacity of the site, however, sites on the Little Popo Agie River were generally rated lower than those sites on the Middle Popo Agie River due to the magnitude of the potential flooding in the City of Lander.

- Streamflow Augmentation. Each reservoir site is evaluated with respect to its ability to provide for streamflow augmentation at critical reaches in the watershed. The primary target is the reach of the Middle Popo Agie River above the City of Lander. Consequently, those reservoirs located in the Middle Popo Agie River basin above the City of Lander received a higher rating. Reservoirs with larger potential storage volumes were also assumed to provide the most benefit to streamflow augmentation.

- Irrigation Benefits. Each reservoir site is evaluated with respect to potential benefits to irrigation. Reservoir storage can promote conservation within an irrigation company by storing all or a portion of the water conserved for use later in the irrigation season. This criteria provided the highest ratings to those reservoir sites that are located above the majority of the irrigation headgates as well as those sites that offer the most storage capacity.

- Flow Availability. The flow available for storage at each reservoir site was evaluated. Each site was rated from low to high depending on the flow available for storage.

- Permitting. Permitting directly impacts the feasibility of constructing a reservoir. Those sites located within the boundary of the Shoshone National Forest or the Wind River Indian Reservation were rated lower than sites located on private property or state lands located outside the boundary.

- Construction Costs. Each reservoir site is evaluated with respect to the total construction costs. Those sites with construction costs exceeding $15M received a low rating. Sites with construction costs between $5M and $15M received a medium rating while those sites with construction costs less than $5M received the highest rating.

- Cost Per Acre-Foot. Unit costs were determined for each reservoir site and were based on the total construction costs and the potential storage capacity. Those sites with unit costs exceeding $3,000 per acre-foot of storage received a low rating. Sites with unit costs between $1,000 and $3,000 per acre-foot received a medium rating while those sites with unit costs less than $1,000 per acre-foot received the highest rating.

- Related Costs. Related costs were qualitatively evaluated for each reservoir site. The related costs include the cost associated with appurtenant structures such as pipelines/channels for off-channel reservoirs, land and structure acquisition costs (considered significant for those sites that require inundation of residences/property), highway relocation, access and road construction, etc.

- Flood Control Integration. The NRCS recently completed a review of alternative flood control plans to reduce flooding within the City of Lander. Each reservoir site is qualitatively evaluated with respect to its potential to reduce the peak discharge from the 100-year flood thereby reducing the cost of the alternative flood control structures proposed by the NRCS. With respect to this criteria, each site was evaluated with respect to location within the watershed and potential storage capacity. Those sites with significant potential storage located in the Middle Popo Agie basin received the highest rating.

The results of the evaluation and screening process are presented in Table 9.5. Based upon the information presented in this table, several sites have been identified for further investigation as part of the watershed management and irrigation rehabilitation plan. These sites are specifically listed below:

- Sawmill Creek – Neff Park (Middle Popo Agie River)
- Crooked Creek – Meyer Basin (Middle Popo Agie River)
- Little Popo Agie – Red Canyon (Little Popo Agie River)
- Mid-Valley – (Middle Popo Agie River)
- Middle Popo Agie – Roaring Fork (Middle Popo Agie River)

Table 9.5 Storage Site Evaluation Matrix.

Basin	Site Number	Site Name	Flood Control Benefit	Streamflow Augmentation	Irrigation Benefits	Flow Availability	Permitting Feasibility	Construction Costs	Cost per Acre Foot	Related Costs
NORTH	18	North Popo Agie	1	1	2	3	2	1	1	2
	28	Surrel Creek No. 1	1	1	2	3	1	3	3	1
MIDDLE	1	Baldwin - Farlow	1	1	1	1	2	2	2	2
	5	Crooked Creek - Elderberry	2	1	1	1	1	2	2	2
	6	Crooked Creek - Meyer Basin	2	2	3	1	2	2	2	2
	9	Hornecker - Borner	1	2	2	3	2	2	1	1
	16	Middle Popo Agie - Mid Valley	3	3	2	3	2	1	2	1
	17	Middle Popo Agie - Roaring Fork	3	3	3	3	1	1	2	2
	24	Sawmill Creek - Neff Park	2	3	3	2	1	2	2	3
	25	Sawmill Creek - Fossil Hill	2	2	2	2	1	1	1	2
	27	Smith Creek	1	1	1	2	1	2	3	1
	30	Thompson Creek	1	2	2	3	1	1	1	1
	33	Worthen Meadows Reservoir	1	1	2	2	2	3	2	3
LITTLE	3	Canyon Creek	1	1	1	1	2	3	2	2
	11	Little Popo Agie - Onion Flats	1	2	2	3	2	2	3	1
	12	Little Popo Agie - Red Canyon	2	2	2	3	2	3	3	2
	13	Little Popo Agie - Twin	2	2	1	3	2	3	2	1
	14	Little Popo Agie - Lyons	2	2	2	3	2	1	1	2

Note: Evaluation criteria were given values ranging from 1 to 3.
1 = Poor
3 = Good

While it is acknowledged that the Mid-Valley storage site received a high rating during the evaluation, from a practical viewpoint it is unlikely that storage at this location would be feasible due to the number of land owners and residences impacted by construction. Consequently, this site was eliminated from further investigation. Figures 9.7 to 9.10 present pertinent data related to those sites selected for the watershed management and irrigation rehabilitation plan.

9.5 On-Farm Improvements

Potential benefits associated with on-farm improvements were discussed in Chapter 8. The potential conservation savings associated with various improvements compared to existing irrigation practices were estimated and presented. In general, programs to promote the transition from less efficient to more efficient application methods are recommended as a means of conservation within the watershed. Several existing agencies provide partial funding for conversion of irrigation application methods that provide conservation of water. These funding agencies are identified and described in Chapter 11. Incentives to further enhance the enrollment of individual irrigators into such a program should be developed as part of the watershed management and irrigation rehabilitation plan. Such incentives may include reducing the cost to the irrigator by increasing the number of beneficiaries. This assumes the conservation savings from on-farm improvements would result in reduced headgate diversions, thereby augmenting downstream flows and providing benefit to a greater number of individuals.

Similar to the evaluation and screening of irrigation rehabilitation plans, several criteria can be developed to identify those locations where conversion of on-farm application methods provide the most benefit to the watershed. These criteria are briefly described below.

- First, those irrigators associated with Middle Popo Agie River basin will provide the most benefit with respect to conservation and potential augmentation of late season low flows. This statement assumes that headgate diversions are reduced and that all, or a portion of the water conserved remains in the stream.

- To the extent that all or a portion of the conservation savings in irrigation rehabilitation projects result in a reduction in headgate diversions, it is assumed that these diversions could be “shepherded” downstream to the critical reaches where flow augmentation is desired. Due to the number of diversions along the river, cooperative agreements along with incentives will be necessary to provide a mechanism to facilitate the “shepherding” concept.

Site 24: Sawmill Creek at Neff Park

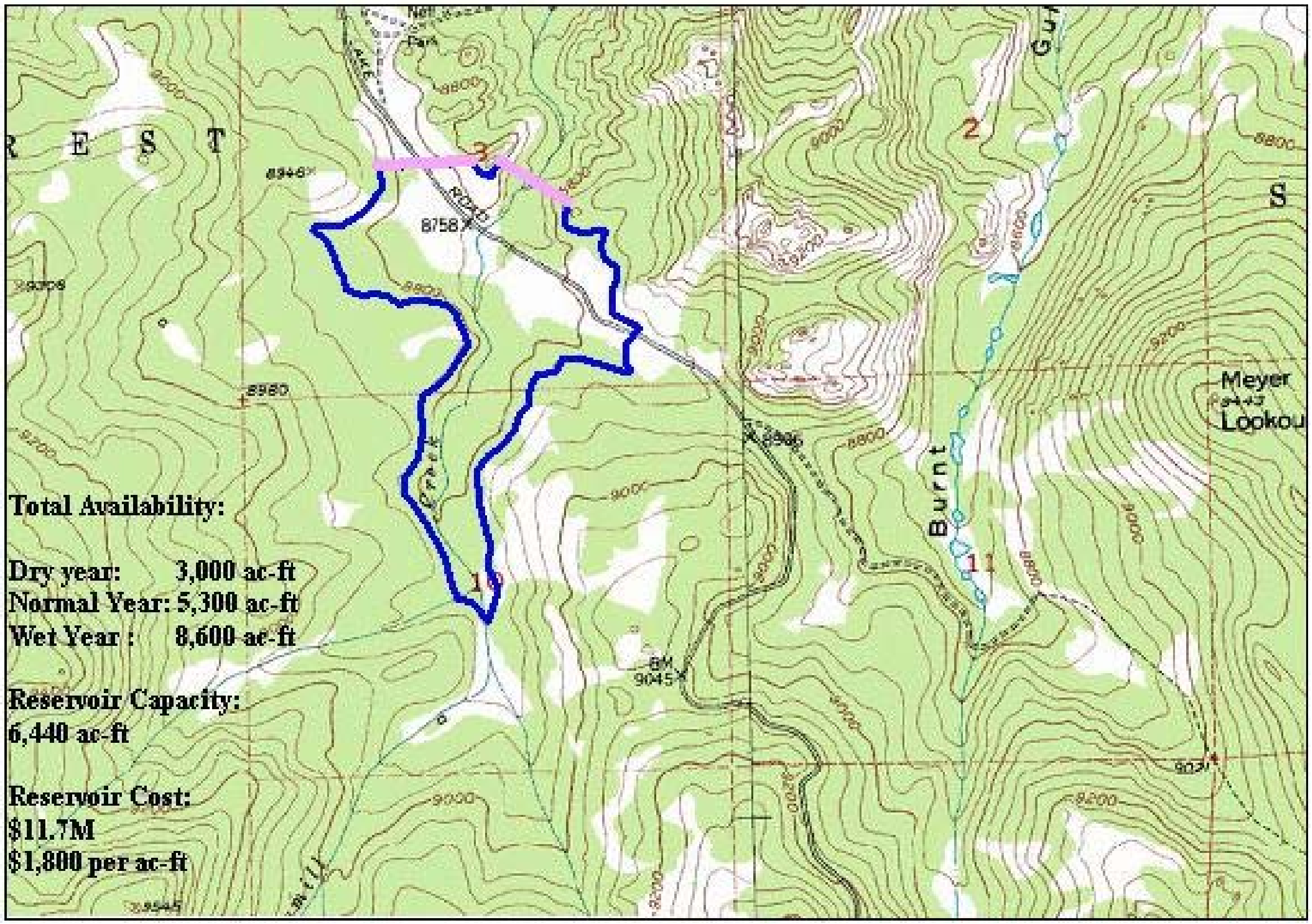


Figure 9.7 Storage Site Location Map: Sawmill Creek – Neff Park (Middle Popo Agie River).

Site 6: Crooked Creek – Meyer Basin

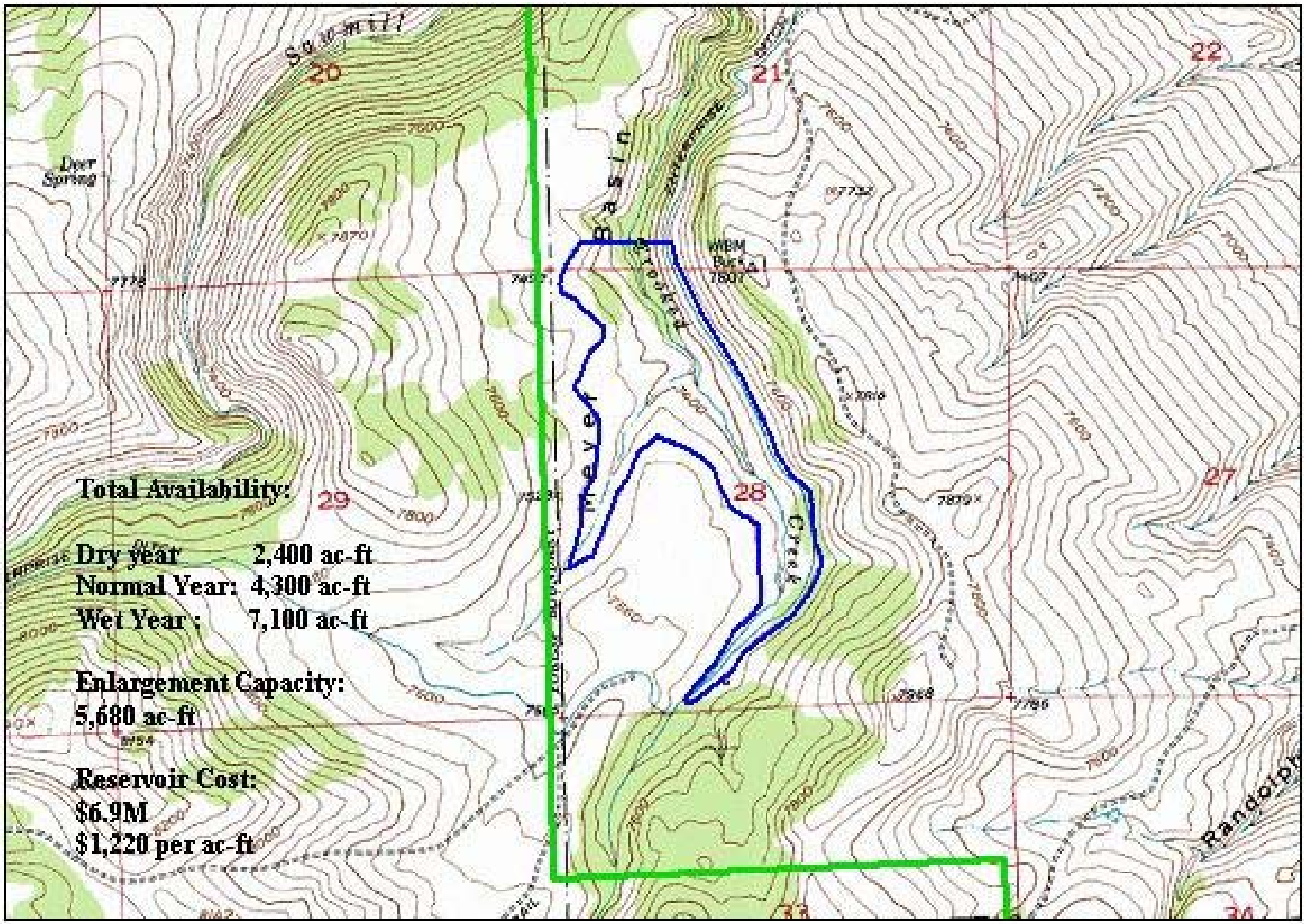


Figure 9.8 Storage Site Location Map: Crooked Creek – Meyer Basin (Middle Popo Agie River).

Site 12: Little Popo Agie – Red Canyon

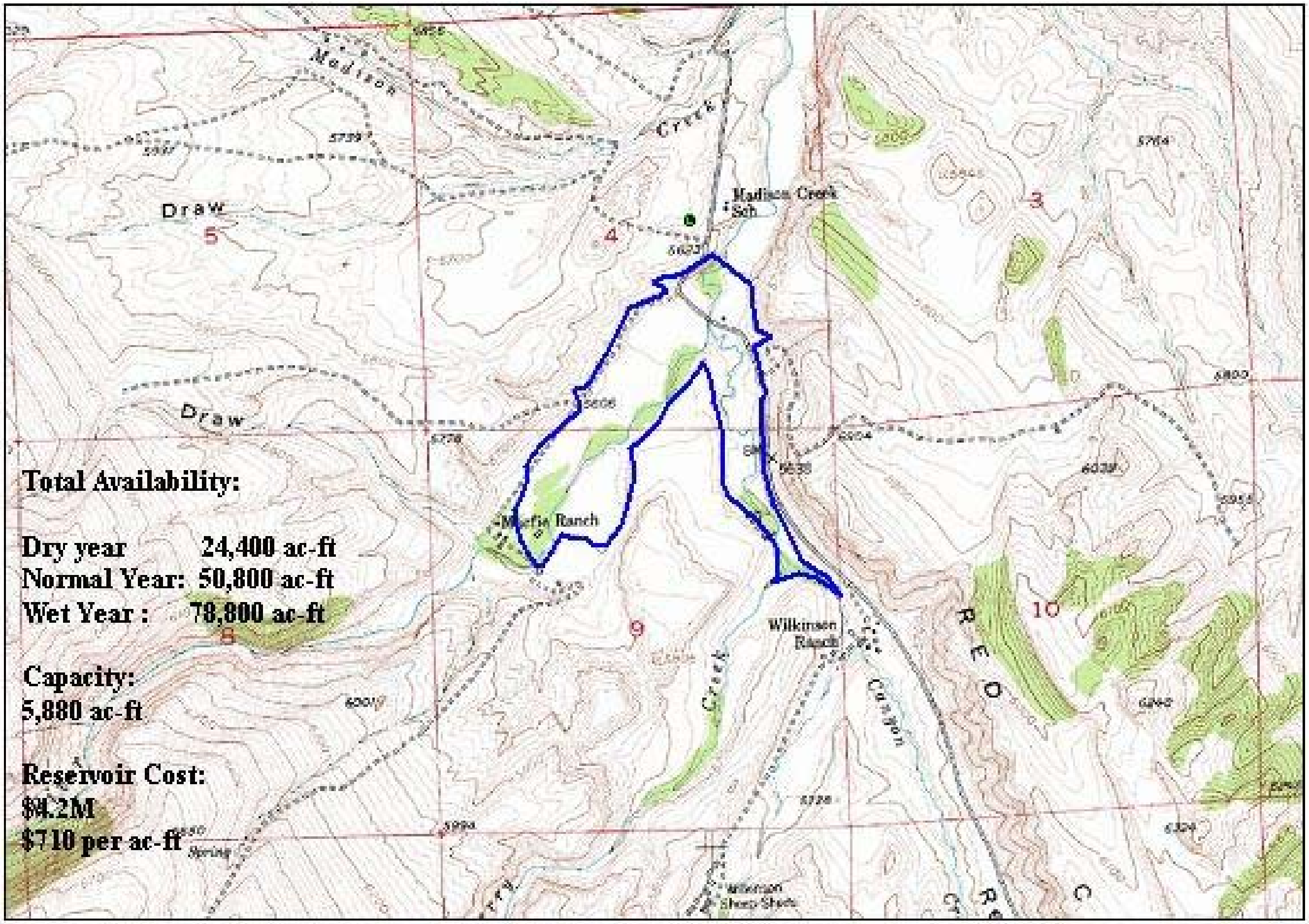


Figure 9.9 Storage Site Location Map: Little Popo Agie – Red Canyon (Middle Popo Agie River).

Site 17: Middle Popo Agie – Roaring Fork

Figure 9.10 Storage Site Location Map: Middle Popo Agie – Roaring Fork (Middle Popo Agie River).

- In view of the difficulties that may exist in arriving at system-wide cooperative agreements, the location of the ditch headgates along the river system was integrated into the evaluation process. The ditches were ranked in order of their relative location to the critical reaches identified for low flow augmentation. Irrigators associated with those ditches located immediately upstream of the critical reach received a higher priority with respect to eligibility for programs developed through the watershed management and irrigation rehabilitation plan.

- Finally, irrigators associated with ditches that have storage facilities within the watershed were assumed to increase the potential benefits associated with on-farm improvements. Releases from existing storage could be reduced and potentially conserved in the reservoir.

In view of these criteria, the maximum benefit associated with on-farm improvements appears to coincide with those irrigators located under the following ditches, in order of priority:

- Cemetery Ditch,
- Dutch Flat / Taylor Ditch,
- Enterprise Ditch,
- Nicol – Table Mountain Ditch, and the
- Gaylor Warnock Ditch.

9.6 The Watershed Management and Irrigation Rehabilitation Plan

The information presented in this chapter provides recommendations for improvements associated with irrigation system conservation and rehabilitation, stream channel condition and stability, storage opportunities, and on-farm improvements. These improvements focus on potential mitigation of several key issues/problems that presently exist within the watershed.

For the Popo Agie River basin, the watershed management and irrigation rehabilitation plan consists of a compilation of the recommendations for each category. The plan is summarized in Table 9.6.

Table 9.6 Popo Agie Watershed Management and Irrigation Rehabilitation Plan.

Irrigation System Rehabilitation Components

Ditch System		Irrigation Rehabilitation Plan Component	Description	Cost
Cemetery Ditch		1	Rehabilitate Parshall Flume	$500
		2	Install measurement devices at lateral split (2)	$4,000
		3	Install measurement devices on 10 turnouts	$10,000
		4	Line reach CD-c	$31,000
		5	Install 2 wasteways / slide gates	$10,000
Dutch Flat - Taylor Ditch		1	Replace Parshall Flume	$5,000
		2	Repair geotextile liner	$2,000
		3	Rehabilitate unstable ditch (GEI, 1984)	$200,000
		4	Install measurement devices at approximately 31 farm turnouts	$31,000
Enterprise Ditch		1	Install measurement device at Sawmill Creek headgate	$5,000
		2	Install measurement device at Crooked Creek headgate	$5,000
		3	Install pipe drop structure	$250,000
		4	Replace drop structure/turnout	$69,000
		5	Replace splitter box	$20,000
		6	Rehabilitate Gabion drop structures (5)	$20,000
		7	Install approximately 15 measurement devices at farm turnouts	$15,000
		8	Line Reach ED-a (approx. 2,500 LF)	$124,000
Gaylor Warnock Ditch		1	Rehabilitate Parshall Flume	$2,000
		2	Install approximately 10 measurement devices at farm turnouts	$10,000
		3	Line Reach GW-a (approx. 500 LF)	$18,000
		4	Install inverted siphon - Option A	$45,000
Nicol Table Mountain Ditch System	Nicol-Table Mountain Ditch	1	Replace diversion structure	$38,000
		2	Replace headgate bypass	$37,000
		3	Replace Parshall Flume	$5,000
		4	Install inverted siphon at Frye Gulch	$50,000
		5	Install approximately 12 measurement devices at farm turnouts	$12,000
		6	Rehabilitate weir	$2,000
	North Lateral	7	Install pipe drop structure (SCS)	$65,000
		8	Rehabilitate inverted siphon	$40,000
		9	Install pipe drop structure (SCS)	$65,000
		10	Replace approximately 11 farm turnouts / install slide gates	$22,000
		11	Install measurement devices (21)	$21,000
		12	Line reaches of North Lateral (SCS) (approx. 3000 LF)	$135,000
		13	Replace flume with inverted siphon (SCS)	$50,000
	Parker - McBride Lateral	14	Install inverted siphon (SCS)	$43,000
		15	Replace approximately 6 farm turnouts / install slide gates	$12,000
		16	Install measurement devices (12)	$12,000
		17	Line ten reaches on Parker McBride lateral as per SCS (approx. 4000 LF)	$180,000
Wise Ditch		1	Rehabilitate headgate/wasteway	$4,000
		2	Rehabilitate Parshall Flume / stabilize banks	$5,000
		3	Replace drop structure/turnout/hills stabilize ditch/lining	$80,000
		4	Replace flume with inverted siphon	$45,000
		5	Replace approximately 10 farm turnouts / install slide gates	$20,000
		6	Install approximately 10 measurement devices at farm turnouts	$10,000
		7	Line Reach WD-a (approx. 1500 LF)	$70,000
		8	Little Popo Agie River bank stabilization	$20,000

Storage Components

Basin	Site Number	Site Name	Storage Volume (ac-ft)	Cost: Construction	Cost: $/ac-ft
Priority 1 Sites					
Middle Popo Agie	6	Crooked Creek - Meyer Basin	5,680	$ 6,912,000	$ 1,220
Middle Popo Agie	17	Middle Popo Agie - Roaring Fork	22,260	$ 36,540,000	$ 1,640
Middle Popo Agie	24	Sawmill Creek - Neff Park	6,440	$ 11,696,000	$ 1,820
Little Popo Agie	12	Little Popo Agie - Red Canyon	5,880	$ 4,204,000	$ 710
Priority 2 Sites					
North Popo Agie	28	Surrel Creek No. 1	3,880	$ 3,885,000	$ 1,000
Middle Popo Agie	33	Worthen Meadows Reservoir	450	$ 800,000	$ 1,780
Little Popo Agie	11	Little Popo Agie - Onion Flats	9,000	$ 8,592,000	$ 950
Little Popo Agie	13	Little Popo Agie - Twin	4,600	$ 1,944,000	$ 420
Little Popo Agie	14	Little Popo Agie - Lyons	9,776	$ 37,660,000	$ 3,850

Stream Channel Restoration Components

Stream	Reach
Middle Popo Agie	Mortimer Lane to confluence with North Popo Agie River
Little Popo Agie	Lyons valley to confluence with Popo Agie River
Popo Agie	Confluence North Popo Agie and Middle Popo Agie to Hudson Siding
Twin Creek	Confluence with Little Popo Agie to upstream crossing of Hwy 287

Potential Restoration Strategies

Riparian Vegetation Degradation:	**Riparian Degradation:**
Grazing management	Restoration of channel profile
Riparian buffer zones	Structural rehabilitation measures
Revegetation	Non-structural rehabilitation measures
Levee Confinement and Floodplain Isolation:	**Rigid Planform Control :**
Restore floodplain access	Apply bioengineered erosion control methods
Gradient restoration facility	Establish migration corridors / erosion setback limits where feasible

On-Farm Components

Ditches:	Potential Improvements	
Cemetery Ditch	Low Pressure Sprinkler Conversions:	$500 - $600/Acre
Dutch Flat / Taylor Ditch	LEPA Sprinkler Conversions	700/Acre
Gaylor - Warnock Ditch	Gated Pipe Installation	$150-$250/Acre
Nicol-Table Mountain Ditch	Surge Irrigation Conversion	$350-$450/Acre
Enterprise Ditch	Information Based Irrigation Scheduling	$1/Acre (1)
	Subsurface Drip Irrigation Systems	$600-$1500/Acre

(1) Assumes two stations at $10,000 each providing benefit to all irrigated acres.

[yellow box] Irrigation component providing conservation benefits

Chapter

10

PERMITTING REQUIREMENTS

When various components of the watershed and irrigation rehabilitation plan proceed to construction, certain permits, rights-of-way and easements will be required. The following information was generated during an investigation into these requirements.

1. U.S. Army Corps of Engineers

Section 404 of the Clean Water Act regulates discharge of dredge or fill material into waters of the United States. All Wyoming water bodies and wetlands are regulated under Section 404. The Omaha District of the U.S. Army Corps of Engineers administers the Corps Regulatory Program in Wyoming. Consequently, the Corps of Engineers (COE) should be contacted with a letter describing the project during the initial stages of the final design of watershed and irrigation system improvements. This letter will determine the Section 404 Permit requirements for the project. Based on previous conversations and experience, the COE will respond with a letter indicating the requirements that are necessary prior to construction of the project.

Typical projects requiring permits include placement of riprap, roadway fill, dam construction, and channel modification. Consequently, construction storage projects within the study area would likely require completion of the 404 permit process. Exceptions to the rule include irrigation and agricultural activities. Discharges associated with siphons, pumps, headgates, wingwalls, weirs, diversion structures and other such facilities related to irrigation ditches are excluded.

2. Wyoming Game and Fish Department.

If a Section 404 permit is required, coordination with the Wyoming Game & Fish Department (WGFD) will be necessary for this project to proceed to construction. Comments will be provided by the WGFD during the permit review process for the Section 404 permit. Wyoming Game and Fish Department must also be notified when chemical herbicides are applied in ditches.

3. Wyoming DEQ, Water Quality Division

If a Section 404 permit is required, Section 401 of the Clean Water Act requires that the state pollution control agency provide certification that the project will not impair water quality and violate state water quality standards. Section 401 pertains to both the construction and subsequent operation of all facilities involving discharge to waters of the U.S. In Wyoming, the Department of Environmental Quality, Water Quality Division coordinates the 401 certification process. The USEPA provides 401 certification on Indian lands.

Permits may be required under the National Pollutant Discharge Elimination System (NPDES) for construction activities.

4. State Historic Preservation Office

Formal approval from the State Historic Preservation Office must be obtained if the Section 404 Permit is required.

5. Wyoming State Engineer's Office

The Wyoming State Engineer's (WSEO) strategic plan states that the goal of the office is to *"provide for the proper regulation, administration, management, and protection of the waters of the State of Wyoming. The regulatory function of the office includes the issuance of permits prior to construction or development for placing water to beneficial use and the administration of available water supplies. All impoundments, diversions, spring developments and groundwater wells are regulated by the State Engineer's Office."* Consequently, coordination with the State Engineer's Office will be a part of most foreseen projects.

For irrigation system rehabilitation and construction projects, plans and specifications detailing the construction of the improvements to either the diversion facilities or gaging stations will be required by the State Engineer's Office.

Dam and reservoir projects will require coordination with the WSEO to secure dam construction permits and adjudicated water rights. Dams greater than 20 feet high and/or impounding 50 acre-feet or more of water must comply with the Wyoming Safety of Dams regulations.

6. National Environmental Policy Act (NEPA)

Projects taking place on Federal lands or involving Federal funding require compliance with the National Environmental Policy Act (NEPA). The National Environmental Policy Act (NEPA), of 1969 established national environmental policy and goals for the protection, maintenance, and enhancement of the environment. NEPA requires all federal agencies to examine the environmental consequences of major proposed actions, such as building a new facility, and to conduct a decision making process that incorporates public input.

NEPA requires a systematic process when an action that could significantly affect the environment is proposed. If the proposed action meets certain criteria that have been previously determined as having no significant environmental impact, the project may qualify for a categorical exclusion. A categorical exclusion exempts the project from further environmental evaluation under NEPA. Certain categories of routine actions, such as maintenance of roads and buildings, are excluded from the NEPA process.

If the action is not granted a categorical exclusion, an initial determination as to whether an Environmental Assessment (EA) or an Environmental Impact Statement (EIS) is required. If impacts appear to be significant, an EA to study the impacts of the proposed action, alternatives to the action, and whether the action will create an environmental impact significant enough to warrant an EIS is prepared. If the EA shows the proposed action would not significantly affect the environment, a Finding of No Significant Impact (FONSI) is issued. On the other hand, if the EA shows the action has the potential to significantly affect the environment an EIS must be prepared.

7. Shoshone National Forest (USDA)

Construction of projects within the boundary of the Shoshone National Forest will require coordination through the United Stated Department of Agriculture. Special Use Permits, with respect to NEPA, will likely be required for any facility place on forest lands.

8. Land Ownership and Property Owners

Where applicable, permission should be negotiated for easement/right-of-access for all construction activities associated with the project.

Chapter

11

FUNDING SOURCES

11.1 Funding Sources

Project funding/financing is a critical aspect associated with the implementation of watershed improvement projects. Given the scope of the investigation and the perceived projects which the PACD may pursue as part of it watershed plan, there may be a large variety of funding sources which may be available to provide funding for future watershed improvements.

With respect to irrigation system rehabilitation, funds (50% grant, 50% loan) are available through the WWDC to implement improvements associated with the main canal facilities (i.e., diversion structure, main delivery canal, laterals, turnout structures, etc.). These funds are not available for on-farm improvements and require the formation of a district that can incur debt and assess users fees. The loan obligation may be partially reduced through other funding sources that also carry a grant/loan obligation.

Alternative sources of funding to watershed projects are discussed in the pages that follow. Potential sources include local, state, and federal entities. Much of the information contained in this report was obtained through the Wyoming State Engineers Office Water Conservation and Water Management Program website (http://seo.state.wy.us/wconsprog/wconsprog.html) and is reproduced herein. The USEPA "Catalog of Federal Funding Sources for Watershed Protection, Second Edition" was referred to as a source of information regarding federal sources of funding (http://www.epa.gov/owow/watershed/wacademy/fund.html).

11.2 Local Funding Sources

11.2.1 Popo Agie Conservation District Irrigation Water Management Program

The Popo Agie Conservation District administers the Irrigation Water Management Program (IWM). The IWM program was initiated with the goal of improving irrigation water systems, reducing soil erosion, conserving water, and improving water quality and productivity. Irrigation ditch companies or groups are eligible to receive funding for projects such as headgate rehabilitation or replacement, pipeline construction, etc. The PACD allocates funds for the program from their annual operating budget established through mil levy.

Assistance to the irrigator is provided on a cost-share basis between the ditch company and the PACD with the PACD providing 60 percent of construction costs.

The contact for this funding source is Jeri Trebelcock at the Popo Agie Conservation District (307-332-3114).

11.2.2 Ducks Unlimited

Ducks Unlimited, Inc. is a funding source for wetlands and waterfowl restoration. Ducks Unlimited (DU) conducts program development through a "Partner" agency in providing short-term project funding assistance. Money availability is limited to what is within the organizational system. Generally, there is $20,000 to $30,000 available annually statewide with additional funding support from project specific donations.

Ducks Unlimited offers a waterfowl habitat development and protection program called MARSH which stands for Matching Aid to Restore States Habitat. This is a reimbursement program that provides matching funds for restoration, protection or enhancement of wetlands. The financial extent of this program is dependent on DU's income within the state.

MARSH projects must significantly benefit waterfowl. Projects receiving funding support must be on lands that can demonstrate at least a 30-year project life at a minimum. Groups requesting assistance must be able to demonstrate capacity to execute long-term habitat agreements, deliver and manage projects and be willing to assume project liability. DU's goal is to match MARSH funds equally with private, state or federal sources. Their objective is to obtain maximum leverage possible to maximize benefit to waterfowl. Therefore, leveraged projects have a greater likelihood of being approved.

Specifics for proposal submission, budget preparation, project development and receipt of funding can be further explained by DU's local coordinator who can provide additional information relating to the program and provide "Partner" contact opportunities at a local level. The contact for questions related to funding is Barry Floyd (307-472-6980).

11.2.3 Wyoming Council of Trout Unlimited

The mission of the Wyoming Council of Trout Unlimited is to conserve, protect and restore Wyoming's coldwater (trout) fisheries and their watersheds. The Council is made up of 16 Chapters located throughout the state.

Trout Unlimited provides funding and volunteer labor for a variety of stream and watershed projects such as erosion control and fish habitat structures, willow and other riparian plantings and stream protection fencing. Embrace-A-Stream grants are available for up to $10,000 per project. Partnerships are encouraged and can include local conservation districts and state and federal agencies. The contact for this funding source is Kathy Buchner (307-733-6991).

11.3 State Funding Sources

11.3.1 Office of State Lands and Investments

The Office of State Lands and Investments is the administrative advisory arm of the Board of Land Commissioners and the State Loan and Investment Board. In addition, the Office carries out several programs under its own authority. The Office is responsible for the management and administration of programs affecting resource management, economic development and quality of life in Wyoming.

Farm and Irrigation Loans. In 1921 the Legislature established the farm loan program to provide long-term real estate loans to Wyoming's agricultural operators. In 1955 the Legislature established the irrigation loan program for small and large agricultural water development projects. The farm and irrigation loan programs provide financial assistance to Wyoming's agricultural industry and finances the development of water resources throughout the state. Under this program, individuals may borrow up to 50 percent of the appraisal value of their farm. Loans are available for terms up to 30 years at 8 percent interest. The maximum amount of these loans is $600,000. The principal contact for this program is Fred Pannell at (307-777-6635).

Joint Powers Act Loan Program. In 1974 the Legislature authorized the Joint Powers Act Loan Program to benefit local communities for infrastructure needs. These loans are approved from funds within the State's Permanent Mineral Trust Fund. These programs are an aid to cities, counties and special districts in providing needed government services and public facilities. Joint Powers Act loans vary in term from 5 to 30 years at an interest rate of 6 percent. The principal contacts for this funding source is Jim Whalen (307-777-6639).

Small Water Development Project Loan Program. Under this program, the State Lands and Investment Board may make loans to court approved water districts, to agencies of State and local government, persons, corporations, associations, and other legal entities in Wyoming to finance the construction of water development projects. Projects eligible for funding are defined as projects for development and use of water upon agricultural lands in Wyoming for agricultural purposes. Water development projects may include projects to convert dry land into irrigated land as well as projects, which will lead to more efficient use of water and/or increased crop or forage production. Loans may not exceed $150,000. Loans are available for terms up to 40 years at an interest rate of 6 percent. The Principal contact for this program is Fred Pannell (307-777-6635).

In addition to these funding programs, the Office of State Lands and Investments may have additional funding available for larger water development programs. Rules have not been written for the administration for these funds. Information pertaining these funds can be obtained from Fred Pannell (307-777-6635).

11.3.2 Wyoming Game and Fish Department

The Wyoming Game and Fish Department offers a funding program to help landowners, conservation groups, institutions, land managers, government agencies, industry and non-profit organizations develop and/or maintain water sources for fish and wildlife. This program also provides funding for the improvement and/or protection of riparian/wetland areas for fish and wildlife resources in Wyoming.

Riparian Habitat Improvement Grant. The purpose of this program is to improve or maintain riparian and wetland resources. Fencing, herding, stock water development, streambank stabilization, small damming projects and beaver transplanting are a few examples of efforts that qualify under this program. Permits, NEPA compliance, construction, maintenance, access and management planning are all grantee responsibilities. There is $10,000/project maximum available with 50% cash or in-kind required from grantee.

Water Development/Maintenance Habitat Project Grant. The purpose of this program is to develop or maintain water for fish and wildlife. Spring development, windmills, guzzlers, water protection and pumping payments are examples of the extent of this program. Permits, NEPA compliance, maintenance, access and water rights are responsibilities of the grantee. There is a maximum of $10,000/project and 50% cash or in-kind contribution required from the grantee.

Upland Development Grant. The purpose of this program is to develop upland wildlife habitat. Example project include management, grazing systems, prescribed burning, wildlife food plots such as oat, millet or corn plantings, range pitting and range seeding. Permits, NEPA compliance, maintenance, access and management planning are responsibilities of the grantee. There is a maximum of $10,000/project and 50% cash or in-kind contribution required from the grantee.

Fish Wyoming. The purpose of this program is to develop public fishing opportunities. Examples of projects within this effort are boat ramps and fishing access. This program provides a 50% match of funding which is channeled through a private organization or municipality. There is a funding limit of $20,000 a year/project. The contacts for this funding source are

Gary Butler, Terrestrial Habitat (307-777-4565) and Mark Fowden, Aquatic Habitat (307-777-4559).

11.3.3 Wyoming Water Development Commission

Wyoming Water Development Program. The Wyoming Water Development Commission provides grants and loan funding for water supply feasibility studies and construction projects. Projects must address water supply, transmission or storage. Project planning and development is broken down into three levels. Project planning is covered in Levels I and II, and project construction is covered in Level III. Level I studies carry out necessary reconnaissance work, while Level II studies determine the projects' feasibility. Levels I and II are 100% grant. Project ideas originate with the sponsoring entities and come to the WWDC through applications. The Wyoming legislature must then approve all Level I and II projects.

The Wyoming legislature must also authorize each project and approve funding before a project proceeds to Level III final design and construction. Once this occurs, the staff of the Construction Division works with project sponsors to establish the legal documentation required to make the state funds available and to insure that the project constructed complies with the description, intent, and budget as specified in the enabling legislation. One of the professional staff is assigned to each construction project from design through construction and warranty acceptance. The Construction Division coordinates design engineer selection, plan and specification review, award of construction contract and approves all project payments.

Commission policy allows for grants of 50% of the eligible portions of new development projects, and 50% of the eligible portions of rehabilitation projects. The remainder of funding for eligible portions can be loaned at an interest rate equal to the rate set by the State Loan and Investment Board, currently 7.25% for new development and 6% for agricultural rehabilitation projects. Sponsors may choose to fund the loan portion from local or federal sources.

Small Water Project Program (SWPP). The WWDC administers the Small Water Project Program (SWPP). It is intended to parallel and partner with other local, state, and federal programs that perform water resources planning and water development in the State. Current criteria require that a project have a public entity as the sponsor, have at least 20 taps for a public water supply system or 2,000 irrigated acres for an agricultural project.

Small water projects are defined as those projects that have an estimated total cost of less than $50,000 and provide multiple benefits for an array of interests. Projects may include construction or rehabilitation of small reservoirs, pumping and conveyance facilities, springs, wetland developments, etc. These projects may provide improved water quality and quantity, habitat for wildlife, increased recreational opportunities, address environmental concerns by providing water supplies to support plant and animal species, or serve as instruments to improve rangeland conditions. The contact for this funding source is John Jackson (307-777-7626).

11.4 Federal Funding Sources

11.4.1 Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) was established to provide a single, voluntary conservation program for farmers and ranchers to address significant natural resource needs and objectives. Nationally, it provides technical, financial, and educational assistance; half of it targeted to livestock-related natural resource concerns and the other half to more general conservation priorities. EQIP is available primarily in priority areas where there are significant natural resource concerns and objectives. The EQIP is administered through the NRCS.

Non-federal landowners (including American Indian tribes) that engaged in livestock operations or agricultural production are eligible for funding. Eligible land includes cropland, rangeland, pasture, forestland, and other farm and ranch lands.

Funding assistance is provided for up to 75 percent of costs of certain conservation practices. Funding limitations include a maximum $10,000 per person per year and $50,000 over length of contract.

For more information related to this funding source, contact the local or state NRCS office (Ed Burton, 307-261-6453).

11.4.2 Flood Mitigation Assistance Program

The Flood Mitigation Assistance (FMA) program helps states and communities identify and implement measures to reduce or eliminate the long-term risk of flood damage to homes and other structures insurable under the National Flood Insurance Program (NFIP). Projects may include: (1) elevation, relocation, or demolition of insured structures; (2) acquisition of insured structures and property; (3) dry floodproofing of insured structures; (4) minor, localized structural projects that are not fundable by state or other federal programs (erosion-control and drainage improvements); and (5) beach nourishment activities such as planting of dune grass.

State agencies, participating NFIP communities, or qualified local organizations are eligible for this funding source. Communities that have been suspended from the NFIP are not eligible.

Two types of grants are available. Planning grants assist communities with the development of Flood Mitigation plans (assessment of flood risk and identification of actions needed to reduce risk). Project grants provide for implementation of measures to reduce flood losses. Communities must have Flood Mitigation Plans to be eligible for FMA project grants.

The contact for this funding source is Federal Emergency Management Agency Mitigation Directorate, 500 C Street SW, Washington, DC 20472, (202-646-4621).

11.4.3 Project Impact Grant Program

Project Impact helps communities that have a history of losses from natural disasters or have a significant disaster risk, such as those located in watershed floodplains. Through Project Impact, the Federal Emergency Management Agency (FEMA) assists communities to engage a wide cross-section of its members in a collaborative process to prevent damage due to natural disasters at the local level. Funds are provided to help assess risks, build public-private partnerships, identify and implement projects, and communicate and mentor success. The key is to incorporate and sustain self-reliant disaster resistance into the basic fabric of a community's own vision.

All communities/local governments are eligible for funding with the selection process taking place at the state level. Each state receives an equal portion of funds (grants) from FEMA and divides it among qualified communities within that state.

The contact for information related to this funding source is the state emergency management office.

11.4.4 Flood Hazard Mitigation and Riverine Ecosystem Restoration Program

Informally known as Challenge 21, this watershed-based program focuses on identifying sustainable solutions to flooding problems by examining nonstructural solutions in flood-prone areas, while retaining traditional measures where appropriate. The program will create a framework for more effective federal coordination of flood programs and will create partnerships with communities to develop solutions to flooding problems. Eligible projects will meet the dual purpose of flood hazard mitigation and riverine ecosystem restoration. Projects might include the relocation of threatened structures, conservation or restoration of wetlands and natural floodwater storage areas and planning for responses to potential future floods.

All local governments are eligible for funding. The study area must be in a floodplain. The assistance provided consists for a cost-share between federal and local governments. The federal share is 50 percent for studies and 65 percent for project implementation.

The contact for information related to this funding source is the local/state emergency management office.

11.4.5 Watershed Protection and Flood Prevention Program

Also known as the "Small Watershed Program" or the "PL 566 Program," this program provides technical and financial assistance to address resource and related economic problems on a watershed basis. Projects related to watershed protection, flood prevention, water supply, water quality, erosion and sediment control, wetland creation and restoration, fish and wildlife habitat enhancement, and public recreation are eligible for assistance. Technical and financial assistance is also available for planning and installation of works of improvement to protect, develop, and use land and water resources in small watersheds.

Local or state agency, county, municipality, town or township, soil and water conservation district, flood prevention/flood control district, Indian tribe or tribal organization, or other subunit of state government with the authority and capacity to carry out, operate, and maintain installed works of improvement are eligible for funding through this program. Projects are limited to watersheds containing less than 250,000 acres.

The assistance provided consists of technical assistance and cost sharing (amount varies) for implementation of NRCS-authorized watershed plans. Technical assistance is provided on watershed surveys and planning. Although projects vary significantly in scope and complexity, typical projects entail $3.5 million to $5 million in federal financial assistance.

For funding information contact the local or state NRCS office.

11.4.6 Nonpoint Source Implementation Grants (319 Program)

The 319 program provides formula grants to the states and tribes to implement nonpoint source projects and programs in accordance with Section 319 of the Clean Water Act (CWA). Nonpoint source pollution reduction projects can be used to protect source water areas and the general quality of water resources in a watershed. Examples of previously funded projects include installation of best management practices (BMPs) for animal waste; design and implementation of BMP systems for stream, lake, and estuary watersheds; basinwide landowner education programs; and lake projects previously funded under the CWA Section 314 Clean Lakes Program.

Lead state and territorial nonpoint source agencies and eligible tribes, State and local governments, Indian tribes, and nonprofit organizations may submit applications to states for funds in accordance with the state's work program.

Formula grants are awarded to a lead agency in each state and territory. Eligible tribes may also receive funds. States/tribes/local organizations are usually required to provide 40 percent of total project or program cost.

The contact for this funding source is Beth Pratt, Wyoming Department of Environmental Quality, Water Management Section (307-777-7079).

11.4.7 Watershed Assistance Grants

Today's water quality challenges include habitat loss and nonpoint source pollution from urban, rural, and rapidly growing areas. This pollution impacts the quality of surface and ground water supplies, many of which serve as drinking water sources. Solving such challenges requires partnerships and community-led solutions. To address this need, EPA establishes a cooperative agreement with one or more nonprofit organization(s) or other eligible entities to support watershed partnership organizational development and long-term effectiveness. Funding supports organizational development and capacity building for watershed partnerships with diverse membership. These grants are highly competitive. The USEPA reported funding for only 6 percent of applications received over the last 3 years.

Organizations eligible for funding include nonprofits, tribes, and local governments. The assistance provided consists of grants (match is encouraged but not required). The maximum funding for individual watershed partnership is $30,000.

The contact for this funding source is U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds (4501F), Ariel Rios Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, (202-260-4538).

11.4.8 Wetlands Reserve Program

This voluntary program provides landowners with financial incentives to restore and protect wetlands in exchange for retiring marginal agricultural land. Landowners may sell a conservation easement or enter into a cost-share restoration agreement. Landowners voluntarily limit future use of the land, but retain private ownership. Landowners and the Natural Resources Conservation Service develop a plan for the restoration and maintenance of the wetland.

Participant eligibility for this funding must have owned the land for at least 1 year. The owner may be an individual, partnership, association, corporation, estate, trust, business, or other legal entity; a state (when applicable); a political subdivision of a state; or any agency thereof owning private land. Land must be restorable and be suitable for wildlife benefits.

Three options of assistance are provided to the landowner. The first option involves the USDA purchasing a permanent easement (price is lesser of the appraised agricultural or raw land value, payment cap, or amount offered by the landowner). USDA will pay 100 percent of restoration costs. The second option involves a 30-year easement where the easement payment will be 75 percent of what would be paid for a permanent easement. USDA will pay 75 percent of restoration costs. The last option is a restoration Cost-Share Agreement that involves an agreement (min. 10 yr) to restore degraded wetland habitat. USDA will pay 75 percent of restoration costs.

The program requires acreage authorization levels, not funding levels. Funds are provided to meet acreage levels.

Contact the local or state NRCS office to obtain information related to this funding source.

11.4.9 Bring Back the Natives Grant Program

This program provides funds to restore damaged or degraded riverine habitats and their native aquatic species through watershed restoration and improved land management. Funding is provided by the Bureau of Land Management (BLM), Bureau of Reclamation (BOR), U.S. Fish and Wildlife Service (FWS), USDA Forest Service (FS), and National Fish and Wildlife Foundation (NFWF). Successful projects will provide greater than 2 to 1 non-federal match to federal match and will support the applied ecosystem strategy of BLM, BOR, FWS, FS, and NFWF and address: (1) revised land management practices to eliminate causes of habitat degradation; (2) multiple species benefits, (3) direct benefits to native fish and aquatic community resources in watersheds with land managed by BLM, BOR, or FS; (4) multiple resource management objectives; (5) multiple project partners and innovative partnerships; (6) where appropriate, demonstration of a landscape ecosystem approach; and (7) innovative projects that develop new technology that can be shared with others.

Local governments, states, and local nonprofit organizations are eligible for funding through this program. The assistance provided consists of project grants.

Contact the National Fish and Wildlife Foundation to obtain information related to this funding source.

11.4.10 Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program for people who want to develop and improve wildlife habitat on private lands. It provides both technical assistance and cost sharing to help establish and improve fish and wildlife habitat. Participants work with USDA's Natural Resources Conservation Service to prepare a wildlife habitat development plan in consultation with a local conservation district. The plan describes the landowner's goals for improving wildlife habitat, includes a list of practices and a schedule for installing them, and details the steps necessary to maintain the habitat for the life of the agreement.

To be eligible for funding, individuals must own or have control of the land under consideration and cannot have the land already enrolled in programs that have a wildlife focus, such as the Wetlands Reserve Program, or use the land for mitigation.

The assistance provided consists of a cost-share where USDA pays up to 75 percent (usually no more than $10,000) of the cost of installing wildlife practices. Technical assistance for establishing habitat development projects is also provided.

Contact the local or state NRCS office for information related to this funding program.

11.4.11 Community-Based Restoration Program

The Community-Based Restoration Program (CRP) provides funds for small-scale, locally driven habitat restoration projects that foster natural resource stewardship within communities. The program emphasizes the use of a grassroots, bottom-up approach to restoring fishery habitat across coastal America. The program's objective is to bring together citizen groups, public and nonprofit organizations, industry, businesses, students, landowners, and local government, state and federal agencies to implement habitat restoration projects to benefit living marine resources. Projects might include restoring wetlands, mangroves, and other coastal habitats; improving fish passage and habitat quality for anadromous species; restoring oyster reefs removing exotic vegetation and replanting with native species; removing dams; and similar projects to restore habitat or improve habitat quality for populations of marine organisms. Partnerships are sought at the national and local level to contribute funding, land, technical assistance, workforce support, or other in-kind services.

State, territorial, local, or tribal governments; regional governmental bodies; public or private agencies or organizations; universities and colleges; and private profit and nonprofit organizations are eligible for this funding source. The assistance provided consists of project grants (cooperative agreements).

For more information regarding this funding source, contact the U.S. Department of Commerce National Oceanic and Atmospheric Administration Office of Habitat Conservation, FHC3 1315 East-West Highway, Silver Spring, MD 20910, (301-713-0174).

11.4.12 Partners for Fish and Wildlife Habitat Restoration Program

The Partners for Fish and Wildlife Habitat Restoration Program, through partnerships with conservation groups and federal/state/tribal/local government agencies, provides technical and financial assistance to private landowners interested in voluntarily restoring or otherwise improving native habitats for fish and wildlife on their lands. This program focuses on restoring former and degraded wetlands, native grasslands, stream and riparian areas, and other habitats to conditions as natural as feasible. Under cooperative agreements, private landowners agree to maintain restoration projects, but otherwise retain full control of the land. Since 1987, the program has partnered with more than 19,000 landowners to restore over 409,000 acres of wetlands, 333,000 acres of prairie grassland, and 2,030 miles of in-stream aquatic and riparian habitat. In addition, the program has reopened more than 200 miles of stream habitat for fish and other aquatic species by removing barriers to passage.

Private landowners are eligible for funding and must enter into a cooperative agreement for a fixed term of at least 10 years. The assistance provided consists of a project cost-share or service cost-share, generally limited to less than $25,000. Technical assistance is also provided with respect to habitat assessment and restoration expertise.

For more information related to this funding source, contact Mark Hogan (307-332-8719).

CONCLUSIONS AND RECOMMENDATIONS

Chapter 12

In response to foreseen pressures on the natural resources within the Popo Agie River watershed, the community recognized the need for development of a watershed management and irrigation rehabilitation plan and submitted an application for a Level I study to the WWDC with the PACD as the project sponsor. The results of the Popo Agie River Watershed Study are summarized herein and represent a unique opportunity for the State and the local community to proactively plan for the future of their watershed and its water resources.

In previous chapters, several key issues and problems were identified and ultimately, project goals and objectives were formulated to address these issues and problems. Specifically, plans were developed to address issues associated with irrigation rehabilitation and conservation, flood control, and augmentation of low flows. Water quality data were obtained and integrated into a database to promote the monitoring of water quality within the watershed. Channel stability assessments were completed to identify reaches that are presently impaired. Flow availability was evaluated and provided the information necessary to identify and assess potential storage sites within the watershed. An investigation of on-farm improvements was conducted and potential conservation opportunities identified through the implementation of more efficient irrigation application techniques.

In summary, the following conclusions and recommendations are provided and are based on the information presented in the previous chapters.

- Under existing conditions, the water supply within the watershed in not sufficient to satisfy the demands associated with all the water users; in other words, the surface water resources within the watershed appear to be over-appropriated, especially in the Middle Popo Agie River. This conclusion is supported by the results of the flow availability analysis, field observations and conversations with community residents. These conditions exist to a lesser degree on the Little Popo Agie River and assuming consideration of all water rights of record, similar shortages may be expected on the North Popo Agie River.

- Flood control needs appear to be greater on the Middle Popo Agie River as well as augmentation of low flows (in the reach upstream of the City of Lander). Flood control needs also exist in the Town of Hudson as a result of flood flows generated from both the Middle Popo Agie River as well as the Little Popo Agie River.

- Irrigation water use dominates water usage within the watershed and accounted for approximately 96% of the basin's total use of surface water in 1990. Since the existing surface water sources appear to be "supply limited", improvements to existing irrigation facilities and practices that conserve water will be instrumental in "stretching" the existing the water supplies to meet all the needs within the watershed.

- Of the irrigation systems inventoried and evaluated during this study, several structures are in immediate need of rehabilitation. Additional or improved measurement structures are needed to monitor the deliveries and improve the operation and management of the irrigation diversions. Several improvements have been identified to reduce potential seepage and conserve water.

- The majority of irrigation within the Popo Agie River basin is dominated by conventional flood irrigation methods. Given the irrigated acreage within the basin, a significant potential exists to conserve water through the implementation of more efficient on-farm application methods.

- Based on the geomorphic assessment, several impaired channel reaches were identified within the watershed. It is recommended that these reaches be further investigated. Site-specific solutions should be developed to mitigate the channel impairment and ultimately included in the watershed management and irrigation rehabilitation plan.

- Available water quality data have been incorporated into a database accessible through the project GIS. This information should be accessed and built upon as the PACD continues their water quality monitoring programs.

- The results of the flow availability investigation confirmed that water is available and flows out of the watershed during the spring runoff period, predominantly during May and June.

- Should irrigation rehabilitation or on-farm improvements result in conservation of water and ultimately, reduced diversions at the headgate, several institutional constraints must be addressed. These include the administration of water rights associated with all downstream diversions, cooperative agreements likely required to "shepherd" the water to reaches impacted by low flows, and development of incentives for irrigators to enroll in the conservation projects.

- Based on the flow availability and site-specific topography, several existing and potential storage sites were evaluated. Existing reservoirs offer limited potential for enlargement and provide limited benefits to address the key issues and problems in the watershed. Based on the needs within the watershed, reservoirs located in the Middle Popo Agie River watershed were prioritized during the evaluation. Several potential reservoir sites were identified for further investigation. Storage at these sites provides benefits for flood control and low flow augmentation. In addition, the benefits of conservation associated with either on-farm improvements or rehabilitation of irrigation conveyance facilities may be enhanced through storage.

- During a more detailed investigation of potential storage sites, several institutional constraints must be addressed. These include the release of water from storage and the administration of water rights associated with all downstream diversions, and cooperative agreements likely required to "shepherd" the water to reaches impacted by low flows. In addition, objectives of the recently completed Wind River/Big Horn River Basin Plan must be considered and the impact of these storage sites evaluated in the context of the basin plan. Finally, stipulations and conditions in the Yellowstone River Compact should be more fully evaluated.

- The NRCS has recently completed a flood control study of alternative improvements in the City of Lander. Storage within the watershed may potentially reduce the costs associated with the alternatives proposed by the NRCS and provide for savings associated with flood control within the community. Additional investigation into this issue is warranted.

- Several funding sources exist for funding of improvements within the watershed including on-farm improvements, irrigation rehabilitation projects, stream enhancements/restoration projects, and conservation and flood control projects. Creative strategies for funding/financing of projects should be more fully investigated following identification of projects worthy of additional evaluation and potential implementation.

- One of the most critical issues that must be addressed is the need for a clear and concise consensus among the parties/entities within the watershed. The community has made significant progress in this area through outreach programs and public meetings. Implementation of projects within the watershed will likely require consensus and continued effort in this area is recommended.

As stated previously, implementation of a watershed management and irrigation rehabilitation plan will require funding from several sources. To be eligible for funding from WWDC, a district must be formed that has the capability to incur debt and assess its users. This issue must be addressed to facilitate the progression of this Level I study into a Level II study associated with selected project improvements and ultimately to construction in Level III.

Finally, to move forward in the planning process following the completion of this Level I study, procedures and criteria may be needed to prioritize those projects worthy of additional consideration. This process may be facilitated by initial consideration of smaller projects to "test the waters" associated with district formation as well as consensus among the water users and beneficiaries.

Chapter 13

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APPENDIX A

PUBLIC COMMENTS

USDA

Natural
Resources
Conservation
Service

320 East Lincoln Street
Riverton, WY 82501
307-856-7502 Ext. 113
FAX 307-856-2383

June 12, 2003

To: Anderson Consulting Engineers, Inc.

I have reviewed your Popo Agie River Watershed Level I Study. I like the way you put the digital report together. It is a very effective way to navigate back and forth between the visual aspects of the GIS layers, pictures, spreadsheets, and text files. I have a few comments on some little details:

- the precipitation layer in GIS should change color for 7-9 inch so that it differs from the 9-11 inch zone
- the public land survey system labels (GIS) seemed to be skewed
- who did the Wise Ditch study (from Misc. Irrig. in notebook hard copy)?
- the flood insurance map GIS layer seems to be a combination of 500 and 100 year polygons when you look at the chart for that layer
- the Irrigation Inventory & Seepage page could not be displayed (from Jeri's copy on her laptop hard drive)
- (Hydrology) Basin Boundaries: Mainstem– can't differentiate difference between the Little and Middle Popo Agie - both look yellow
- I was under the impression that the Popo Agie Conservation District was going to get a hard copy of the whole Study. From what I have seen the the 3 ring binders, there is a lot of "stuff" that is not in there.

Again, nothing earth shaking, but some things to consider while you are making revisions.

.

Sincerely,

Don Gaddie,
Wind/Big Horn Team Leader

Carrie -
Thank you for your comments, I've forwarded them on to Anderson Consulting and Wyoming Water Development for their review.
Jeri
-----Original Message-----
From: Kevin and Carrie Johnson [mailto:cajohnso@wyoming.com]
Sent: Thursday, June 12, 2003 5:32 AM
To: Jeri Trebelcock
Subject: Comments

Here it is the 12th of June & I was really hoping I could come up with some really good comments regarding the Anderson Consulting document, but ran out of time. So ... here goes:

1. I would like to see the Popo Agie River Drainage forming a watershed district for funding of projects on the watershed.
2. I would like to see the emphasis of the projects to be more efficient delivery system of the water for irrigation.

As much as I would like to see some water storage projects, I just think the NEPA process will delay any efforts toward that end. By putting in more efficient water delivery (pipe, concrete or line ditches to minimize subirrigation and loss of water) I think we could save a tremendous amount of water & will be better equipped to handle drought situations.

Carrie

TO: BURNIE DAVISON, WASHAKIE DISTRICT RANGER

FROM: GREGORY S. BEVENGER, HYDROLOGIST

SUBJECT: REVIEW COMMENTS – DRAFT FINAL REPORT FOR POPO AGIE RIVER WATERSHED STUDY, LEVEL I

DATE: JUNE 8, 2003

CC: LIZ OSWALD, DAVE CAWRSE, BRYAN ARMEL, REBECCA AUS, BRAD HIGGINSON

- THE ENTIRE REPORT NEEDS TO BE CHECKED FOR SPELLING AND SENTENCE STRUCTURE.
- Discussion on DEQ stream classifications seems to be out-of-date. DEQ recently changed their classification system and the report needs to reflect this.

- For good reason the consultant delineated the Popo Agie basin into three major sub-basins and numerous minor basins. Nonetheless, a tie to State-sanctioned 5th and 6th level HUC's needs to be made so various users can share information.

- Chapter 3 presents good discussion on land use in general but little analysis on hydrologic condition, especially uplands, as compared to a reference. How has the various land uses affected the water balance and cycling of water through the watershed? Has flooding been exacerbated by changes in infiltration or increases in connected disturbed area?

- The Rosgen Level I delineation is incomplete. It appears the focus is on major channels. Delineation of 1st, 2nd, and 3rd order channels is just as important, particularly if these channels are in degraded condition as they could then be contributing to conditions in the larger channels. Note the Shoshone Forest is delineating all of its channels as part of the Common Water Unit.

- The Rosgen Level II narrative could be improved by discussion on where these reaches are in the evolutionary sequence continuum. Impairment discussions need to include inability of reaches to transport their sediment load (due to such things as diversions and increased sediment supply from bank erosion) and loss of the water table (due to such things as channel downcutting and groundwater extraction).

- The potential reservoir discussion fails to account for channel maintenance flows awarded to the Forest Service as part of the Big Horn adjudication. By-pass flow requirements may preclude development of the category 4 reservoirs. Note the Shoshone Forest is producing a GIS layer showing the locations of the quantification points.

- Storage location maps presented in Chapter 9 could be deleted and reference made to maps in Appendix C.

Jack -
Thank you for your comments, I've forwarded them on to Anderson Consulting and Wyoming Water Development for their review.
Jeri

-----Original Message-----
From: Jack States [mailto:djstates@onewest.net]
Sent: Tuesday, June 10, 2003 10:24 PM
To: jerit@wyoming.com
Subject: Re: Draft Report WWDC Level 1 Watershed Study

At first glance the sheer size of the report is impressive. After careful inspection, less than 2/3 of it has information useful to the Conservation District as a "tool" in developing a watershed plan, the rest is basically filler. The text is highly repetitious throughout the various chapters and some of the material is more suited for an appendix than in the body of the report (e.g. Funding sources and permitting requirements). The litmus test for acceptance of this report is whether or not the project purpose and objectives were attained. I tend to be forgetful, but it seems to me that what we asked for in this study is not clearly stated nor reflected in the listing 1.5 on page 1-10. It is incumbent on the contractor to specifically outline the requested products up-front (in the introduction) and to highlight the specific outcomes in an executive summary. The conclusions and recommendations section (12.0) does not do this. I ask that the contractor meet these obligations.

Quoting from page 1-11, "the primary goal of the study is to combine a wealth of previously obtained information with newly obtained data from this study to form a comprehensive Watershed Management Plan and Irrigation System Rehabilitation Plan, (Chapt 9). So where is the watershed plan referenced on page 9-23? 9-24 is a chart and may include the missing 9-23 but that is unclear. Is there more text dealing with economic solutions (not just estimated costs) and recommended specific actions (not just a "to do" list)?

Although it is a major strength of the report, did we specifically request an irrigation rehabilitation plan or did the study just evolve in that direction? In the watershed analysis there are only generalities and repetitious statements that have already been voiced by the Lander 20/20 committee. We need additional information. For example water supply needs of various users were not quantified so it is impossible to determine what should be planned for. When and how much water does the City of Lander use? Industry?, Agriculture?. What are the economic benefits and what are the negatives? I note here that improvements leading to decreases in consumptive use may jeapordize the adjudicated appropriations of irrigators under current Wyoming Water Law. Why is this not addressed?

The watershed Use Model (Chapt 6) is an interesting extrapolation of incomplete data for a limited period. It is technically flawed in that "available water" (as inadequately or poorly defined at 6.4.3, page 6-14) estimates are based on assumptions that cannot be validated without stream flow gages at both ends of a stream reach and at points of confluence, thus measuring consumption and return flows. Nowhere in the document was the validity of the model questioned. There needs to be a recommendation for acquisition and installation and placement of stream gages to refine accuracy of the data essential to development of our watershed management plan!!!

Finally there are many graphics presented, particularly maps in the geomorphic classification, that are unreadable and therefore do not serve the purposes for inclusion. They need to be enlarged and printed in color. With the technology today that should not be difficult, nor overly expensive. Given the amount of State dollars expended in this project, surely some could be devoted to making this a more user friendly document. In my opinion the report is unacceptable as it stands.

Jack States

At 11:18 AM 5/21/2003 -0600, you wrote:
>Committee -
>
>At the May 12th Steering Committee meeting the "draft" report for the
>Popo
>Agie River Watershed Study was distributed. The report, prepared by
>Anderson Consulting Engineers, Inc., is a comprehensive inventory of the
>physical characteristics of the watershed including irrigation,
>geomorphology, storage, and water use. The comment deadline is June
>12th. Comments can be sent to me at the PACD Office or to Phil Ogle,
>Wyoming Water Development.
>
>If you missed the meeting please stop by the PACD Office at 201 Main to
>pick up your copy, or I will be happy to mail your report if you'll give
>me a call at 332-3114.
>
>Also, please mark your calendars for our next steering committee
>meeting: June 30, 2003 7:00 to 9:00 P.M.
>War Bonnet Room, Inn at Lander
>
>Please have your report read and ready to go to work!
>Hope to see everyone then.
>Thanks Jeri

APPENDIX B

SOIL MAPPING UNIT DESCRIPTIONS

Soil Mapping Unit Descriptions.

Mapping Unit	Description
WY06	Typic Haplocryalfs, Typic Dystrocryepts and Typic Haplocryolls, loamy-skeletal and Histic Cryaquepts, fine-loamy over sandy or sandy-skeletal. On stable slopes which are older than Pinedale (Late Wisconsin), the predominate soils are Haplocryalfs. Dystrocryepts occur on slopes greater than 40%, and on Pinedale and younger surfaces (Pinedale tills and holocene surfaces). Haplocryolls occur
WY08	Rock outcrop and Lithic Cryorthents, loamy-skeletal. These residual landscapes present a rugged appearance with 50 to 60% of the area covered by rock outcrop. The thin Cryorthents occur intermingled with the bedrock.
WY09	Typic Haplargids and Typic Haplocalcids, fine-loamy over sandy or sandy-skeletal, mesic and Typic Torriorthents, fine-loamy and coarse-loamy, mesic. Aridisols occur on colluvial and alluvial landscapes while Entisols occur on residual landscapes.
WY09	Ustic Haplargids and Ustic Haplocalcids, fine-loamy over sandy or sandy-skeletal, frigid and Ustic Torriorthents, fine-loamy and coarse-loamy, frigid. In this region, the soils in this unit have frigid temperature regimes. These soils occur on old alluvial terraces along major rivers. Soils younger than mid-Pleistocene age are an association of Haplargids and Haplocalcids. On older
WY11	Calcic Haplosalids, fine, mesic. These soils are associated with marine shales and occur in topographic depressions where run off water from the surrounding landscape accumulates and evaporates concentrating salt.
WY17	Typic Torriorthents, loamy-skeletal, mesic and Rock Outcrop. These stony soils occupy ridge crests where coal bed fires have created clinker. The soils tend to be much coarser than the soils on the adjacent lower slopes, and contain hard clasts.
WY27	Typic Torrifluvents and Typic Haplaquolls, fine-loamy over sandy or sandy-skeletal, mixed, frigid These soils occur along riparian areas with the Torrifluvents developing along channels scoured by flooding and the Haplaquolls developing on low gradient channel sections where vegetation is well established and high water tables occur during most of the year.
WY34	Ustic Haplargids and Ustic Natrargids, fine-loamy, frigid. These soils occur as an association on residual landscapes and in local colluvium derived from Tertiary age parent materials. Natrargids show less productivity under sagebrush and grass than Haplargids.
WY35	Typic Natrargids and Typic Torriorthents, fine, frigid. These soils occur on landscapes underlain by Triassic and Cretaceous bedrock (shales). The Torriorthents occur in a badlands type topography, while the Natrargids occur on small, local alluvial fans at the foot of badland scarps, and on low gradient slopes.
WY36	Ustic Torriorthents and Ustic Haplocalcids, coarse-loamy, frigid. These soils occur on calcareous sandstone of Permian age (redbeds). Haplocalcids occur on low gradient slopes; Torriorthents on slopes greater than 10%.
WY37	Typic Petrocalcids and Ustic Calciargids, fine-loamy over sandy or sandy-skeletal, frigid. These soils occur on the highest terraces along major streams where the surfaces are mid Pleistocene age or older. On some surfaces, the petrocalcic horizon of the Palecalcids is nearly continuous; on other surfaces, Palecalcids and Haplocalcids occur as a complex.
WY38	Ustic Haplocambids and Ustic Haplargids, coarse-loamy, frigid. These soils occur as a complex on late Pleistocene age terraces along major streams, and on slopes of less than 15% gradient of the same age.
WY39	Ustic Haplargids, Ustic Haplocambids and Ustic Natrargids, fine-loamy, mixed, frigid. On Tertiary parent materials along the flank of the Wyoming Range uplift, the soils are found in an association reflecting slope position and parent material sodium content. The Haplargids occur on stable, low gradient slopes. Haplocambids are on steeper slopes and Natrargids occur on fans where erosional
WY40	Ustic Haplocambids and Ustic Torriorthents, coarse-loamy, mixed and Typic Torrifluvents, loamy-skeletal, mixed, frigid. This landscape has shallow and moderately deep Haplocambids and Torriorthents occurring on slopes along ephemeral channels and Torrifluvents along gully bottoms.
WY42	Typic Hapludolls and Typic Hapludalfs, loamy-skeletal, mixed, frigid. These soils are similar to those in Soil Zone 3. They occur in foothills along the margin of the Powder River Basin.
WY45	Typic Hapludalfs and Aridic Haplustepts, loamy-skeletal, mixed, frigid. These soils occur along the base of the mountain ranges in the region and support open stands of Ponderosa pine as well as other conifers. The Hapludalfs are on low relief slopes and nearly level surfaces. The Haplustrepts are on slopes greater than 15% and on the narrow valley floors of canyons.

(Sources: University of Wyoming Agricultural Experiment Station)

APPENDIX C

INVENTORY OF HYDRAULIC STRUCTURES AND DITCH CONDITIONS

Table C-1a. Inventory of Hydraulic Structures: Big Cottonwood Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
Headgate	048	Concrete structure with steel slide gates. Concrete aged but in good condition. Rock check dam diverts flow from the North Fork Popo Agie River.	>20 yrs	Clean and maintain as needed. Inspect annually.
Parshall Flume	049	Steel flume with concrete abutments and highwater bypass. Crack in left abutment, remainder of structure in good condition. Flow through flume is not uniform. Curved approach and rocks in channel upstream preventing smooth inflow conditions.	>20 yrs	Rehabilitate structure by repairing existing cracks. Remove rocks in approach to flume to restore uniform flow conditions.
Road Crossing	050	Road crossing and highwater inflow from Mtn Range ditch. Culvert is under North Fork Road.	>20 yrs	Replace culvert
Culvert	052	109" wide arch CMP lining small section of the ditch to reduce seepage. Minor visible seepage still evident.	>20 yrs	Regular maintenance.
Drop Structure	055	Concrete drop structure in good condition.	>20 yrs	Inspect annually
Splitter Box	059	Concrete splitter box proportionally divides flow to 4 laterals. No measurement devices. Downstream half of structure has significant cracking and heaving.	10-15 yrs	Replace structure and install measurement devices.
Farm Turnout Structures	N/A	Condition of farm turnout structures varies from poor to good. There are approximately 5 turn outs between the headgate and the splitter box. None are equipped with slide gates.	10-20 yrs	Replace approximately 5 turnout structures / install slide gates
Measurement Devices	N/A	Measurement devices are absent at all turnouts	N/A	Install approximately 10 measurement devices

Table C-1b. Inventory of Ditch Conditions: Big Cottonwood Ditch

GPS	Condition/Comments	Action Recommended
99	Ditch erosion and sedimentation problems in vicinity upstream of Highway 287, downslope of Taylor / Dutch Flat Ditch (Reach CD-a).	Line reach.
100-11	Seepage in reach downstream of Highway 287 (Reach CD-b)	Line reach.
83-85	Seepage in reach in vicinity of Parshall flume, upstream of subdivision (Reach CD-c)	Line reach.

Table C-2a. Inventory of Hydraulic Structures: Cemetery Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
The Cemetery ditch was studied in greater detail in 1984 by the SCS. Many of the recommendations of that report are incorporated herein; other recommendations have been mitigated. This inventory did not include evaluation of the entire length of the ditches or all hydraulic structures. This inventory includes items indicated as major structures or problematic by ditch representatives.				
Diversion	079	Diverts flow from Middle Popo Agie River. Concrete structure with wooden gate. In good condition. New flood wall installed.	>20 yrs	Replace existing stop logs with slide gate within existing structure.
Diversion Headgate	082	Concrete/ native rock structure; older concrete is deteriorating. Recently poured concrete in good condition. Steel gate on ditch is in good condition. Winter gate doesn't close / leaks. Bypass weir leaks underneath.	>20 yrs	Replace existing weir for bypass flows. Replace existing slide gate on bypass ("winter" gate).
Parshall Flume	084	Steel flume in earthen ditch section. New measurement staff. Flume is not set level. Inlet tilts to the right bank and the outlet tilts to the left bank.	>20 yrs	Remove and reinstall flume.
Culvert	092	Culvert at driveway crossing restricts conveyance at higher diversions	10-20 yrs	Replace with properly sized culvert.
Culvert	093	Culvert at driveway crossing restricts conveyance at higher diversions.	10-20 yrs	Replace with properly sized culvert.
Splitter Box	101	Splits flow to Henry Lateral and Beebe Lateral. No measurement devices. Concrete structure with wood checks. Concrete in good condition.	>20 yrs	Install measurement devices.
Farm Turnout Structures	Various	Condition of farm turnout structures varies from poor to good. Approximately 8 to 10 turn outs. Based upon initial inspection, approximately 50% require rehabilitation/replacement.	1–20 yrs	Replace approximately 5 turnout structures. Install slide gates.
Measurement Devices	Various	Measurement devices are lacking on farm turnouts.	N/A	Install measurement devices at approximately 10 farm turnout structures.
Wasteway	None	No wasteway exists to relieve flood flows. SCS (1983) documented potential overtopping of ditch bank during several storm scenarios	N/A	Select appropriate sites and install approximately 2 wasteways.

Table C-2b. Inventory of Ditch Conditions: Cemetery Ditch

GPS	Condition/Comments	Action Recommended
99	Ditch erosion and sedimentation problems in vicinity upstream of Highway 287, downslope of Taylor / Dutch Flat Ditch (Reach CD-a).	Line reach.
100-11	Seepage in reach downstream of Highway 287 (Reach CD-b)	Line reach.
83-85	Seepage in reach in vicinity of Parshall flume, upstream of subdivision (Reach CD-c)	Line reach.

Table C-3a. Inventory of Hydraulic Structures: Dutch Flat / Taylor Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
The Taylor / Dutch Flat ditch was studied in greater detail in 1984 by the SCS. Many of the recommendations of that report are incorporated herein; other recommendations have been mitigated. This inventory did not include evaluation of the entire length of the ditches or all hydraulic structures. This inventory includes items indicated as major structures or problematic by ditch representatives.				
Headgate	002	Twin slide gates to 28" diameter pipes to divert flow from Middle Popo Agie River. Concrete in good condition	>20 yrs	Inspect annually.
Measurement Flume	003	Steel flume not level. Steel in fair condition, some rust evident.	10-15 yrs	Replace.
Lined Reach	005	Lined reach through golf course. Liner was loosely installed in places; appears to have been installed over rocks/roots	5-15 yrs	Inspect frequently. Partially remove and reinstall where loose.
Culvert and Lateral Headgate	009	Concrete structure and steel trash rack in fair condition. Concrete failing in transition area.	15-20 yrs	Replace concrete in transitional area.
Inverted Siphon	011 and 012	Inverted siphon under Hwy 287 with turnout. Concrete with steel trash rack. Debris and maintenance are problems.	>20 yrs	Continue regular cleaning and maintenance. Inspect annually.
Inverted Siphon	010	Inlet: Concrete with steel bar trash rack. Concrete is in poor condition and has failed in several locations. Check log slots gone. Exposed rebar in wing walls. Siphon reportedly leaks. Outlet: Fair condition. Turnouts without measurement devices. Siphon Pipeline: reportedly leaks and restricts conveyance of ditch	5-10 yrs	Replace inlet / siphon / outlet.
Wasteway	016	Concrete with wood stop logs. No cracks and in good condition. Concrete apron is undermined at end of wasteway. Wasteway channel incised.	5-10 yrs	Replace wasteway.
Farm Turnouts	Various	Conditions of individual farm turnouts range from poor to good. According to SCS report, there are 31 turnouts. Based upon those inspected during this field study, approximately 50% merit replacement	1 to 20 years	Replace approximately 15 farm turnouts, install slide gates.
Measurement Devices	Various	Measurement devices are lacking on farm turnouts.	N/A	Install approximately 31 measurement devices.

Table C-3b. Inventory of Ditch Conditions: Dutch Flat / Taylor Ditch

GPS	Condition/Comments	Action Recommended
007	Unstable slope in vicinity of Highway 287. Previously investigated by WWDC (GEI, 1984). Reach TD-a	Rehabilitate as per GEI, 1984
005	Ditch liner in vicinity of golf course shows signs of potential failure at upstream end. Loosely installed, sags.	Repair liner through approximately 75 feet of lined ditch.
17	Ditch is cut into steep sideslope along Lyons Valley, sandstone. Signs of seepage in this reach, losses not quantified. SCS (1984) reports as unstable.	Line reach.

Table C-4a. Inventory of Hydraulic Structures: Enterprise Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
The Enterprise ditch was studied in greater detail in 1986 by the SCS. Many of the recommendations of that report are incorporated herein; other recommendations have been mitigated. This inventory did not include evaluation of the entire length of the ditches or all hydraulic structures. This inventory includes items indicated as major structures or problematic by ditch representatives. This study did not extend beyond split of Enterprise Ditch to laterals.				
Headgate	1010	Roaring Fork diversion structure. SCS (1986) reported insufficient capacity.	N/A	Replace structure
Headgate	119	Generally fair condition. Remote. Lacks capacity to convey large events (SCS, 1986).	10-20 yrs	Replace structure.
Ditch	1011	Seepage reach. Ditch is perched on steep side slope.	N/A	Line reach
Headgate	116	Crooked Creek diversion.. Concrete abutments with wooden slide gates. Concrete is old and deteriorated. Wood is old but functional. Wasteway stop logs have been replaced. Posts holding slide gates in place are wearing and loose.	10-20 yrs	Replace structure. Install Parshall flume.
Turnout	114	Concrete and wood structure. Numerous cracks and deteriorated concrete.	5-10 yrs	Replace structure
Turnout Drop Structure	112	Deteriorated concrete with numerous cracks, leaks. Plywood flume controls a vertical drop of approximately 20’.	5-10 yrs	Replace turnout structure. Install drop structure.
Splitter Box	120	Divides flow between Deadman Gulch and Blue Hill Laterals. Blue Hill flows continue down Beason Creek. Wood with wooden weir. Structure leaks, but was lined with geotextile in an attempt to stop leaks. No measurement devices.	0-10 yrs	Replace structure. Install measurement devices.
Rock Gabion Drop Structures	126, 127, 128, 129, 130	Five rock gabion drop structures have been installed on Beason Creek. Poor to fair condition. Banks eroding, partial bypass of flows. Most show indications of potential failure: slope downstream, piping.	10-20 yrs	Repair bank erosion and bypasses. Monitor structures periodically. Replace if failure imminent.
Wasteway and Willow Creek Crossing	131	Concrete with steel gate to spill pipe.	>20 yrs	None. Inspect annually.
Farm Turnouts	N/A	Condition of farm turnouts in inventoried reach is generally poor (approx. 3-4)		Replace approximately 4 farm turnouts.
Measurement Devices	N/A	No measurement devices were observed on turnouts within the inventoried reach.	N/A	Install measurement devices on all farm turnouts (approx. 4).

Table C-4b. Inventory of Ditch Conditions: Enterprise Ditch

GPS	Condition/Comments	Action Recommended
1011	Ditch is cut through limestone bedrock and perched on steep sideslope. Various attempts have been made in the past to mitigate seepage losses. Reach ED-a	Line reach, approx. 2,500 LF.
1011-1016	Seepage study reach ED-b	Line reach.
118 - 114	Seepage study reach ED-c	Line reach.

Table C-5a. Inventory of Hydraulic Structures: Gaylor Warnock Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
Headgate	023	Structure is a mix of new and old concrete. Structure facilitates diversion from Middle Popo Agie or bypass return to it. Concrete is generally in good condition; consists of a mix of older and new concrete. Steel twin slide gates functional and good condition.	>20 yrs	None. Inspect annually.
Parshall Flume	024	Steel with concrete headwall and apron in excellent condition. Flow obstruction at inlet: rocks and bendway. Flow is not even across flume.	>20 yrs	Check installation of flume to ensure accuracy. Clean approach channel of boulders in attempt to evenly distribute flow across flume, clean staff gage.
Pipe Inlet and Wasteway	025	Inlet to pipeline running parallel to Sinks Highway. Inlet is concrete with a steel trash rack. Concrete is deteriorating below waterline. Emergency spillway on ditch bank is concrete chute to take flows if pipe is blocked or restricted. Future road widening project may require change of the pipe alignment.	10-15 yrs	Road project may require realignment. Inspect condition annually in addition to frequent debris check/removal.
Wasteway / Sediment Trap	029	Structure designed to trap bedload in ditch and facilitate flushing of sediment from trap. It is concrete with wood stop logs. There are numerous cracks and concrete spalling. The slide gate doesn't appear to be fully closeable; there is significant flow lost under gate at the time of the evaluation.	10-15 yrs	Replace structure with wasteway.
Pipeline and Siphon	042-045	Buried pipe daylights at inlet to inverted siphon. Transition area has cracking concrete. Emergency spill to a ditch running across the slope to the drainage crossed by the siphon. Concrete abutments with steel pipe trash rack. Minor deterioration of concrete wing walls. Siphon outlet is in excellent condition.	>20 yrs Pipe/Siphon 5-10 yrs transition	Replace concrete in transitional area.
Measurement Flume and Turnout	046	Concrete headwalls to steel turnout. Steel metal slide gate on turnout, no measurement device. No screws on slide gates. Flume is in fair condition but appears to be off level; there is leakage underneath flume.	5-10 yrs	Replace flume. Install measurement device at turnout. Repair or replace turnout slide gates.

Table C-5a. Inventory of Hydraulic Structures: Gaylor Warnock Ditch (Continued)

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
Farm Turnouts	N/A	Estimated approximately 8 – 10 farm turnouts on the ditch. Existing turnouts range in condition from poor to fair.	N/A	Replace approximately 8 – 10 farm turnouts on ditch., install slide gates.
Pipeline Sections	031, 034, 036, 040	There are four pipe sections of ditch in addition to the initial section at Sinks Hwy. Pipes are 48-in CMP's in fair condition; minor leaks were evident. Pipes have concrete transitions.	10–20 yrs	Inspect annually and repair leaks as needed.
Measurement Devices	N/A	No measurement devices were noted on farm turnouts.	N/A	Install measurement devices on all farm turnouts (approx. 8-10)

Table C-5b. Inventory of Ditch Conditions: Gaylor Warnock Ditch

GPS	Condition/Comments	Action Recommended
030	Steep slope with rocky subgrade. Ditch is erosive in this location and contributes sediment to downstream reaches.	Install pipe drop structure.
45-46	Seepage reach. Should consider design and construction of additional inverted siphon to bypass reach with no turnouts.	Install inverted siphon
273-274	Seepage study reach GW-a.	Line reach, approx. 800 LF.
276-277	Seepage study reach GW-b.	Line reach, approx. 1,800 LF.
277-278	Seepage study reach GW-c.	Line reach, approx. 1,500 LF.

Table C-6a. Inventory of Hydraulic Structures: Lyons Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
Headgate Diversion	111	Lyons ditch diversion and grade control on the Little Popo Agie River. Concrete structure with wooden stop logs. Concrete in fair condition with a few cracks. Stop logs in poor condition. Slide gate good condition. No Measurement device.	>20 yrs	Replace stop logs. Inspect annually. Install measurement device.
Culvert	139	48-inch concrete pipe, good condition, does not appear to limit conveyance.	>20 yrs	Inspect.
Culvert	143	Arched concrete pipe, good condition, does not appear to limit conveyance.	>20 yrs	Inspect.
Culvert	145	Arched concrete pipe, good condition, does not appear to limit conveyance.	>20 yrs	Inspect.
Farm Turnouts	N/A	Estimated approximately 6-8 farm turnouts on the ditch. Existing turnouts were generally in poor condition.	N/A	Replace approximately 6-8 farm turnouts on ditch.
Measurement Devices	N/A	No measurement devices were noted on farm turnouts.	N/A	Install measurement devices on all farm turnouts (approx. 6-8).

Table C-6b. Inventory of Ditch Conditions: Lyons Ditch

GPS	Condition/Comments	Action Recommended
N/A	The overall condition of the ditch is good, however low slope and aquatic vegetation cause low velocities and restricted conveyance.	Develop annual aquatic vegetation control program.

Table C-7a. Inventory of Hydraulic Structures: Nicol / Table Mountain Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
The Nicol / Table Mountain Ditch was studied in greater detail in 1986 by the SCS. Many of the recommendations of that report are incorporated herein; other recommendations have been mitigated. This inventory did not include evaluation of the entire length of the ditches or all hydraulic structures. This inventory includes items indicated as major structures or problematic by ditch representatives.				
Nicol / Table Mountain Ditch: Upstream of Split				
Point of Diversion	152	Diversion structure on Middle Popo Agie River. Poor condition; concrete undermined and failing. Steel slide gate damaged; reportedly cannot be closed.	0-10 yrs	Replace concrete structure and slide gate.
Headgate / Wasteway	151	Headgate for ditch facilitates spill back to Middle Popo Agie River. Concrete in poor condition, slide gate leaks, and gate frame damaged.	0-10 yrs	Replace concrete structure and slide gate.
Parshall Flume	153	Flume in good condition however, severe bank erosion downstream. The flume is sloped due to bed degradation on the downstream end.	10-20 yrs	Replace flume. Stabilize bed and banks.
Concrete Lining	160	Concrete trapezoidal channel approximately 600' long. Built in 1973, berm raised in 2000 to increase conveyance capacity. Minor cracking, generally good condition.	10-20 yrs	Inspect annually.
Wasteway at Frye Gulch	162	Structure facilitates waste of flood waters from Fry Gulch. Wooden structure in poor condition. High maintenance, poor access. Heavy sediment from Frye Gulch reduces conveyance capacity in ditch.	0-10 yrs	Install inverted siphon across Frye Gulch.
Splitter Box	1001	Splits flow to North Lateral and Parker McBride Lateral. Structure is in fair condition. Old deteriorated concrete remains. New concrete repairs at footing of dividing wall have been undermined. Stop logs are only means of flow control.	10-20 yrs	Replace concrete structure. Install slide gates to facilitate control of flow.
Farm Turnouts	N/A	Estimated approximately 12 farm turnouts on the ditch. Existing turnouts range from poor to good condition.	N/A	Replace approximately 8 farm turnouts on ditch, install slide gates.
Measurement Devices	N/A	No measurement devices were noted on farm turnouts.	N/A	Install measurement devices on all farm turnouts (approx. 12)

Table C-7a. Inventory of Hydraulic Structures: Nicol / Table Mountain Ditch (Continued)

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
Nicol / Table Mountain Ditch: North Lateral				
8' Sharp Crested Weir / Wasteway	1002	Concrete structure with steel plate weir. Heavy sediment on upstream side of weir. Bed degradation and undermining of structure at downstream end.	>20 yrs	Remove sediment on upstream side of weir. Repair bed of structure..
Siphon	174-175	Steel box drop inlet in poor condition. Inlet structure is undermined and deteriorated. Capacity is limited. Overflow is tied to old ditch alignment, and could cause sever erosion under significant flows. No control structure to control overflow.	10-20 yrs	Replace siphon with siphon designed to convey adequate capacity. Replace inlet and outlet..
7' Sharp Crested Weir	176	Concrete structure with patched undermining. Weir in good condition. Heavy sediment deposition upstream of weir due to significant erosion of ditch bed and banks upstream.	>20 yrs	Removed sediment upstream of weir. Mitigate erosion problems upstream of structure.
Nicol / Table Mountain Ditch: Parker McBride Lateral				
8' Sharp Crested Weir	1003	Concrete structure with steel plate weir. Good condition. Channel approach is good with no erosion downstream of structure.	>20 yrs	None. Inspect annually.
Flume	1004	SCS (1986) reports flume across drainage required replacement with siphon.	N/A	Replace flume with inverted siphon, 250 ft of 30-inch pipe.
Wasteway	None	Concrete wasteway with stop logs. Concrete in poor condition.	10yrs	Replace concrete structure.
Farm Turnouts	N/A	Estimated approximately 12 farm turnouts on the ditch. Existing turnouts range from poor to good condition.	N/A	Replace approximately 7 farm turnouts on ditch.
Measurement Devices	N/A	No measurement devices were noted on farm turnouts.	N/A	Install measurement devices on all farm turnouts (approx. 12)

Table C-7b. Inventory of Ditch Conditions: Nicol / Table Mountain Ditch

GPS	Condition/Comments	Action Recommended
Nicol / Table Mountain Ditch: Upstream of Split		
149	Ditch is cut through fractured and jointed sandstone. At several locations, the ditch is narrow and conveyance is restricted creating a bottleneck for the ditch system.	Enlarge approximately 400 feet of ditch through rock section.
159-268	Seepage study NTM-b begins in the vicinity of the existing Parshall flume and extends downstream approximately 3,000 feet. This reach includes portions of the ditch where it is cut through sandstone.	Line reach.
Nicol / Table Mountain Ditch: North Lateral		
N/A	SCS (1986) recommended lining portions of the lateral to reduce seepage losses.	Line reaches.
Nicol / Table Mountain Ditch: Parker McBride Lateral		
N/A	SCS (1986) recommended lining of a total of approximately 4,000 feet of Parker McBride lateral distributed at approximately 10 locations.	Line reaches.
1001	Over-steepened erosive reach.	Install pipe drop structure (800ft, 24-inch diameter according to SCS, 1986)
1005	SCS (1986) recommended inverted siphon across drainage	Install inverted siphon, 460 ft, 30-inch diameter.
1006	SCS (1986) recommended pipe drop structure and inverted siphon under Coal Gulch	Install pipe drop structure and inverted siphon

Table C-8a. Inventory of Hydraulic Structures: North Fork Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
Diversion Headgate	075	Aged concrete diversion structure. No concrete cracking evident. Frequent debris removal evident. Slide gate leaks when shut, creating problems during winter freeze.	>20 yrs	Replace slide gate. Maintain regular debris maintenance.
Measurement Device	075	No measurement device.	N/A	Install measurement device on ditch.
Check Structure and Turnouts	074	Concrete orifice wall to check flow. Concrete is aged and failing. Flow can easily bypass the structure on the right bank. Two turnouts upstream of check, both with no screw on slide gate and no measurement device.	1-10 yrs	Replace concrete check structure. Replace farm turnout structures.
Check Structure and Turnout	073	Concrete check structure and turnout with wood/tarp stop logs. Stop log slot broken off and concrete aged and deteriorated.	1-10 yrs	Replace structure.
Turnout	067	Typical turnout with slide gate. Boards and debris placed in ditch to check flow. No measurement device. Typical of turnouts on the North Fork Ditch.	<10 yrs	Install proper check dams. Install measurement device.
Farm Turnouts	N/A	Estimated approximately 6-8 farm turnouts on the ditch. Existing turnouts were generally in poor condition.	N/A	Replace approximately 9-10 farm turnouts on ditch.
Measurement Devices	N/A	No measurement devices were noted on farm turnouts.	N/A	Install measurement devices on all farm turnouts (approx. 9-10)

Table C-8b. Inventory of Ditch Conditions: North Fork Ditch

GPS	Condition/Comments	Action Recommended
061	Ditch runs down steep slope resulting in downcutting and erosion. Sediment contribution appears significant.	Install concrete drop and grade control structures (approx. 6)

Table C-9a. Inventory of Hydraulic Structures: Snavely / Grant Young Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
Headgate/ Bypass	1020	Cobble check dam on Middle Popo Agie diverts flow to the inlet channel. No measurement device at the headgate. No means of controlling amount of flow entering the ditch upstream of the Headgate. Concrete in fair condition. Ditch heavily covered with vegetation.	10-20 yrs	Inspect annually. Install measurement device. Control vegetation in channel.
Parshall Flume	1022	Steel flume has been removed during highway construction. Heavy vegetation in channel.	0 yrs	Replace flume.
Farm Turnouts	N/A	Estimated approximately 14 farm turnouts on the ditch. Existing turnouts were generally in fair condition, approximately 50% merit replacement.	N/A	Replace approximately 6-8 farm turnouts on ditch, install slide gates.
Measurement Devices	N/A	No measurement devices were noted on farm turnouts.	N/A	Install measurement devices on all farm turnouts (approx. 14).

Table C-9b. Inventory of Ditch Conditions: Snavely / Grant Young Ditch

GPS	Condition/Comments	Action Recommended
N/A	The overall condition of the ditch is good, however low slope and aquatic vegetation cause low velocities and restricted conveyance	Develop annual aquatic vegetation control program.

Table C-10a. Inventory of Hydraulic Structures: Wise Ditch

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
Diversion Headgate	182	Point of diversion on Little Popo Agie River. Consists of concrete headwalls with single steel slide gate and frame. Concrete edges deteriorated, remainder of structure in fair condition. Cobble check dam on Little Popo Agie of local bed materials; appears inefficient at low flows.	10-20 yrs	Inspect annually.
Headgate / Wasteway	183	Allows bypass of diverted flows back to Little Popo Agie River. Concrete Structure and abutments, steel slide gate, and wood stop logs. Structure in fair condition, some cracking concrete and a large crack on the left abutment. Leakage under wasteway stop logs.	10-20 yrs	Rehabilitate structure; repair cracks. Inspect annually.
Parshall Flume	184	Steel flume with concrete headwall. No measurement staff gage. Backfill needed on the downstream end, scour pool downstream of structure.	10-20 yrs	Install measurement staff gage. Backfill downstream and stabilize ditch banks downstream.
Check Turnout/ Drop Structure	185	Concrete drop structure and turnout. Concrete is deteriorated. No gate on turnout; no means of turnout control. No measurement device. Hillslope on right bank unstable. Hay bales and fencing protecting bank. Sediment source	10-20 yrs	Replace concrete structure. Install slide gate and measurement structure on turnout. Hillslope stabilization.
Wasteway / Concrete Lined Ditch	193	Concrete wasteway with wooden stop logs in fair condition.	5-10 yrs	Inspect annually.
Flume Crossing Drainage	194	Concrete flume spanning drainage. Significant undermining at both ends of structure. Leaks several gallons per minute on both sides. Ends of structure have settled.	5-10 yrs	Replace flume crossing.
Farm Turnouts	N/A	Estimated approximately 8 – 10 farm turnouts on the ditch. Existing turnouts range in condition from poor to fair.	N/A	Replace approximately 8 – 10 farm turnouts on ditch.

Table C-10a. Inventory of Hydraulic Structures: Wise Ditch (Continued)

Description	GPS	Condition/Comments	Remaining Design Life	Action Recommended
Measurement Devices	N/A	No measurement devices were noted on farm turnouts.	N/A	Install measurement devices on all farm turnouts (approx. 8-10)

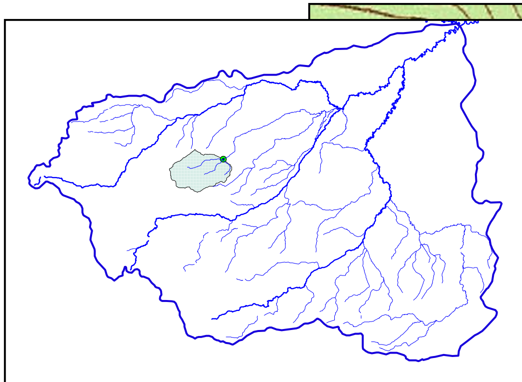
Table C-10b. Inventory of Ditch Conditions: Wise Ditch

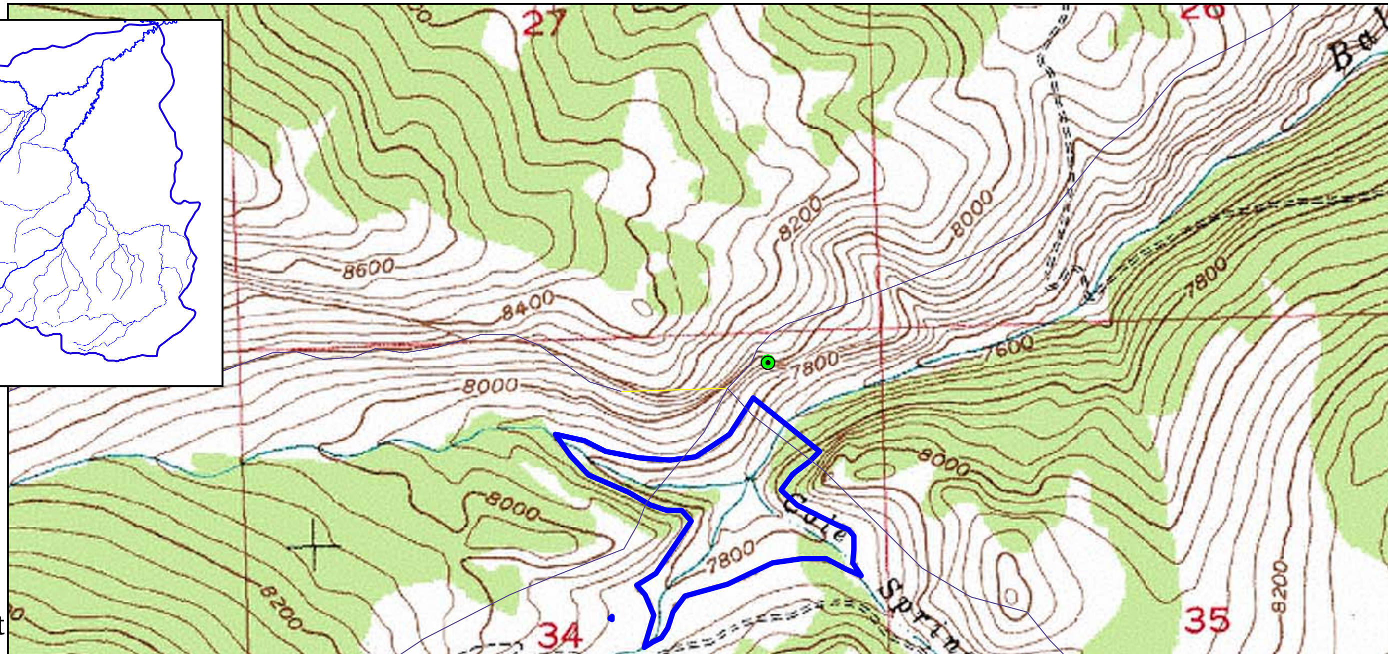
GPS	Condition/Comments	Action Recommended
193	Concrete ditch lining in very poor condition: broken and undermined. (Reach WD-a).	Line reach, WD-a, approximately 1,500 LF
186	Little Popo Agie River bank migration cutting on ditch levee.	Stabilize approximately 300 feet of right bank of Little Popo Agie River with rock riprap.

APPENDIX D

STORAGE SITE LOCATION MAPS

Site 1: Baldwin - Farlow



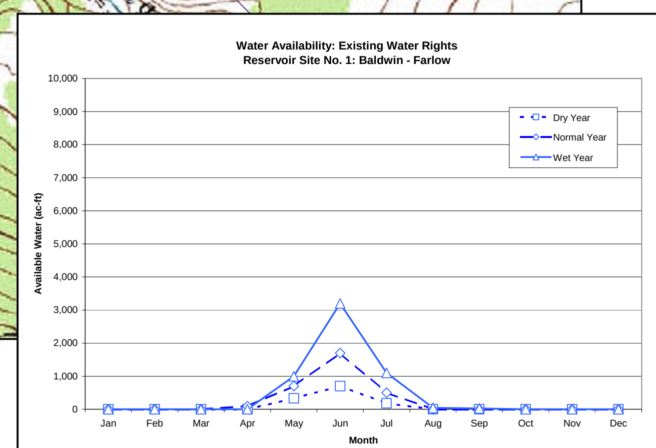


Total Availability:

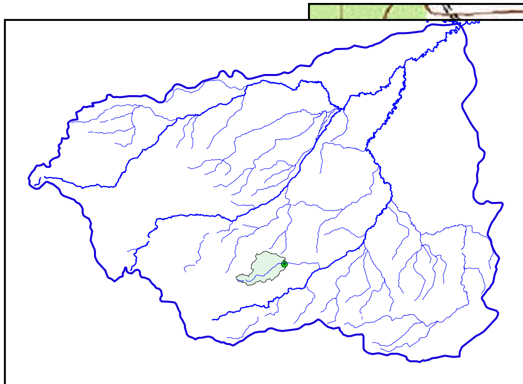
Dry year 1,200 ac-ft
Normal Year: 3,000 ac-ft
Wet Year : 5,400 ac-ft

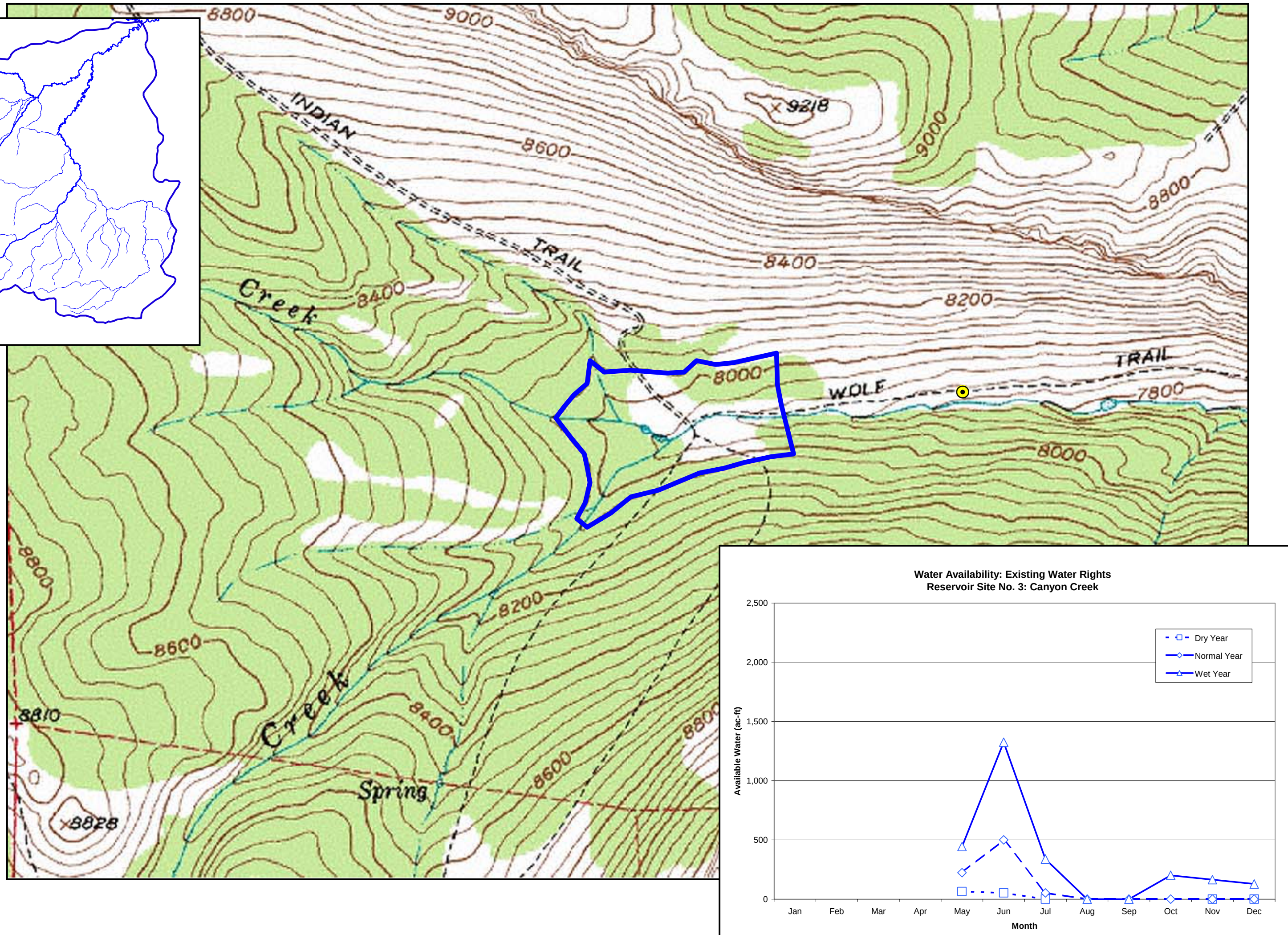
Capacity:
2,000 ac-ft

Reservoir Cost:
$7.5M
$3,730 per ac-ft



Site 3: Canyon Creek





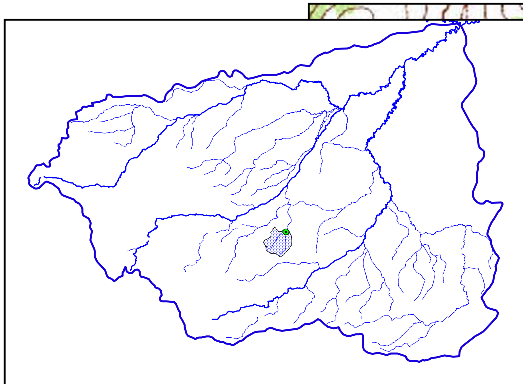
Total Availability:

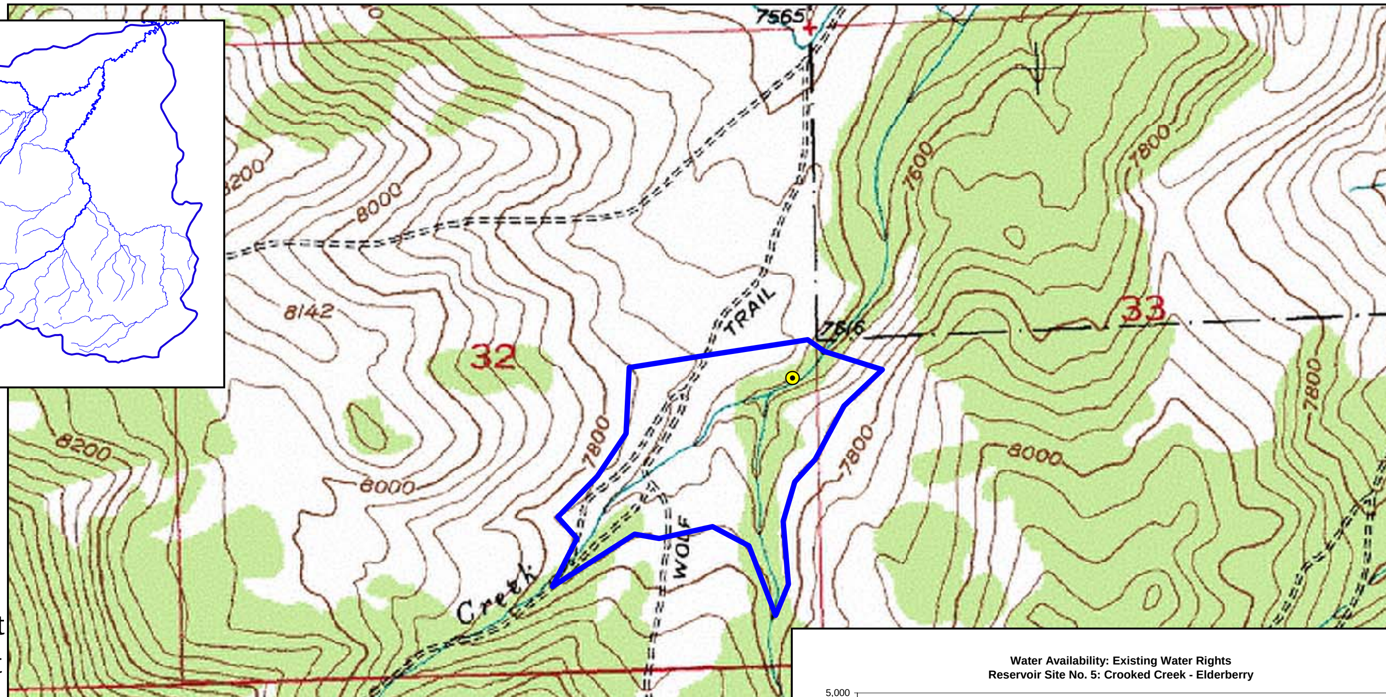
Dry year 100 ac-ft
Normal Year: 800 ac-ft
Wet Year : 2,600 ac-ft

Capacity:
1,395 ac-ft

Reservoir Cost:
$3.5M
$2,500 per ac-ft

Site 5: Crooked Creek - Elderberry



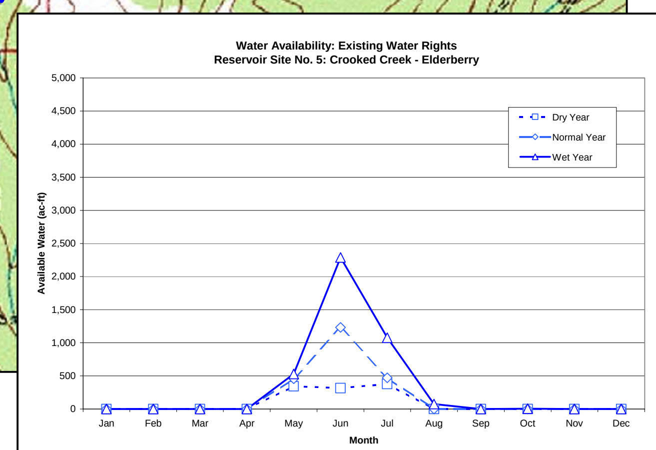


Total Availability:

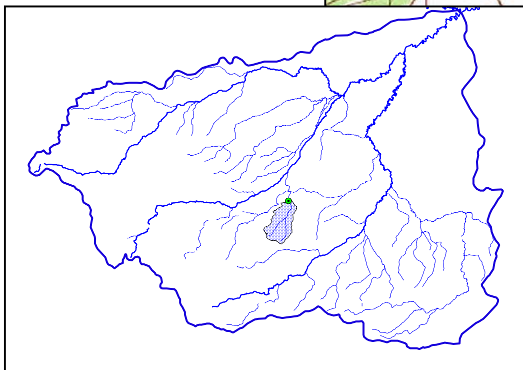
Dry year 1,000 ac-ft
Normal Year: 2,200 ac-ft
Wet Year : 4,000 ac-ft

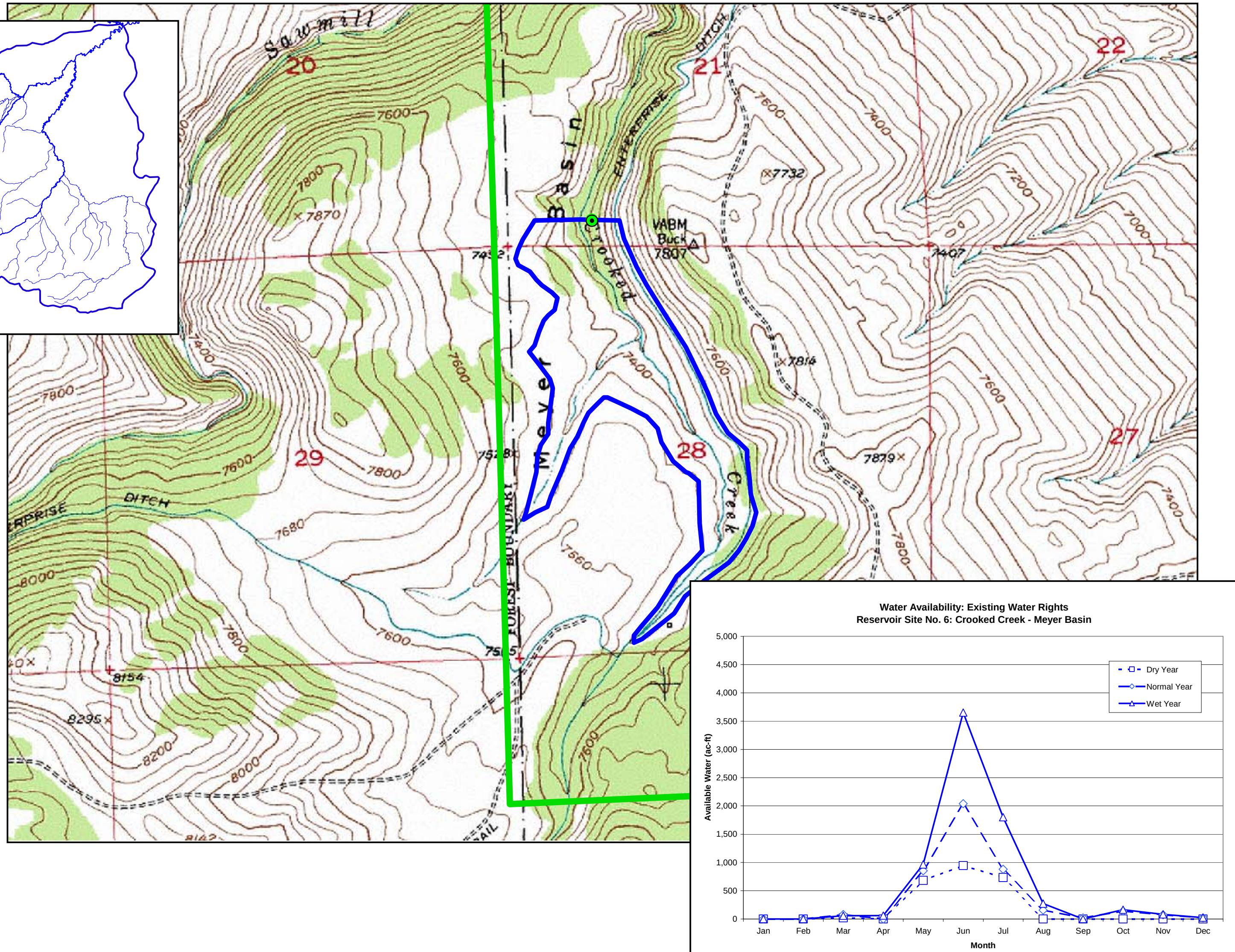
Capacity:
2,600 ac-ft

Reservoir Cost:
$12.7M
$4,900 per ac-ft



Site 6: Crooked Creek – Meyer Basin





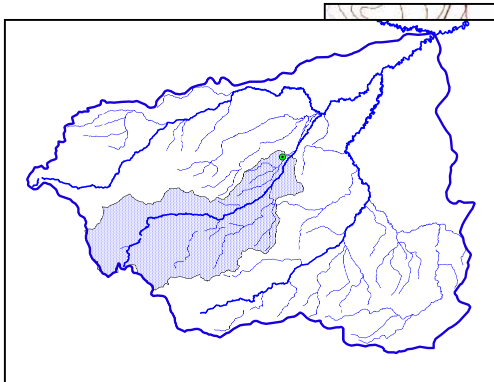
Total Availability:

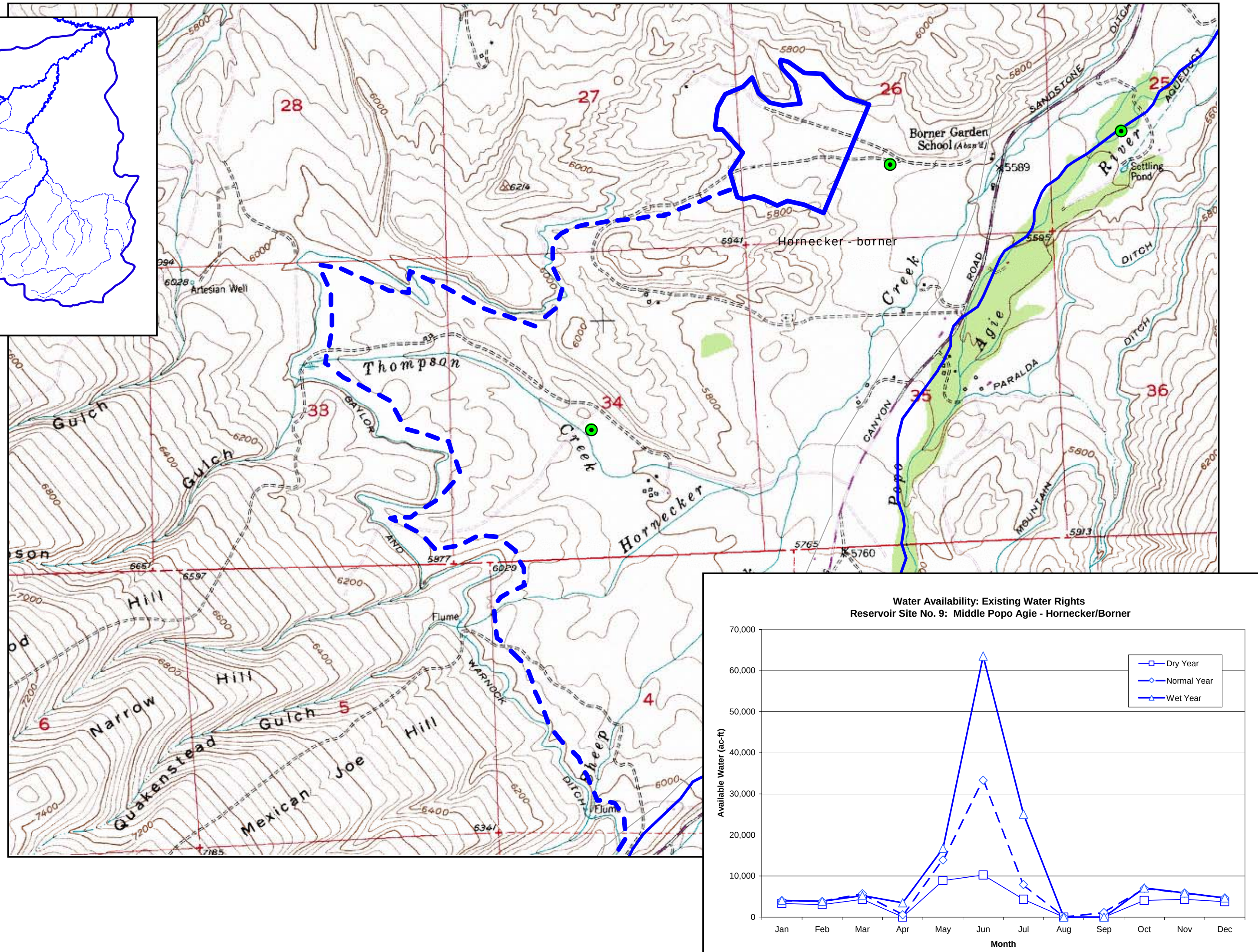
Dry year 2,400 ac-ft
Normal Year: 4,300 ac-ft
Wet Year : 7,100 ac-ft

Enlargement Capacity:
5,680 ac-ft

Reservoir Cost:
$6.9M
$1,220 per ac-ft

Site 9: Hornecker Creek - Borner





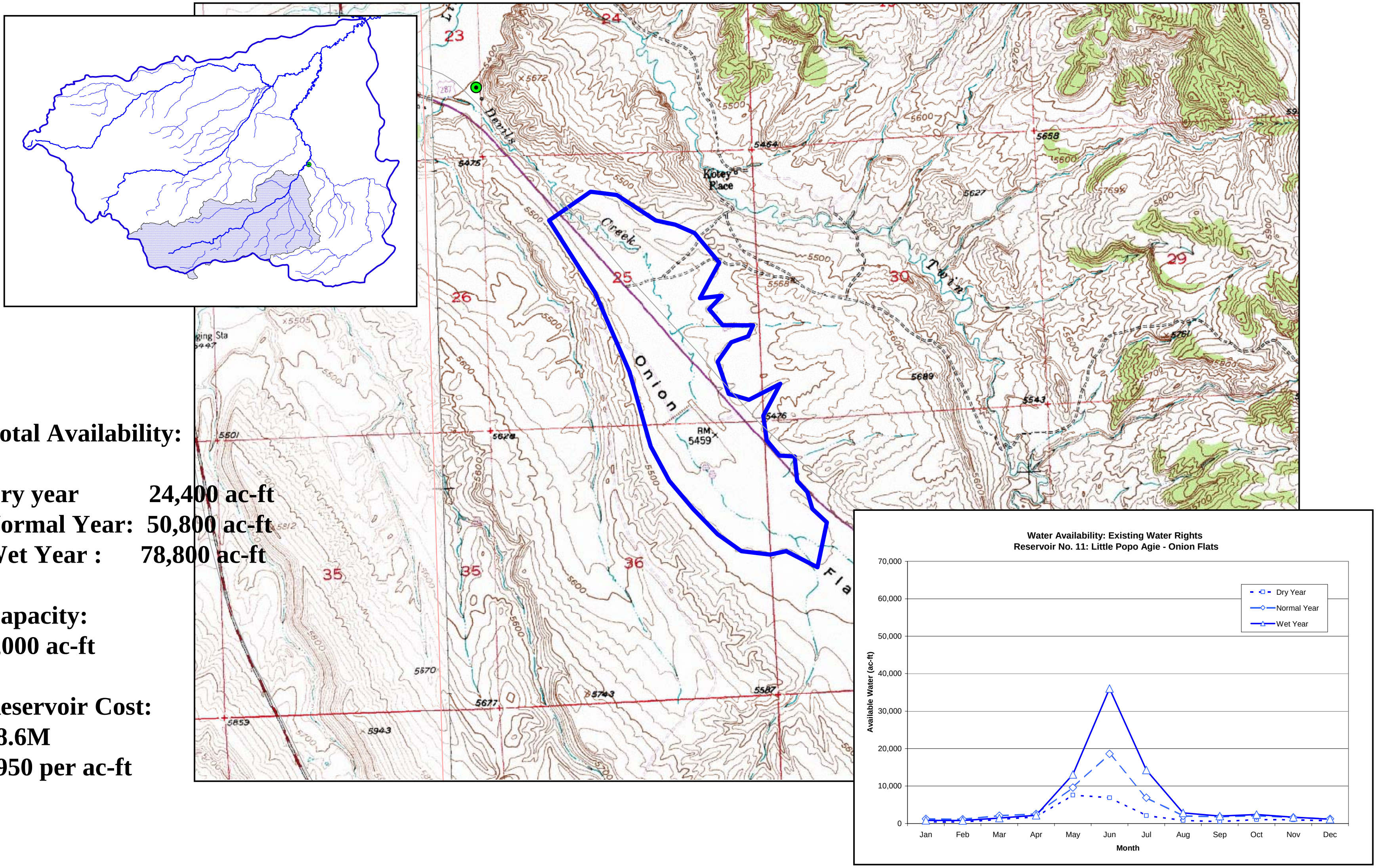
Total Availability:

Dry year 46,300 ac-ft
Normal Year: 87,900 ac-ft
Wet Year : 139,700 ac-ft

Capacity:
3,800 ac-ft

Reservoir Cost:
$13.7M
$3,620 per ac-ft

Site 11: Little Popo Agie – Onion Flats



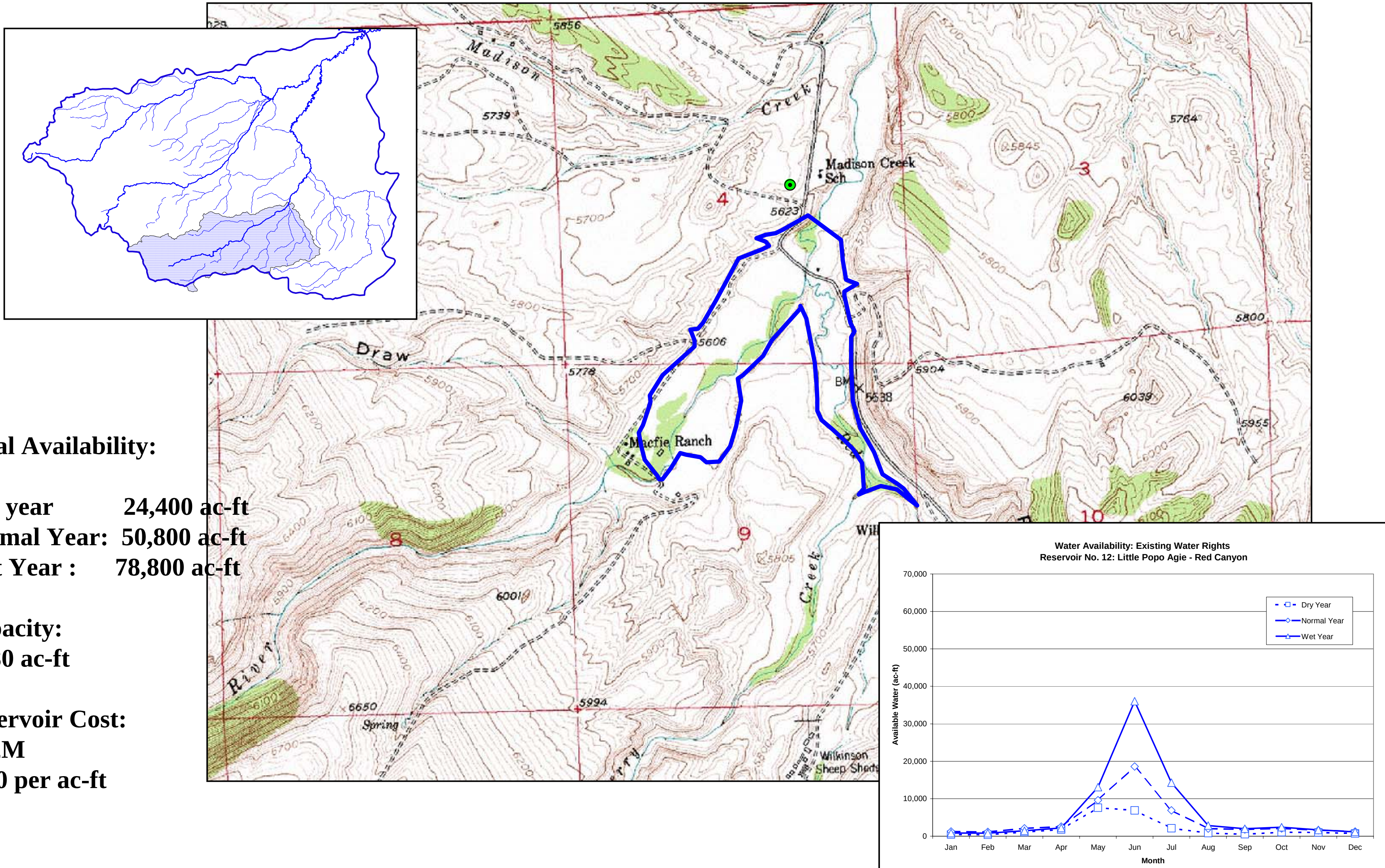
Total Availability:

Dry year 24,400 ac-ft
Normal Year: 50,800 ac-ft
Wet Year : 78,800 ac-ft

Capacity:
9,000 ac-ft

Reservoir Cost:
$8.6M
$950 per ac-ft

Site 12: Little Popo Agie – Red Canyon



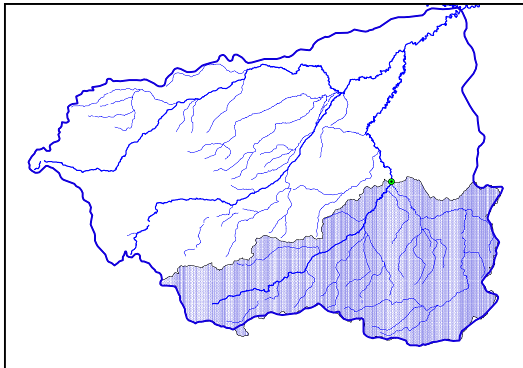
Total Availability:

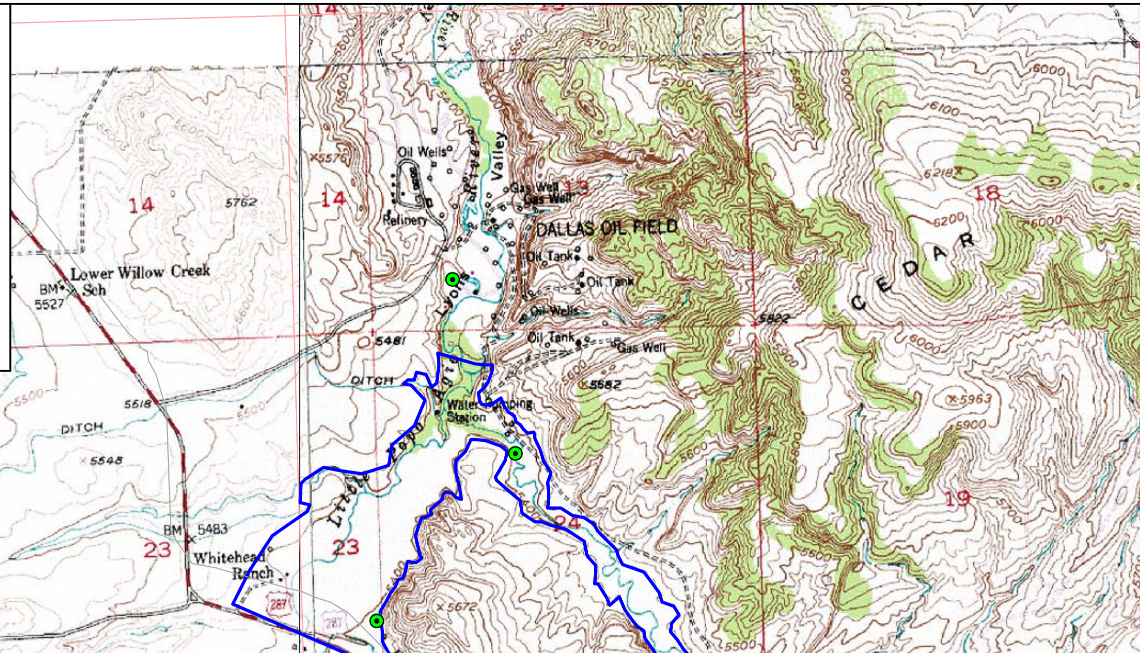
Dry year 24,400 ac-ft
Normal Year: 50,800 ac-ft
Wet Year : 78,800 ac-ft

Capacity:
5,880 ac-ft

Reservoir Cost:
$4.2M
$710 per ac-ft

Site 13: Little Popo Agie – Twin Creek



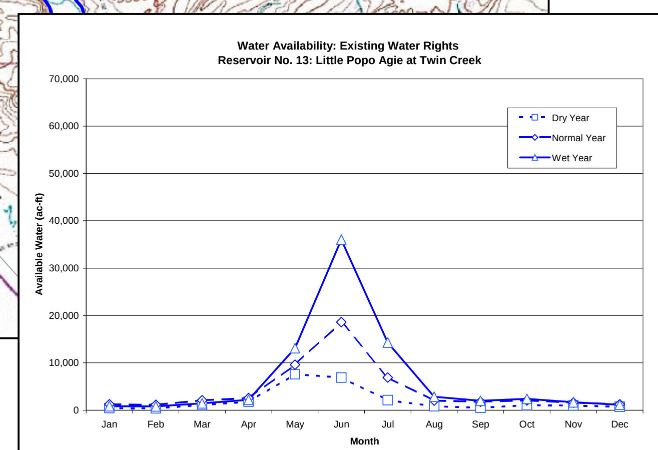


Total Availability:

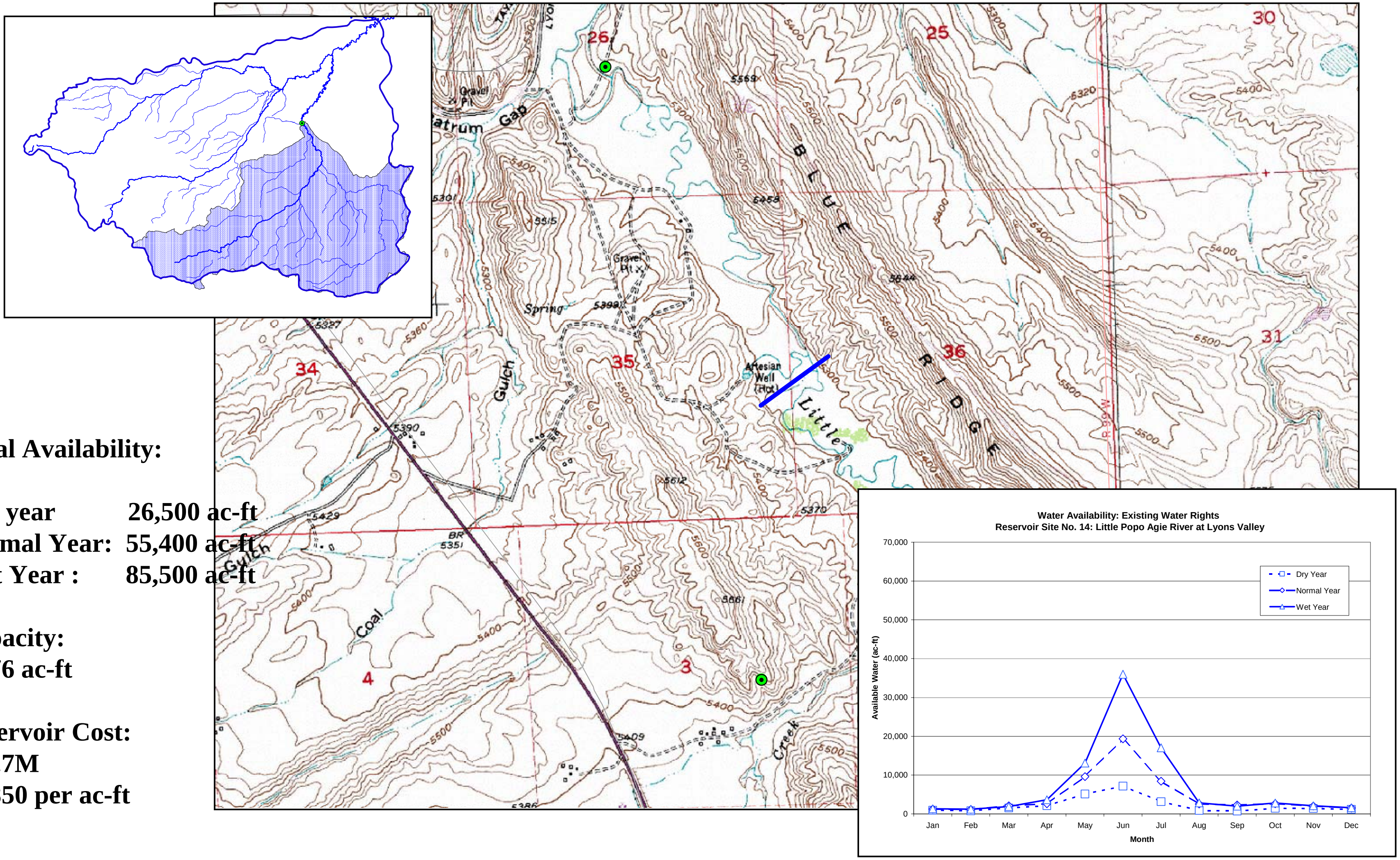
Dry year 24,400 ac-ft
Normal Year: 50,800 ac-ft
Wet Year : 78,800 ac-ft

Capacity:
4,600 ac-ft

Reservoir Cost:
$1.9M
$420 per ac-ft



Site 14: Little Popo Agie – Lyons Valley



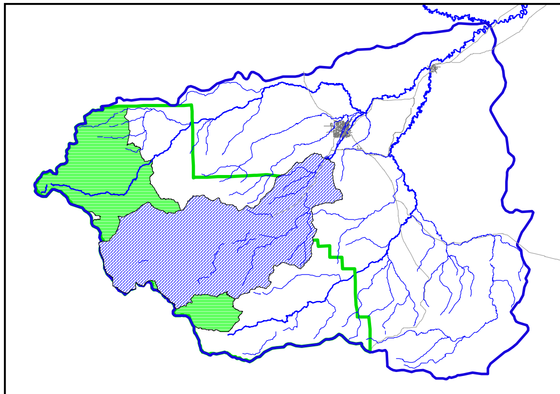
Total Availability:

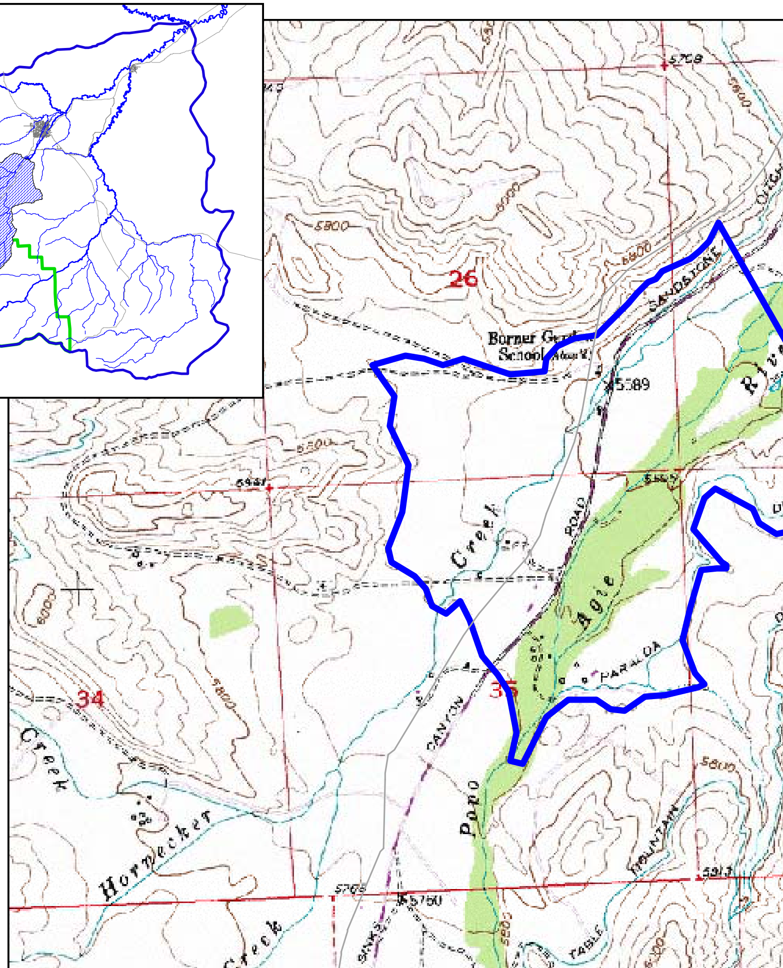
Dry year 26,500 ac-ft
Normal Year: 55,400 ac-ft
Wet Year : 85,500 ac-ft

Capacity:
9,776 ac-ft

Reservoir Cost:
$37.7M
$3,850 per ac-ft

Site 16: Middle Popo Agie – Mid Valley



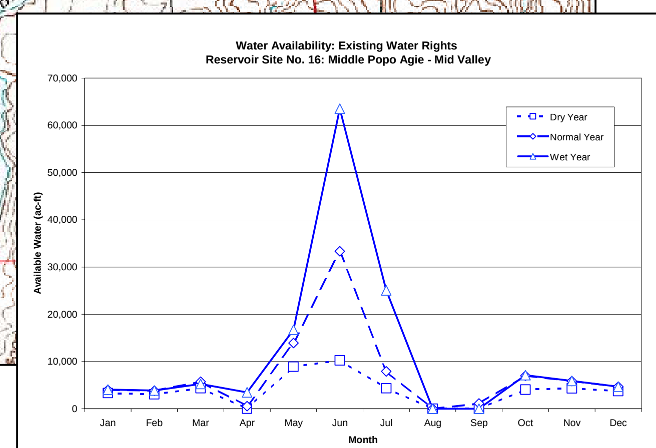


Total Availability:

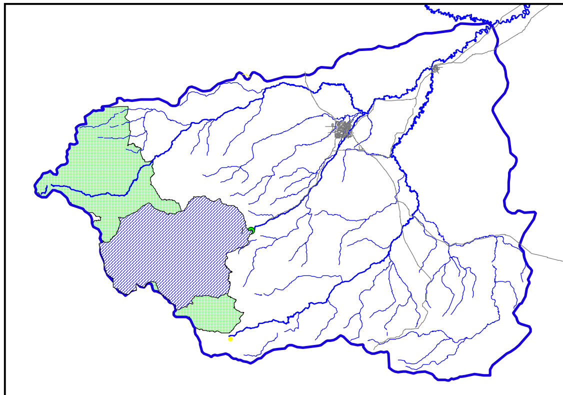
Dry year: 46,300 ac-ft
Normal Year: 87,900 ac-ft
Wet Year : 139,700 ac-ft

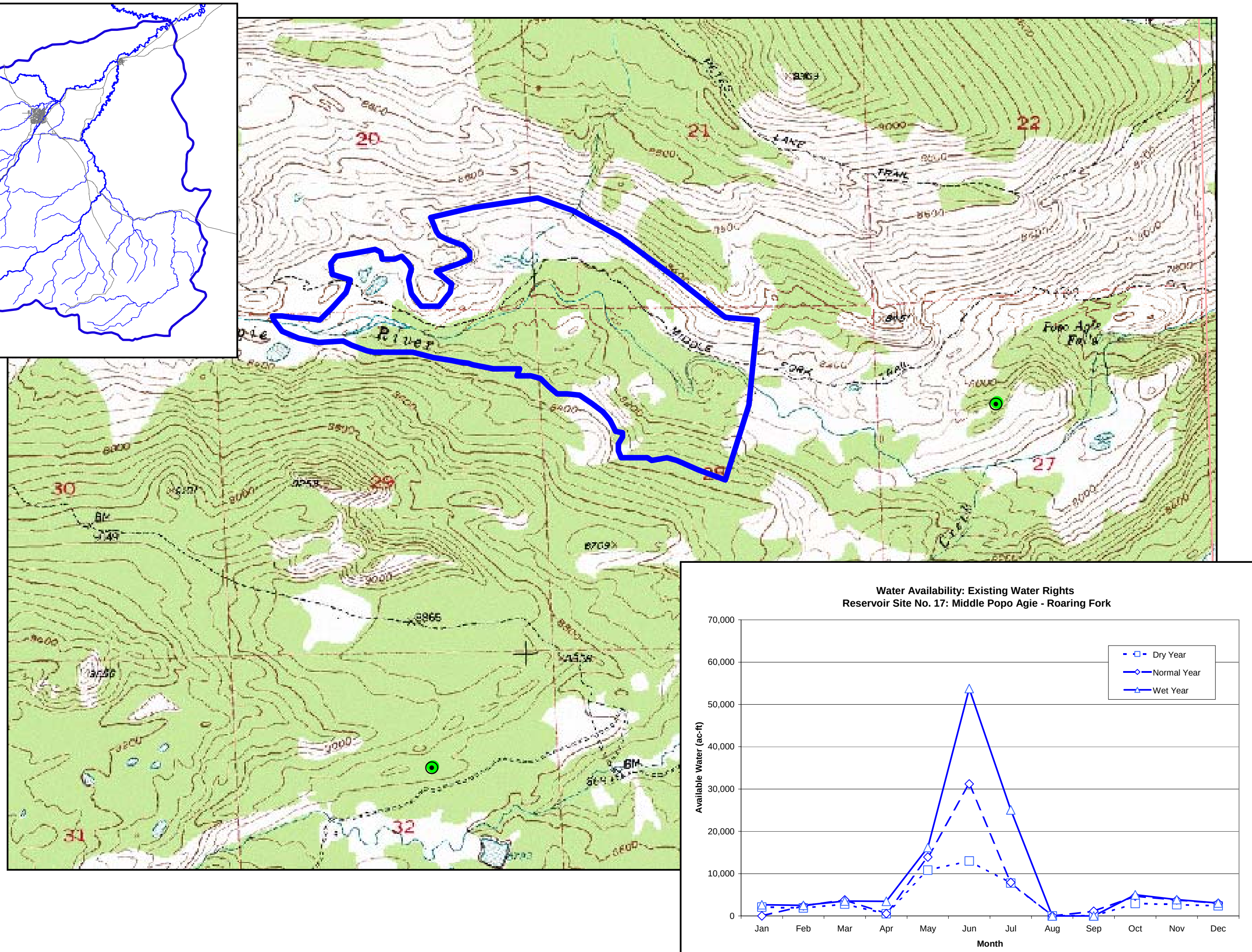
Reservoir Capacity:
29,640 ac-ft

Reservoir Cost:
$43.7M
$1,470 per ac-ft



Site 17: Middle Popo Agie – Roaring Fork





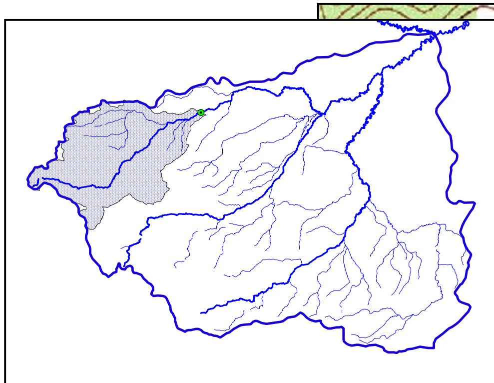
Total Availability:

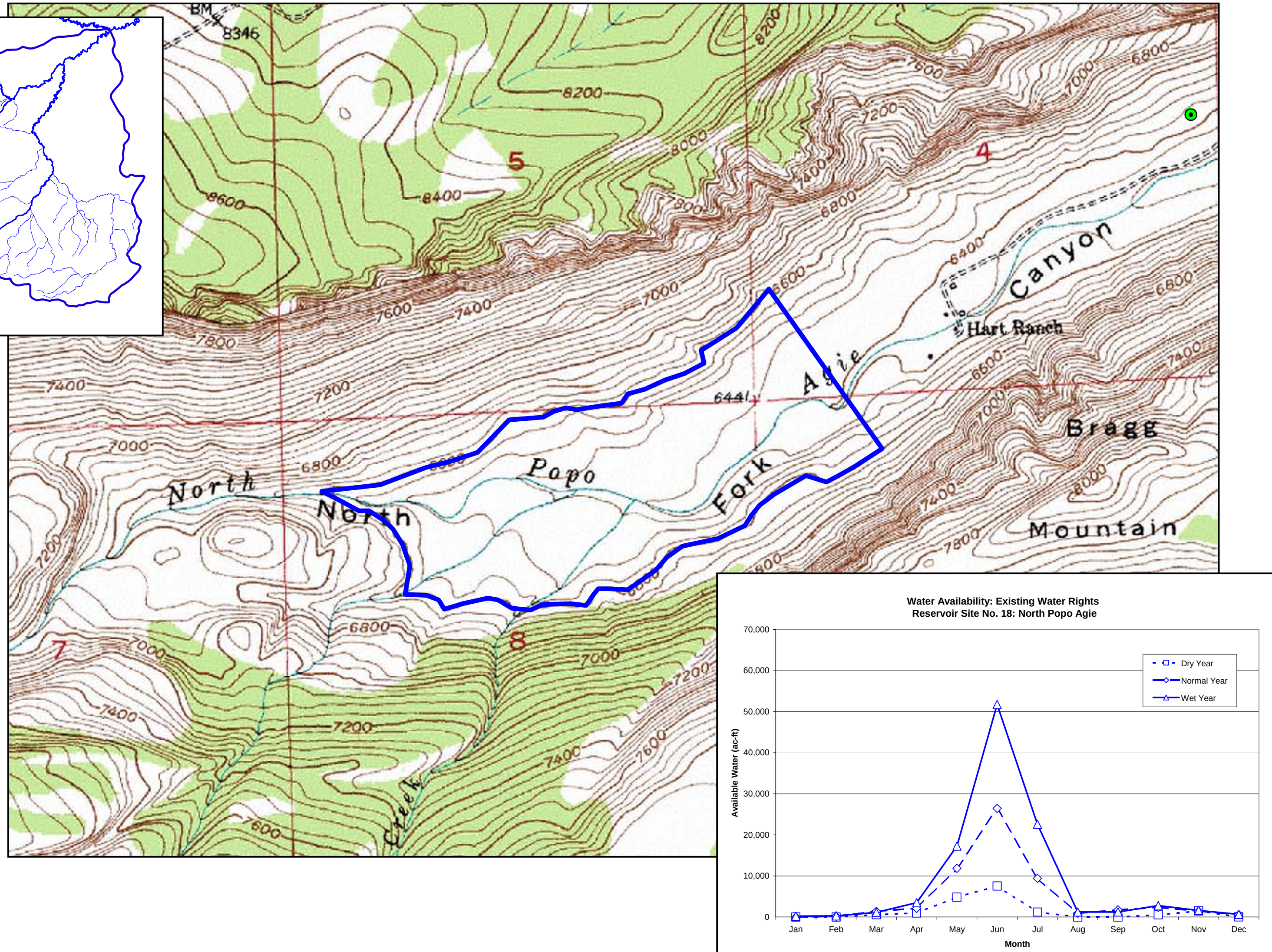
Dry year: 46,800 ac-ft
Normal Year: 72,300 ac-ft
Wet Year : 119,100 ac-ft

Reservoir Capacity:
22,260 ac-ft

Reservoir Cost:
$36.5M
$1,640 per ac-ft

Site 18: North Fork Popo Agie River





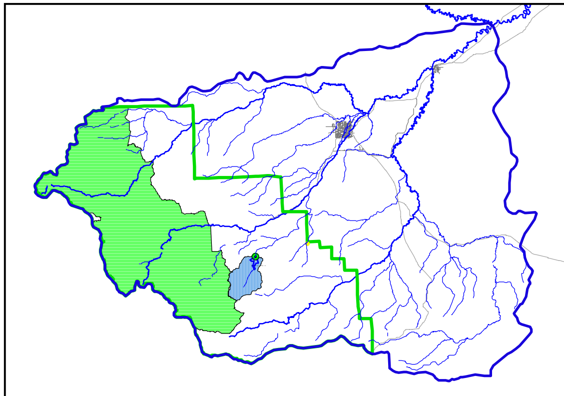
Total Availability:

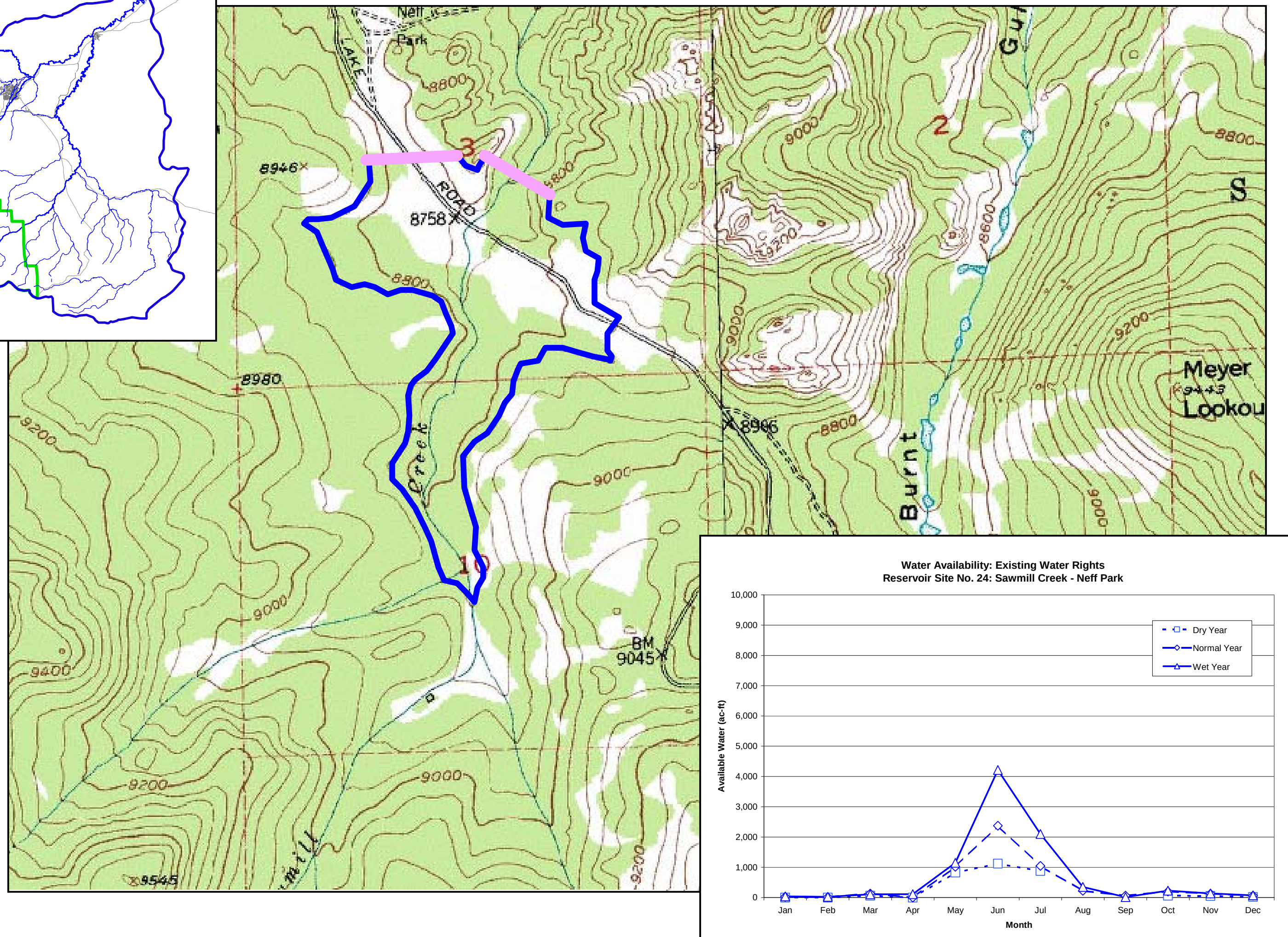
Dry year 17,100 ac-ft
Normal Year: 58,400 ac-ft
Wet Year : 104,200 ac-ft

Capacity:
22,850 ac-ft

Reservoir Cost:
$83.98M
$3,760 per ac-ft

Site 24: Sawmill Creek at Neff Park





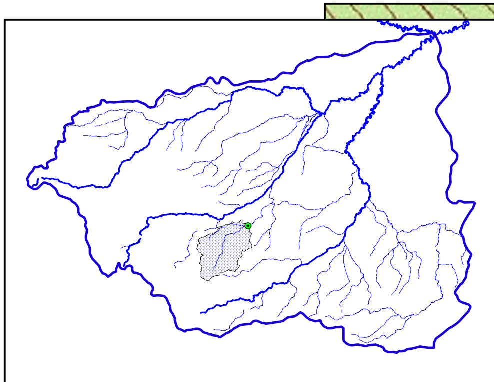
Total Availability:

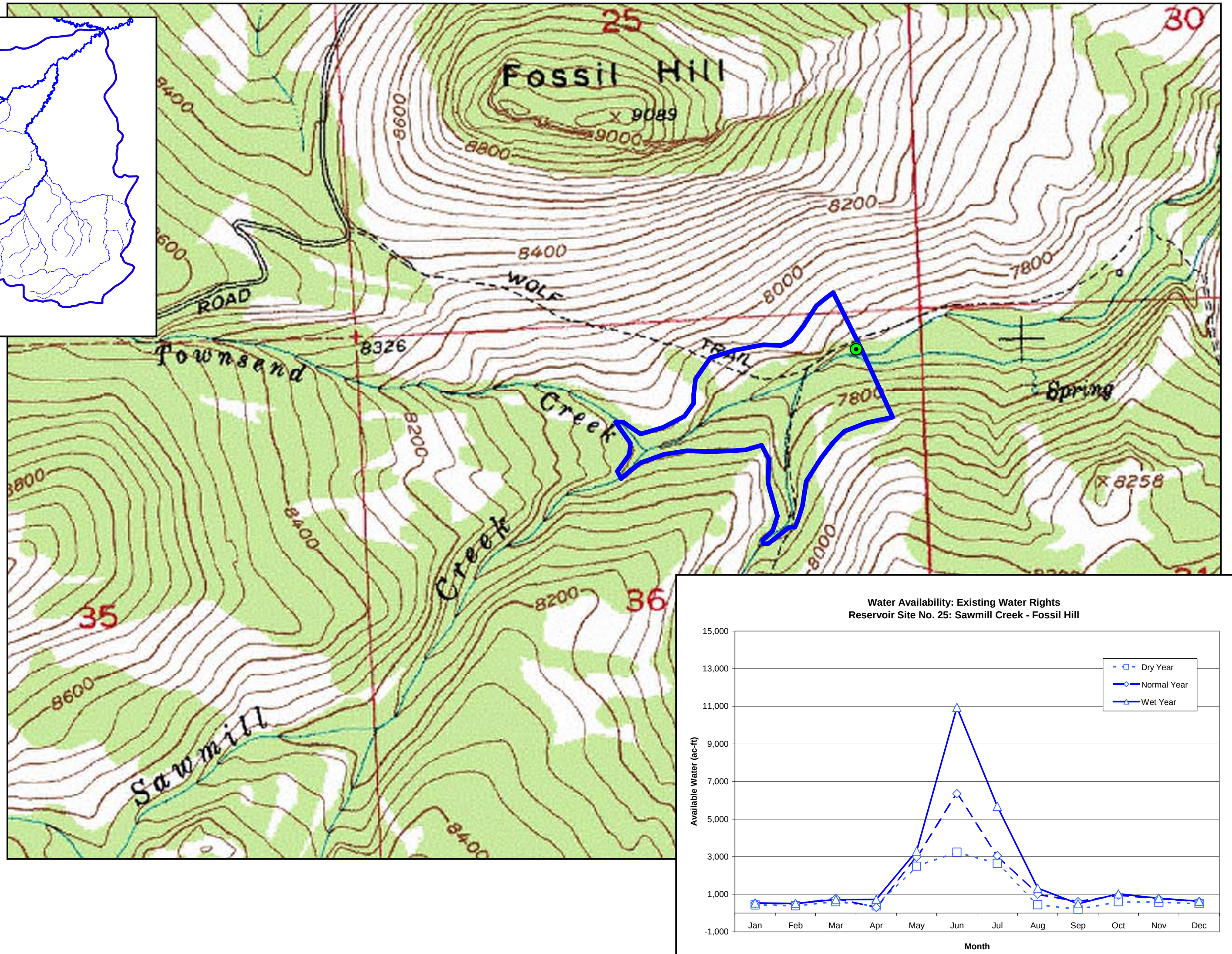
Dry year: 3,000 ac-ft
Normal Year: 5,300 ac-ft
Wet Year : 8,600 ac-ft

Reservoir Capacity:
6,440 ac-ft

Reservoir Cost:
$11.7M
$1,800 per ac-ft

Site 25: Sawmill Creek – Fossil Hill





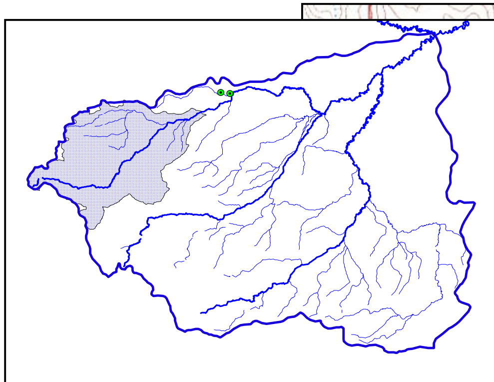
Total Availability:

Dry year 12,500 ac-ft
Normal Year: 18,400 ac-ft
Wet Year : 26,700 ac-ft

Capacity:
4,000 ac-ft

Reservoir Cost:
$32.0M
$7,990 per ac-ft

Site 28: Surrell Creek

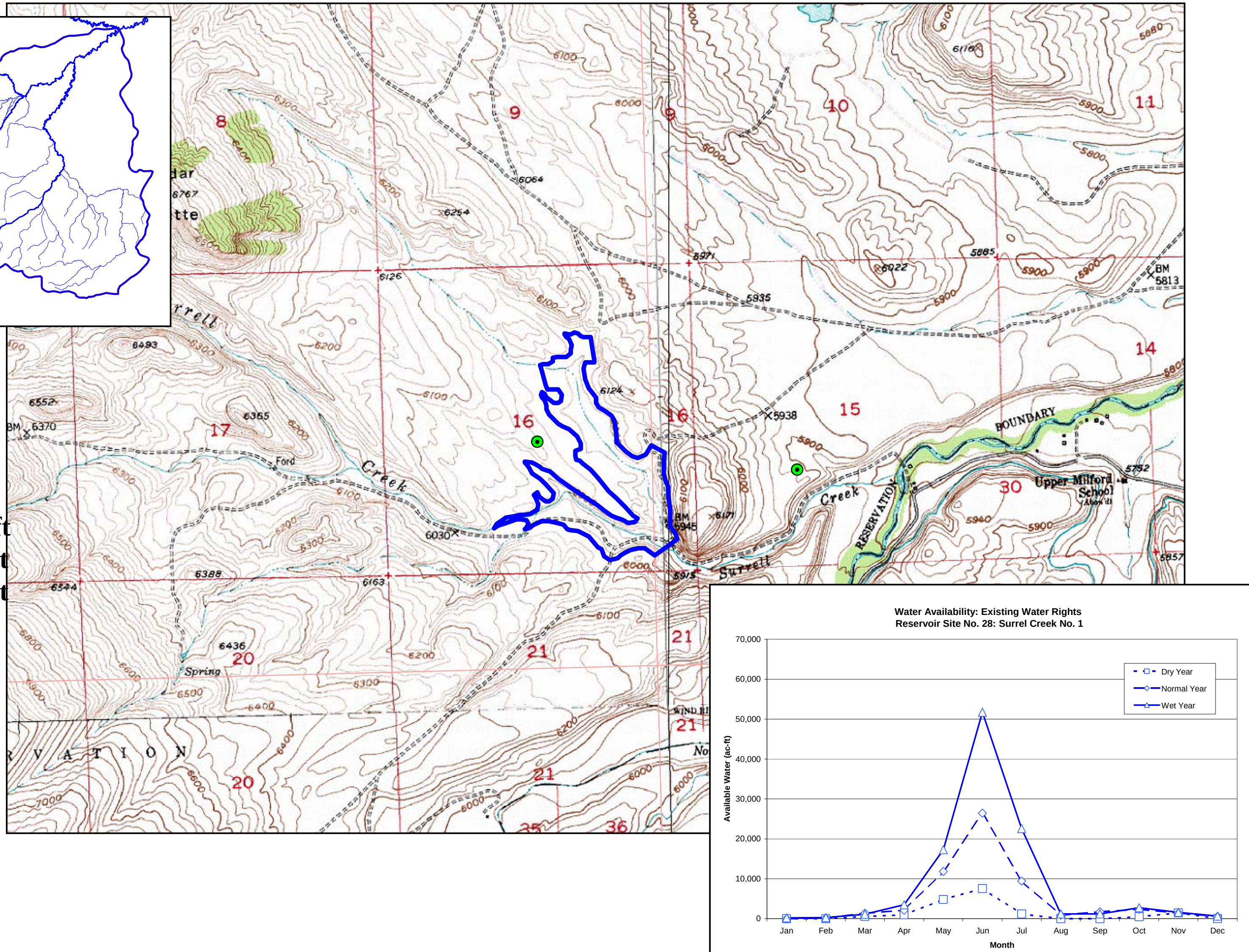


Total Availability:

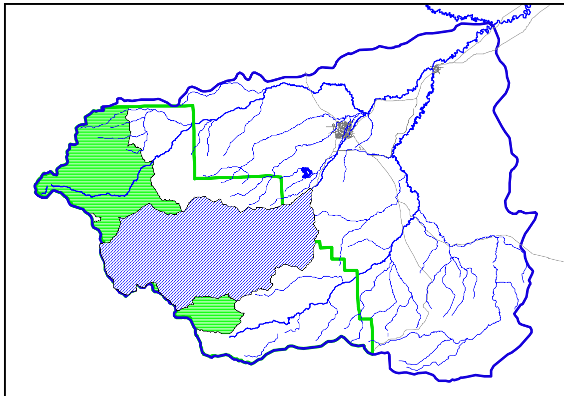
Dry year 17,100 ac-ft
Normal Year: 58,400 ac-ft
Wet Year : 104,200 ac-ft

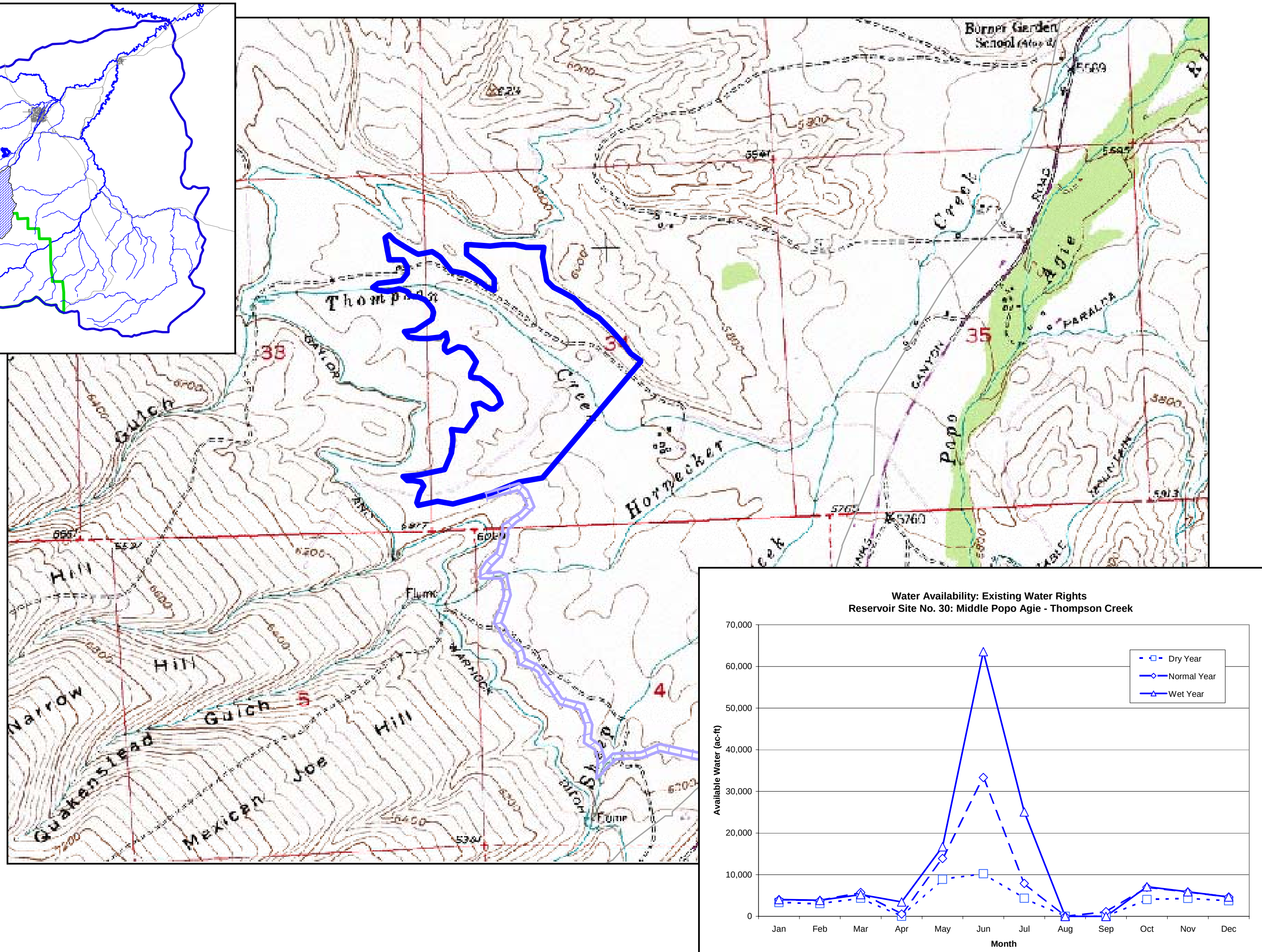
Enlargement Capacity:
3,880ac-ft

Reservoir Cost:
$3.9M
$1,000 per ac-ft



Site 30: Middle Popo Agie – Thompson Cr.





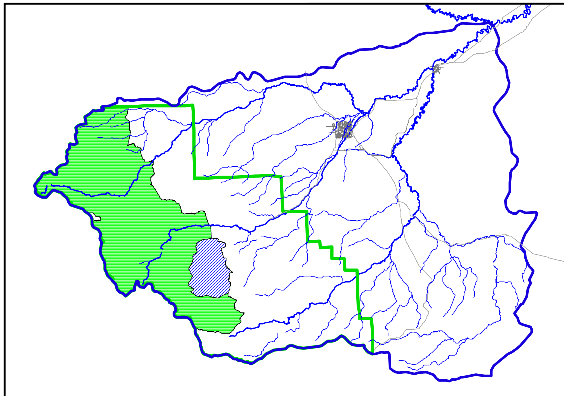
Total Availability:

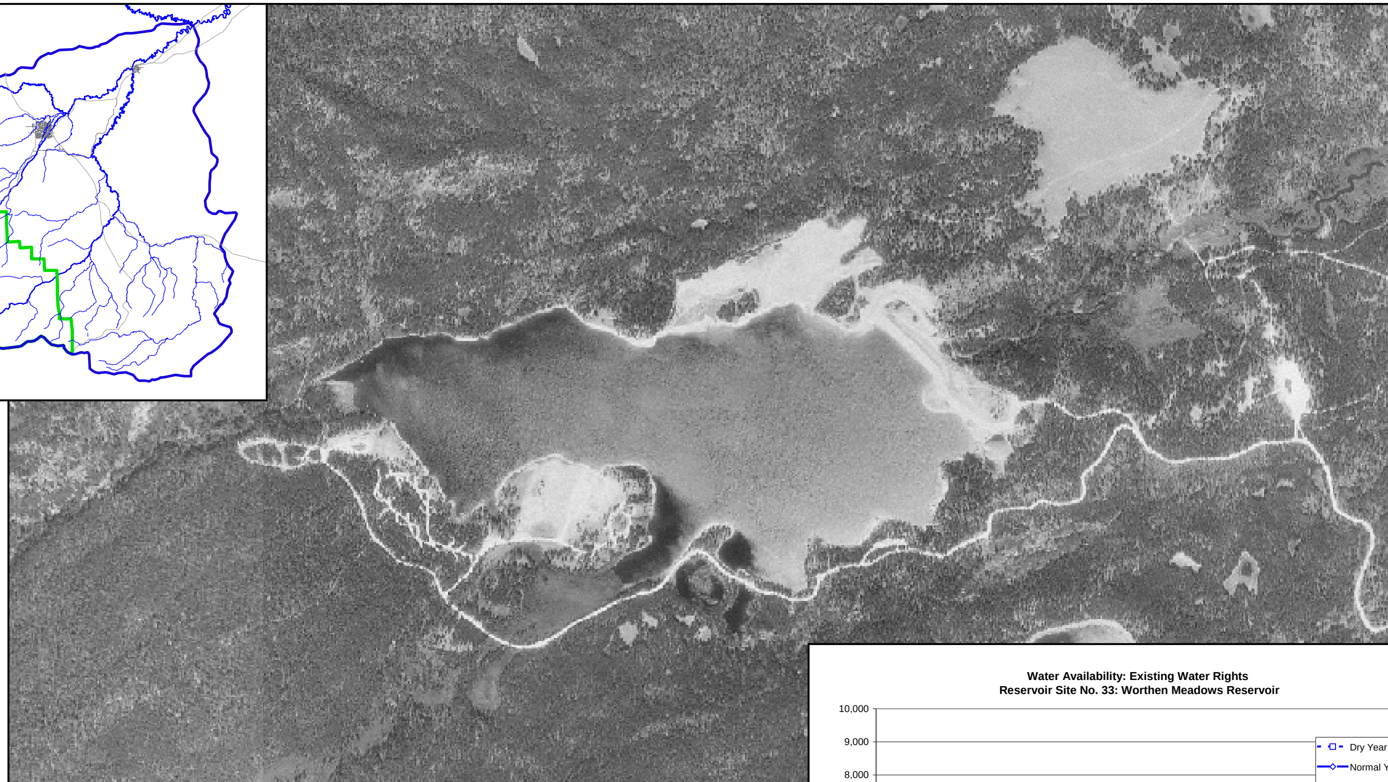
Dry year: 46,300 ac-ft
Normal Year: 87,900 ac-ft
Wet Year : 139,700 ac-ft

Reservoir Capacity:
10,260 ac-ft

Reservoir Cost:
$32.0M
$3,120 per ac-ft

Site 33: Roaring Fork – Worthen Meadows





Total Availability:

Dry year 800 ac-ft
Normal Year: 5,400 ac-ft
Wet Year : 11,400 ac-ft

Enlargement Capacity:
450- 500 ac-ft

Reservoir Cost:
$0.8M
$1,780 per ac-ft